



# Assessment of task ergonomics with an upper limb wearable device

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# Outline

- Introduction
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- 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 disorders (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 not 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





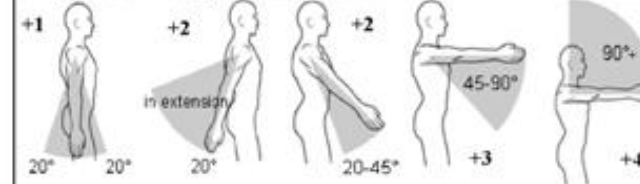
# RULA

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

## RULA Employee Assessment Worksheet

### A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

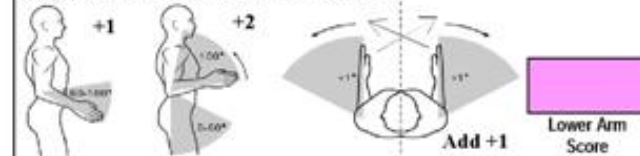


Step 1a: Adjust...

If shoulder is raised: +1  
If upper arm is abducted: +1  
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...

If either arm is working across midline or out to side of body: Add +1

Lower Arm Score

Step 3: Locate Wrist Position:



Step 3a: Adjust...

If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:

If wrist is twisted in mid-range: +1  
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:

Using values from steps 1-4 above, locate score in Table A

Posture Score A

Step 6: Add Muscle Use Score

If posture mainly static (i.e. held > 10 minutes),  
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 7: Add Force/Load Score

If load < 4.4 lbs (intermittent): +0  
If load 4.4 to 22 lbs (intermittent): +1  
If load 4.4 to 22 lbs (static or repeated): +2  
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

Step 8: Find Row in Table C

Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

### SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	Wrist Twist			
		1	2	3	4
1	1	1	2	2	3
	2	2	2	2	3
	3	2	3	3	4
2	1	2	3	3	4
	2	3	3	3	4
	3	3	4	4	5
3	1	3	4	4	5
	2	3	4	4	5
	3	4	4	4	5
4	1	4	4	4	5
	2	4	4	4	5
	3	4	4	5	6
5	1	5	5	5	6
	2	5	6	6	7
	3	6	6	7	8
6	1	7	7	7	8
	2	8	8	8	9
	3	9	9	9	9

Table C: Neck, trunk and leg score

Wrist and Arm Score	Neck, trunk and leg score						
	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

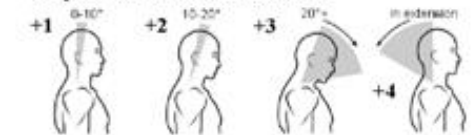
Scoring: (final score from Table C)

1 or 2 = acceptable posture  
3 or 4 = further investigation, change may be needed  
5 or 6 = further investigation, change soon  
7 = investigate and implement change

Final Score

### B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...

If neck is twisted: +1  
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:



Step 10a: Adjust...

If trunk is twisted: +1  
If trunk is side bending: +1

Trunk Score

Step 11: Legs:

If legs and feet are supported: +1  
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	Trunk Posture Score					
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	2	3	4	5	6	7
3	3	4	5	6	7	8
4	4	5	6	7	8	9
5	5	6	7	8	9	10
6	6	7	8	9	10	11

Step 12: Look-up Posture Score in Table B:

Using values from steps 9-11 above, locate score in Table B

Posture Score B

Step 13: Add Muscle Use Score

If posture mainly static (i.e. held > 10 minutes),  
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 14: Add Force/Load Score

If load < 4.4 lbs (intermittent): +0  
If load 4.4 to 22 lbs (intermittent): +1  
If load 4.4 to 22 lbs (static or repeated): +2  
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

Step 15: Find Column in Table C

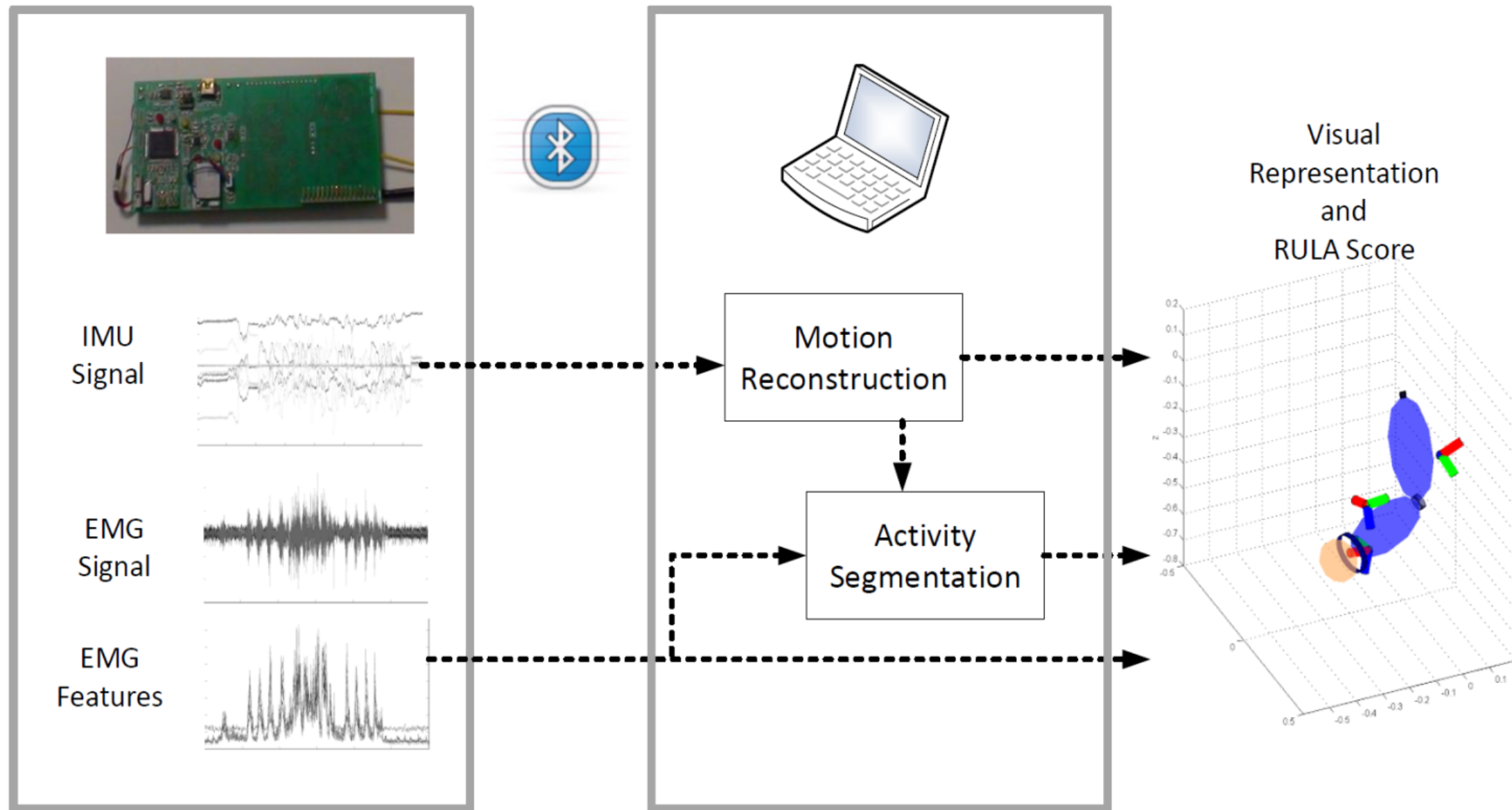
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

# System Architecture

Online, wearable

Offline

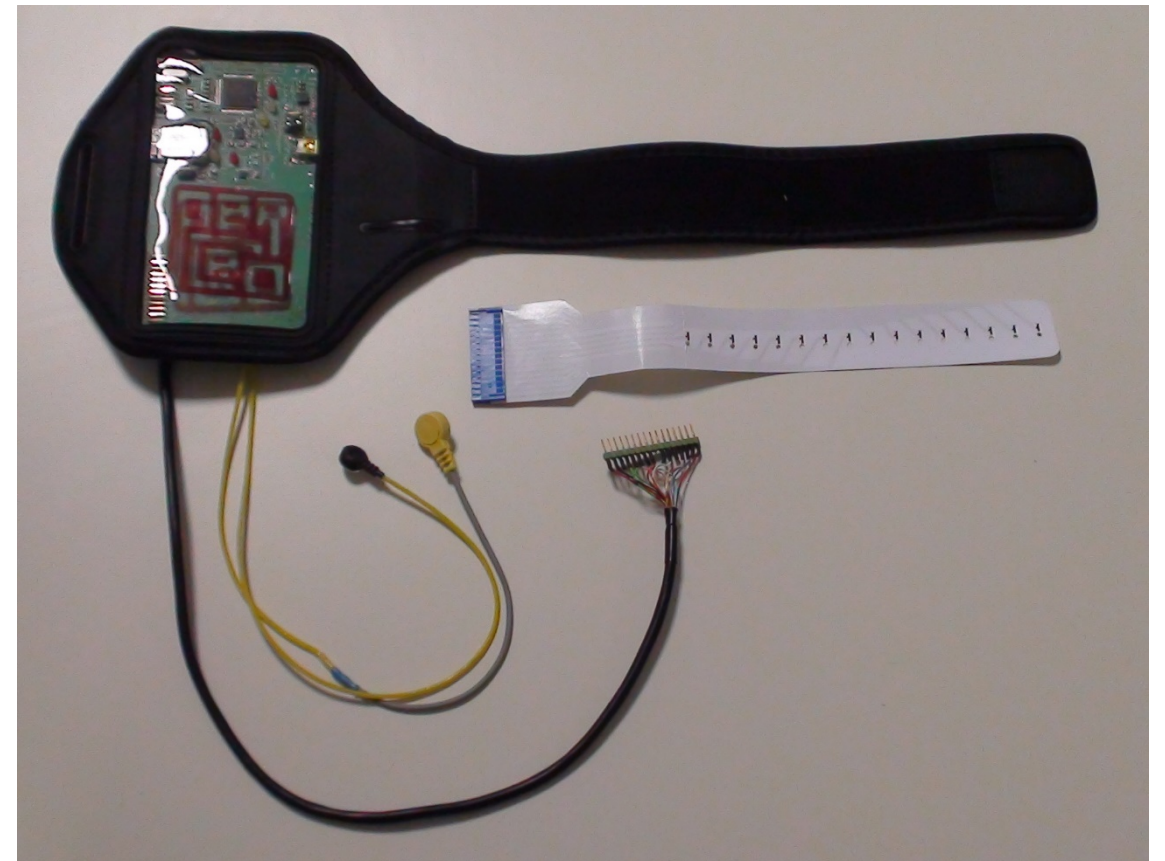




# Device

Fully wearable board supporting:

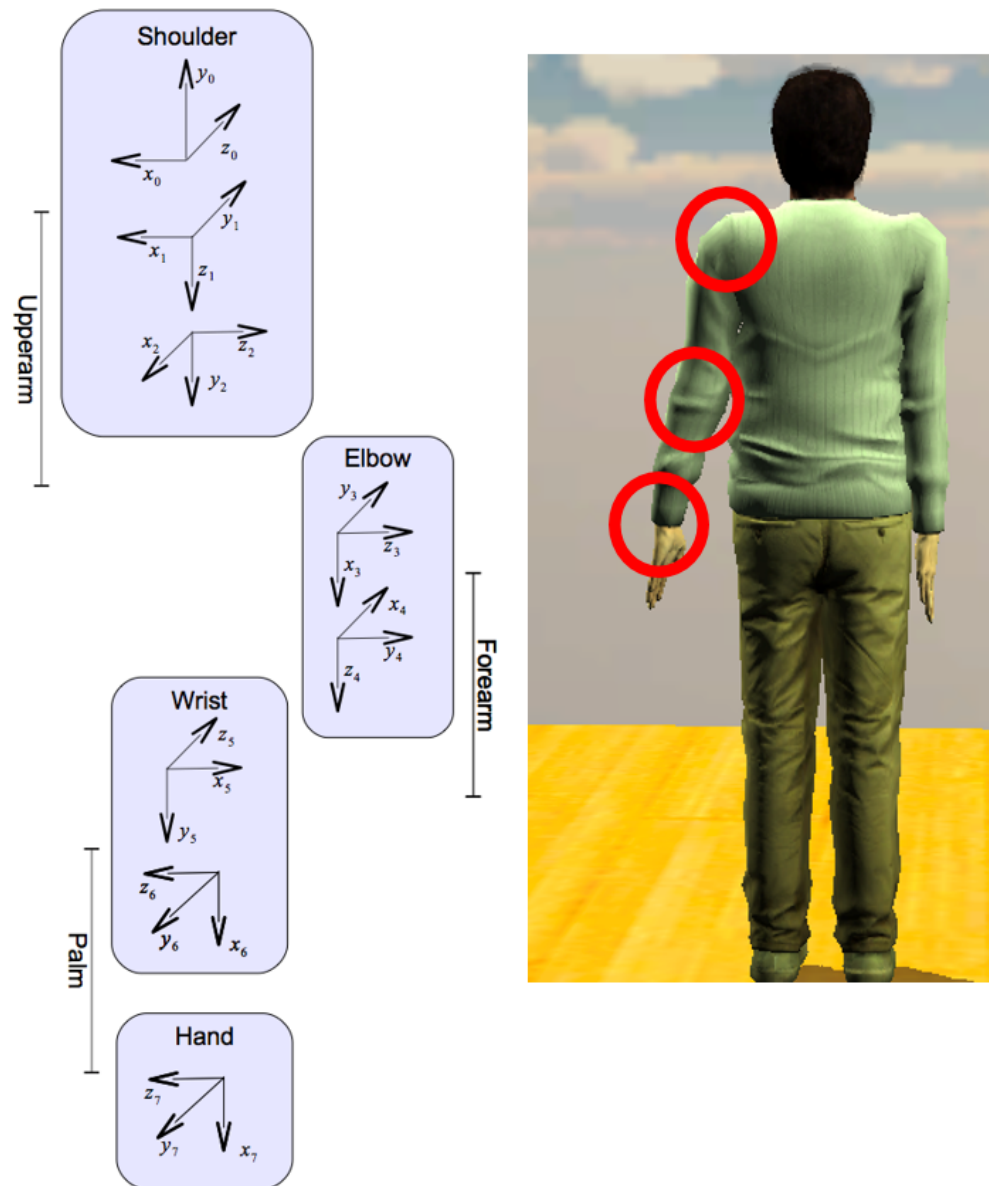
- STM32F micro
- 4 InvenSense 9150 IMUs:
  - 3 axes accelerometer
  - 3 axes gyroscope
  - 3 axes magnetometer
- 32 EMG channels
- Maximum sampling frequencies
  - IMUs @ 100 Hz
  - EMG @ 500 Hz
- On-board EMG filtering and feature calculation





# Motion Tracking

## Kinematic model of the human upper limbs

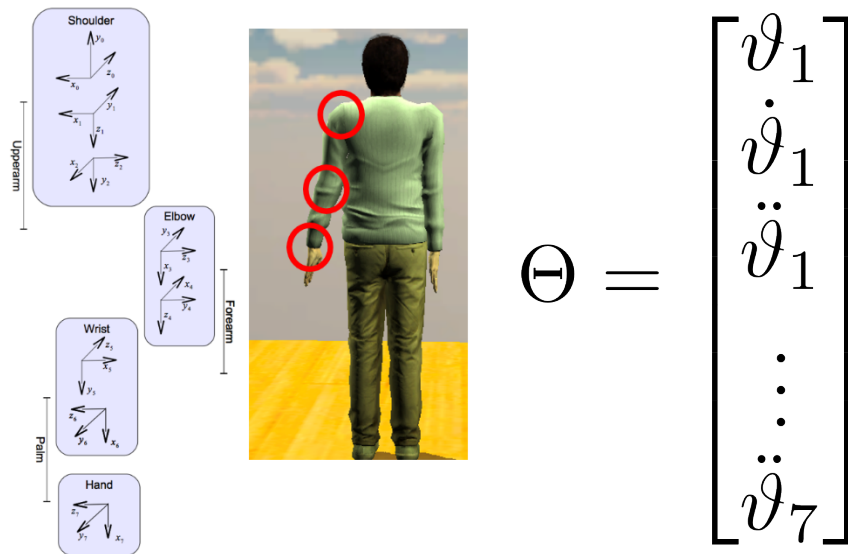


- 7 DoFs rigid bodies kinematic chain
  - Rooted in the chest
  - Shoulder abduction-adduction
  - Shoulder rotation
  - Shoulder flexion-extension
  - Elbow flexion-extension
  - Forearm pronation-supination
  - Wrist flexion - extension
  - Wrist abduction - adduction
- IMUs associated to  $s\#$  frames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

# Motion Tracking

## Unscented Kalman Filter for IMUs sensors fusion

### Filter State

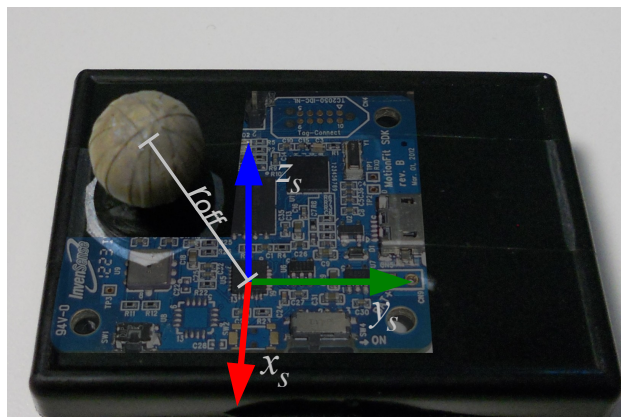


### Process Model

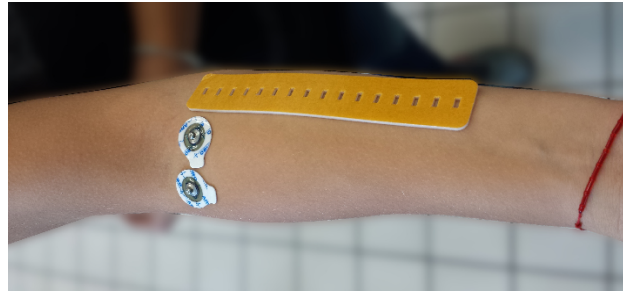
$$\begin{aligned} \vartheta_i(k+1) &= \vartheta_i(k) + T_s \dot{\vartheta}_i(k) + \frac{1}{2} T_s^2 (\ddot{\vartheta}_i(k) + \nu_k) \\ \dot{\vartheta}_i(k+1) &= \dot{\vartheta}_i(k) + T_s (\ddot{\vartheta}_i(k) + \nu_k) \\ \ddot{\vartheta}_i(k+1) &= \ddot{\vartheta}_i(k) + \nu_k \end{aligned}$$

### Measurements Model

$$\begin{aligned} \omega_s^s &= R_p^s (\omega_p^p + \dot{\vartheta}_{p+1} z_0) \\ \ddot{x}_s^s &= R_p^s \ddot{x}_p^p + S(\dot{\omega}_s^s) r_{p,s}^s + S(\omega_s^s)^2 r_{p,s}^s + R_0^s g^0 \\ m_s^s &= R_0^s m^0 \end{aligned}$$



# Muscular activation



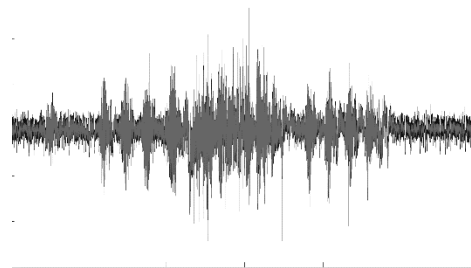
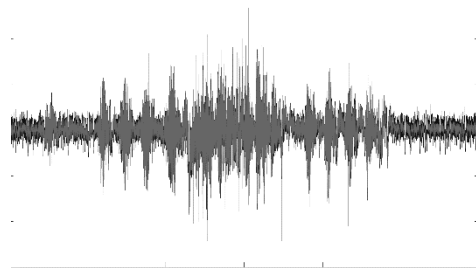
8 Channels  
EMG

Raw Signals

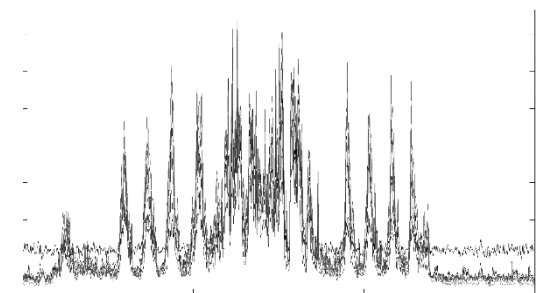
Bandpass Filter  
[20 - 200] Hz

RMS

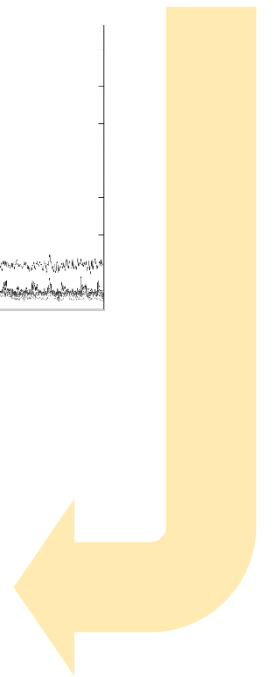
Windows 128ms



MVC



Muscular activation triggers  
Muscular activity intensity measurement

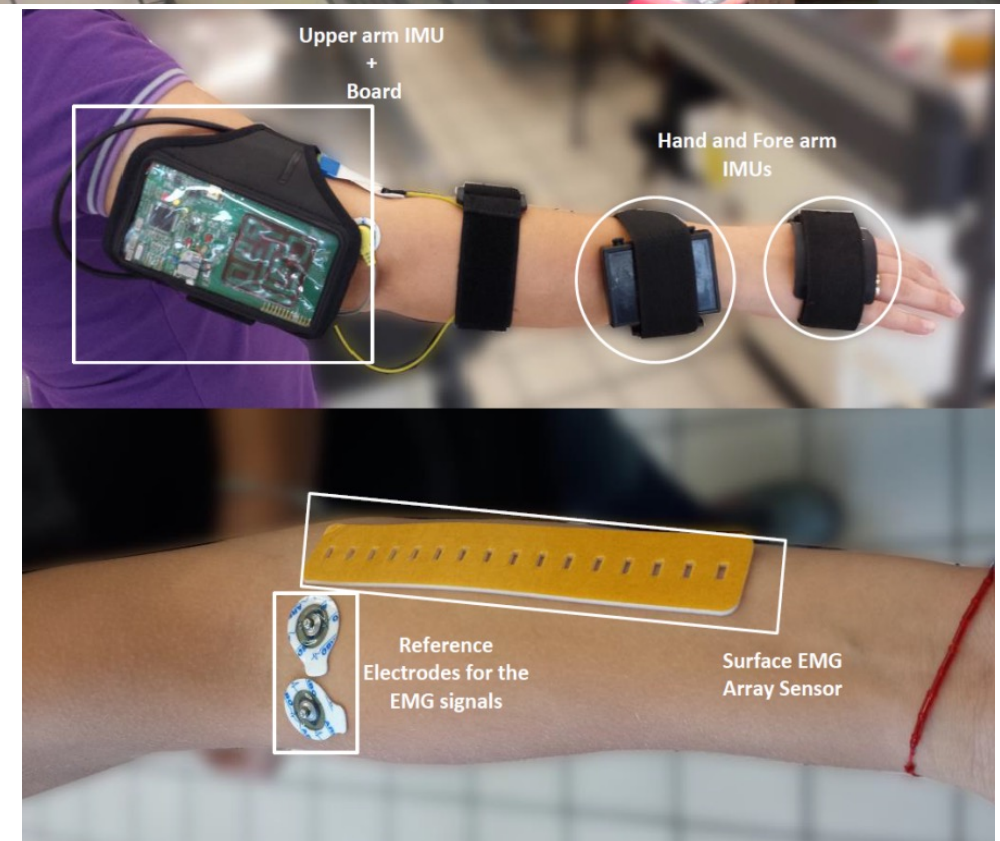




# Experimental Setup

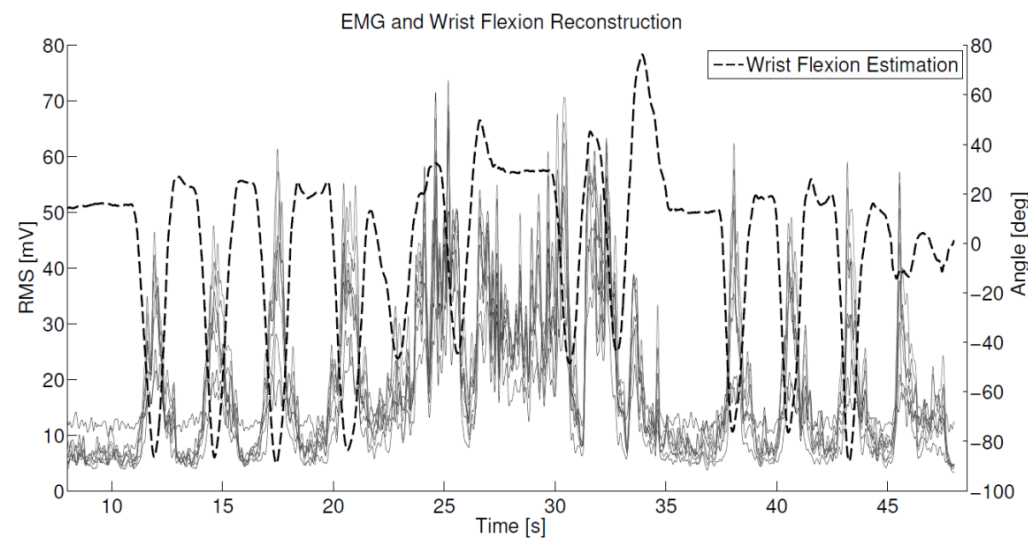
## Method:

- 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

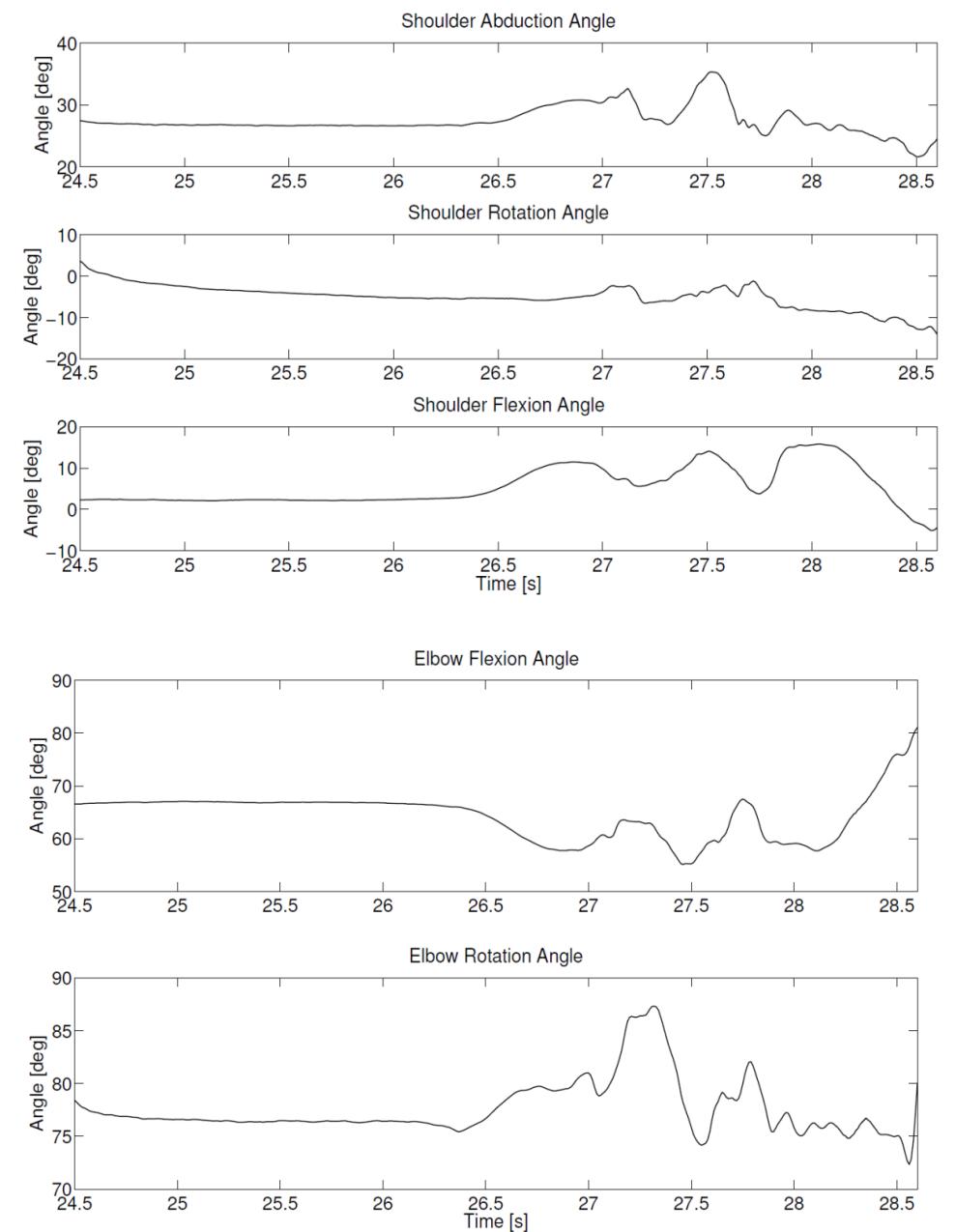
## EMG Bandpower and Wrist motion



## 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





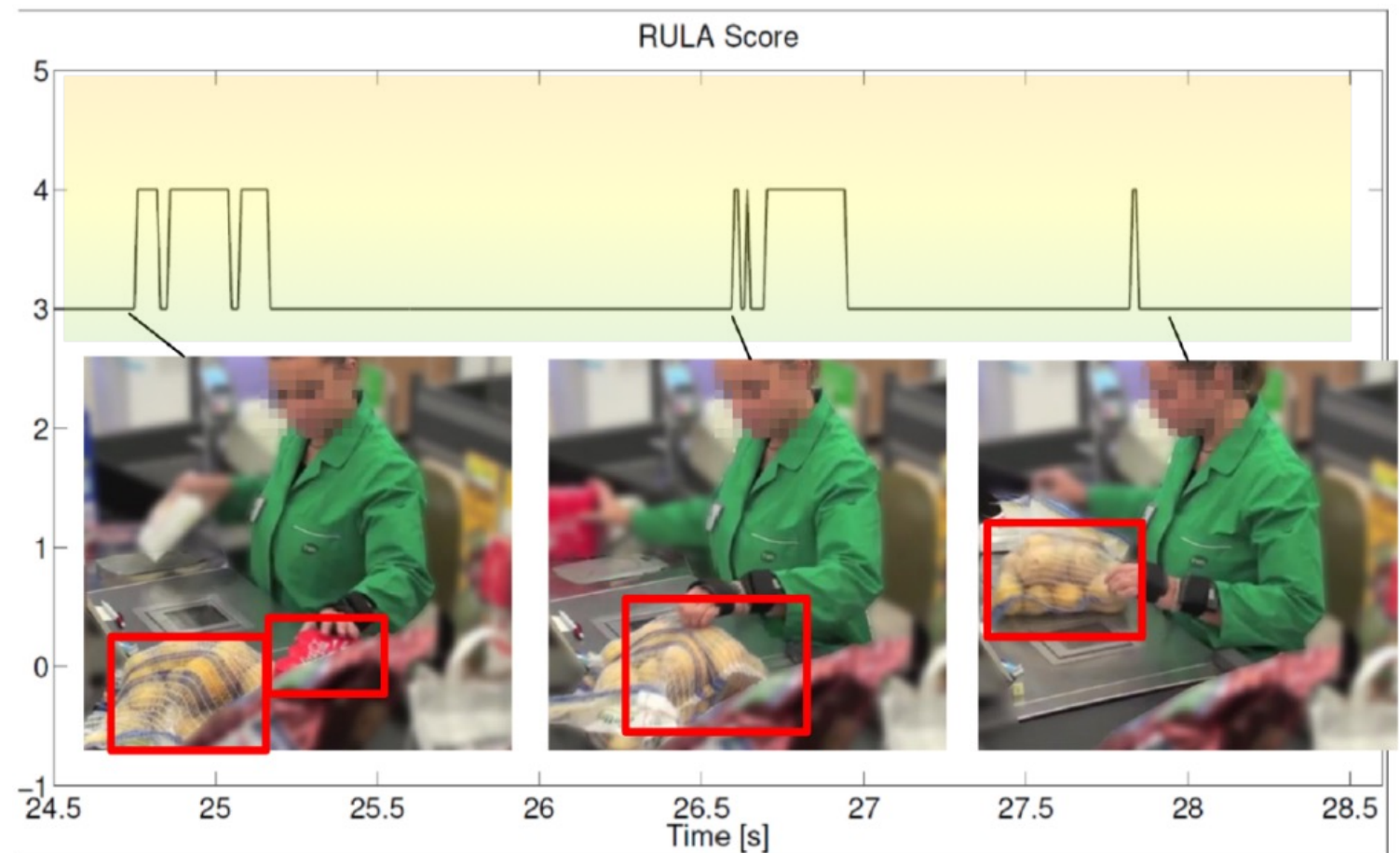
# Ergonomic assessment results

## 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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