Wearable solution for online assessment of biomechanical load risks

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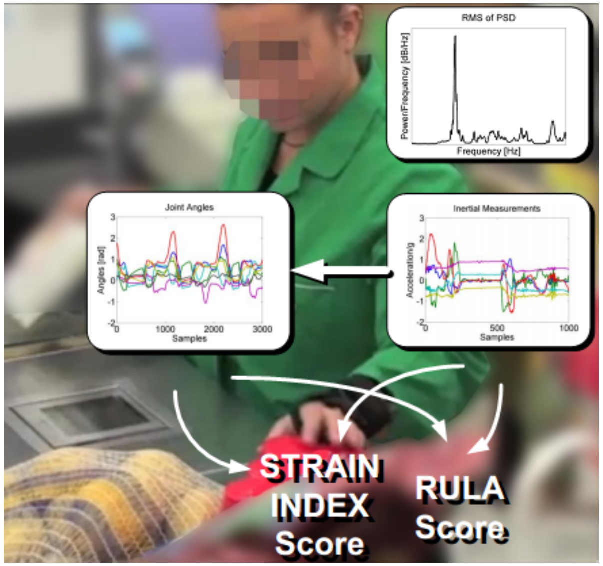
Half-day Tutorial in Bridging Gaps between Computational Biomechanics and Robotics

May 26th ICRA 2015 Seattle



ISTITUTO DI TECNOLOGIE DELLA COMUNICAZIONE, DELL'INFORMAZIONE E DELLA PERCEZIONE
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Background

- Work-related Musculo Skeletal Disorders (WMSD) are the third main reason for disability and early retirement in the U.S.
- In Italy it has been estimated a 159.7% increment in WMSD reports from 2006 to 2009-2010 [2].
- According to this data it is clear how important is correctly diagnosing this kind of pathology.

Traditional Assessment

- Observational techniques (Standard Assessment)
  - Visual inspection
  - Subjective evaluation
- Objective measurements
  - MoCap [2,3]
  - Force exertion (pressure sensors/EMG) [4]
  - MoCap/Force exertion [5,6]
  - Standard assessment Vs Ad-hoc assessment

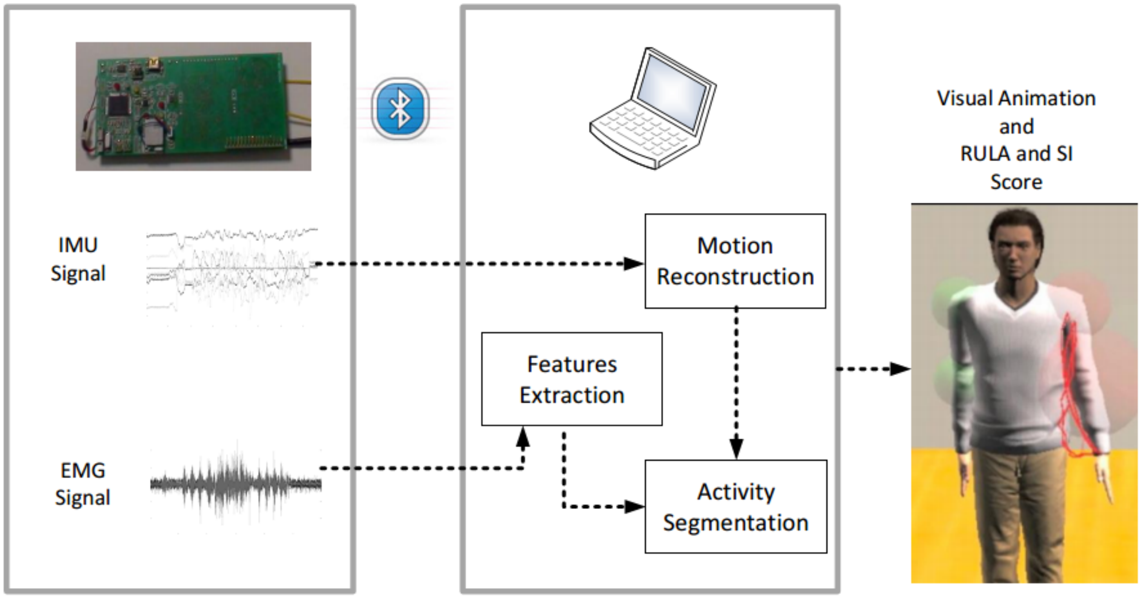
Traditional Assessment

- How to take into account several factors interacting at the same time?
- In general it has been shown that methods assessing different factors lead to different risk evaluations [7].
- How to keep up with the cost increase (money and time) due to the use of more than one method?

Proposed System

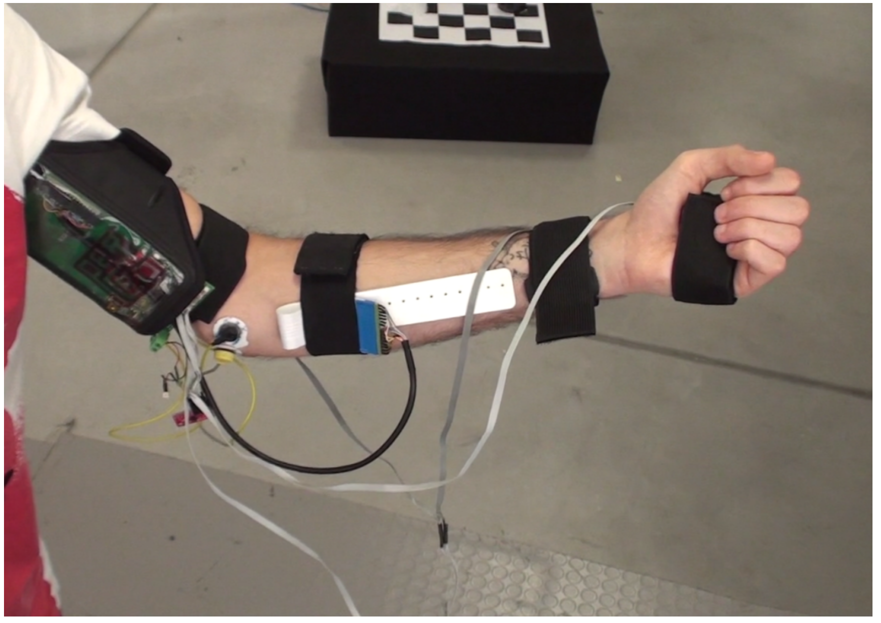
- A novel wearable wireless system capable of assessing the **muscular efforts** and **postures** of the human upper limb for WMSDs diagnosis.
- The system can be used to monitor workers in ecologic environment while they are carrying on their everyday tasks.
- The system provides a **real-time assessment** obtained according to two standard indexes for the analysis of risk factors on workplaces: the Rapid Upper Limb Assessment (RULA) and the Strain Index (SI).

System Architecture



The System Hardware

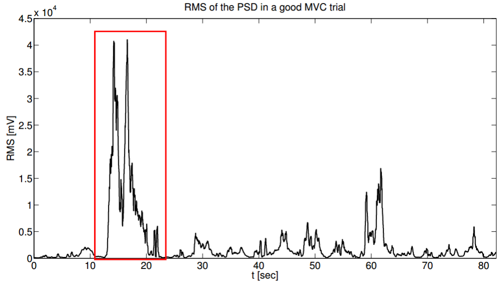
- CPU: STM32F4
- EMG: 8 channels (up to 32)
- IMUs: 9-axis MPU9150
- Bluetooth 4.0
- Webserver on host PC



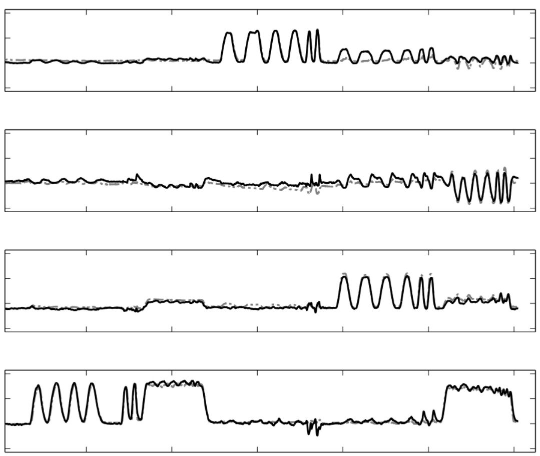
Video

https://www.youtube.com/watch?v=Q5elPTjezVc

Task Segmentation



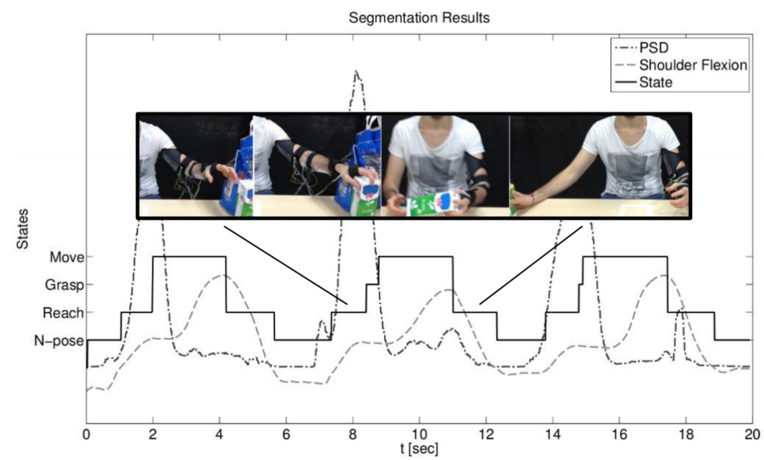
EMG Features



$q/\dot{q}$

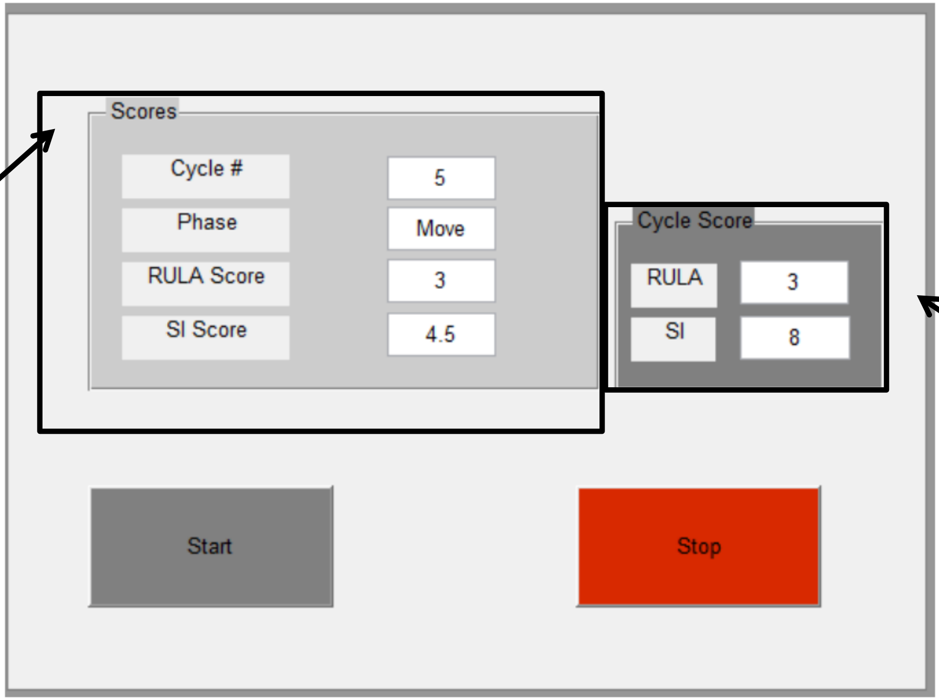
$\bar{p}$

State Machine



System Output

Current Action related information



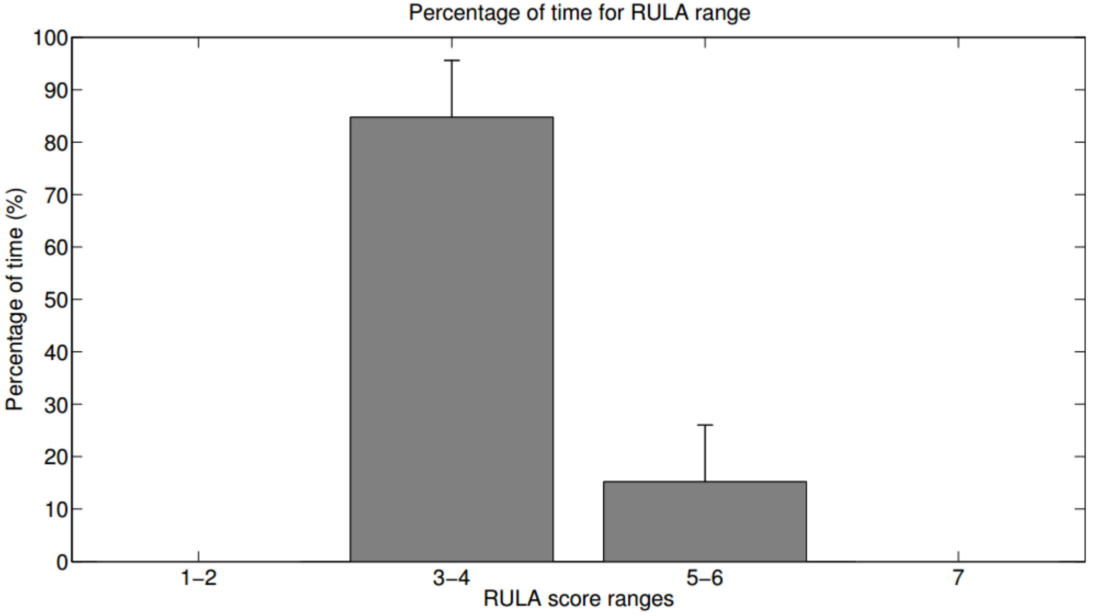
Current Cycle related information

Experimental Setup

- Task: market cashier check-out operations.
- Ten healthy subjects monitored for two check-out operations each.
- Subjects operated in a station ergonomically identical to the real check-out position.
- Every trial was evaluated by two human evaluators to be used as a ground-truth.
- The system practicability was assessed with questionnaires.

Results

- Percentage of time spent in every RULA score range by every subject

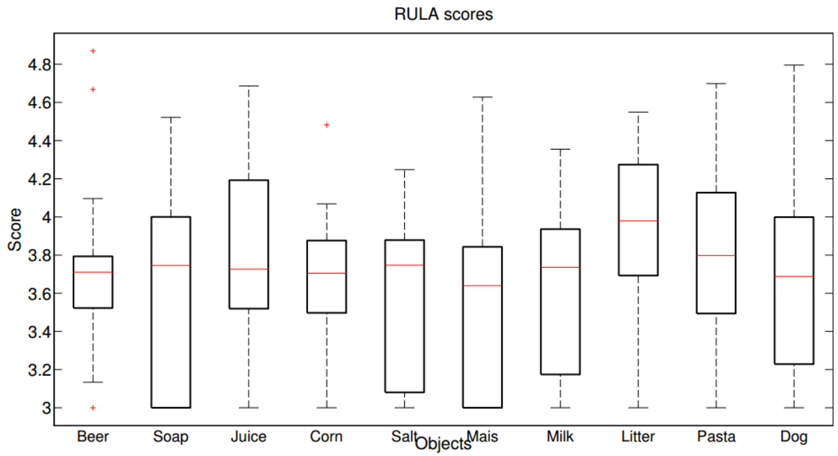


Results

- Comparisons with the human evaluators

Measure	Accuracy %
RULA Action Level	94.79%
SI	44.79%

- System repeatability



Results

- Data were tested for homogeneity with Levene's test.
- A two-way ANOVA was performed on the RULA action level with factors being objects and evaluator type.
- The factor object was found to affect the RULA action level $(p < 10^4)$.
- The factor evaluator type was not significant
- The interaction effect is negligible.

Results

- Wearability assessment of the system, according to questionnaires given to all the subjects. The mean values are shown on according on a Likert scale from 1 to 7.

Parameter	Score
Comfort	5.2
Encumbrance	2
Usability for a complete work turn	5.3

Discussions

- The system is able to give a RULA score estimation congruent to the human evaluators.
- The score associated to every object is repeatable, despite the high variability among subjects (grasp types,…)
- The Cat litter item (heaviest and less comfortable to grasp) has the highest RULA score.
- The lowest score is associated to the Sweet corn can item, that is the lightest and the most easily graspable.

Discussions

- The system gives a SI score congruent to the evaluators in almost the 50% of the cases.
- SI score depends on the intensity of exertion requiring a MVC test.
- As pointed out in [8]:
  - The goodness of the test varies significantly according to the trigger threshold for the intensity of exertion.
  - High-frequency acyclic movements produce artifacts in the EMG signals, that may affect the SI score.

Conclusions

- This work presents a wireless wearable system for online assessment of WMSDs risks for the upper limb.
- The system performs an online score computation according the RULA and SI scoring methods.
- The scores estimated with the proposed approach proved to be congruent with the analysts' scores.
- The users rated the system to be usable for a whole average working turn, being not obstructive or painful during the movements.

Further Developments

- Implementation of a better intensity of effort estimator (both technical and procedural).
- Automatic calibration procedure to estimate limbs lengths autonomously during the calibration procedure.

Thanks

- Emanuele Ruffaldi

- Alessandro Filippeschi

- Italian Ministry of Health and ASL Viareggio

Questions?

thank you!

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