Wearable Computing:
Accelerometers' Data Classification of Body Postures and Movements

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Wearable Computing: Accelerometers’ Data Classification of Body Postures and Movements

UGULINO

DÉBORA

KATIA

EDUARDO

RUY

HUGO FUKS

2 PhD Theses in HAR

Research Area: on-body sensors and hybrid sensors approaches
(Wearable sensors from the Arduino Toolkit)

UGULINO

Research Area: ambient sensors approaches
(mainly based on Microsoft Kinect, and Interactive systems)

EDUARDO

Motivation

- Rise of Life Expectancy and ageing of population
  - UbiComp technologies have the potential to support elderly independent living.
  - Monitoring of Daily Living Activities.
  - Monitoring of Exercises (Weigth Lifting, for example).
    - Qualitative Acitivity Recognition.
  - *Life log* to improve patient's chart.

- A new world, awash of sensors' data
  - How to interpret the raw data?

Relevance of on-body sensors' approach

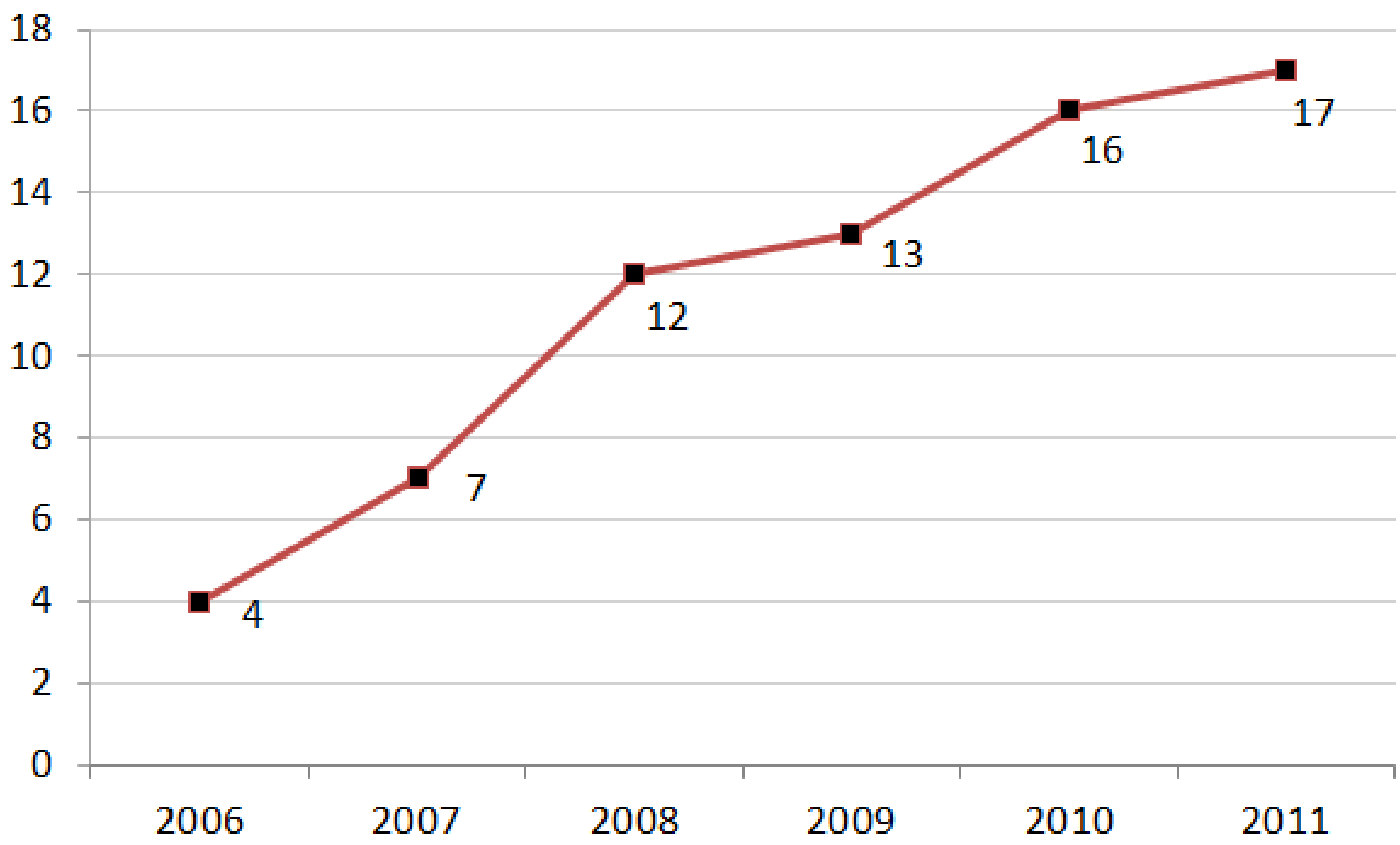
- On-body sensing
  - Outdoor activities (bicycle, jogging, walking)
  - A log for the whole day
  - Personal technology
    - Wearable devices are able to carry many information of a patient

- Ambient Sensing
  - More context information
  - Not so many informations from the patient (heart beating?)
  - Often restricted to indoor environments
  - Privacy issues

Literature Review

- Systematic approach (Reliability and construct validity)
- Research Question: What are the research projects conducted in recognition of human activities and body postures using accelerometers?
- Search string: (((("Body Posture") OR "Activity Recognition")) AND (accelerometer OR acceleration)). Refined by: publication year: 2006 – 2012;
- Results in IEEE database: 144 articles;
- Exclusion criteria
  - Smartphones, image processing, not human, composite activities, games, gesture input recognition, energy consumption
  - We used the most recent publication of same research
- Result: 69 articles

Literature Review



IEEE publications of HAR based on wearable accelerometers

Literature Review

- Technique for activity recognition
  - Machine Learning (70%)
    - Supervised Learning (62%)
    - Unsupervised Learning (7%)
    - Semi-supervised Learning (1%)
  - Treshold-based algorithms (27%)
  - Others (3%)
    - Fuzzy finite state machines, ontology reasoning, etc.

- Subject Independent analysis
  - Only 3 out of 69 papers (4.3%)

Literature Review (recent publications)

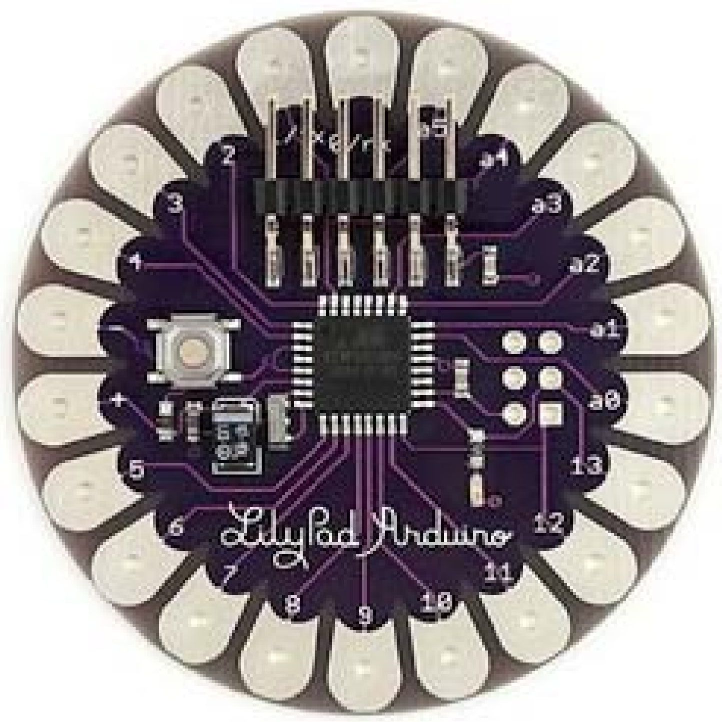
Research	# of sensors	Technique	# of users	Learning mode	Correct (%)
Liu et al., 2012	1	SVM	50	Supervised	88.1
Yuting et al., 2011	3	Threshold-based	10	--	98.6
Sazonov et al., 2011	1	SVM	9	Supervised	98.1
Reiss & Stricker, 2011	3	Boosted Decision Tree	8	Supervised	90.7
Min et al., (2011)	9	Threshold-based	3	--	96.6
Maekawa & Watanabe, 2011	4	HMM	40	Unsupervised	98.4
Martin et al., 2011	2	Threshold-based	5	--	89.4
Lei et al., 2011	4	Naive Bayes	8	Supervised	97.7
Alvarez et al., 2011	1	Genetic fuzzy finite state machine	1	Supervised	98.9
Jun-ki & Sung-Bae, 2011	5	Naive Bayes and SVM	3	Supervised	**99.4**
Ioana-Iuliana & Rodica-Elena, 2011	2	Neural Networks	4	Supervised	**99.6**
Gjoreski et al., 2011	4	Naïve Bayes, SVM, C4.5, Random Forest	11	Supervised	90
Feng, Meiling, and Nan ,2011	1	Threshold-based	20	--	94.1
Czabke, Marsch, and Lueth, 2011	1	Threshold-based	10	--	90
Chernbumroong, et al., 2011	1	C4.5 and Neural Networks	7	Supervised	94.1
Bayati et al., 2011	--	Expectation Maximization	--	Unsupervised	86.9
Atallah et al., 2011	7	Feature Selection algorithms*	11	Supervised	--
Andreu et al., 2011	1	fuzzy rule-based	--	Online learning	71.4

Literature Review

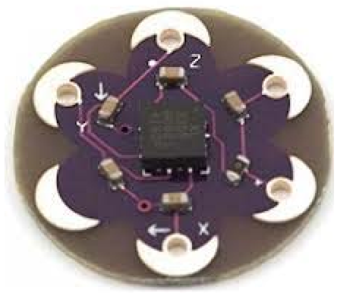
- A few datasets (publicly) available
  - Lianwen Jin (South China University)
    - No timestamp
    - Unsynchronized readings (you must choose one sensor to use)
    - 1278 samples
    - Available (you must send him a signed license agreement)

Building the wearable device

Arduino LilyPad board



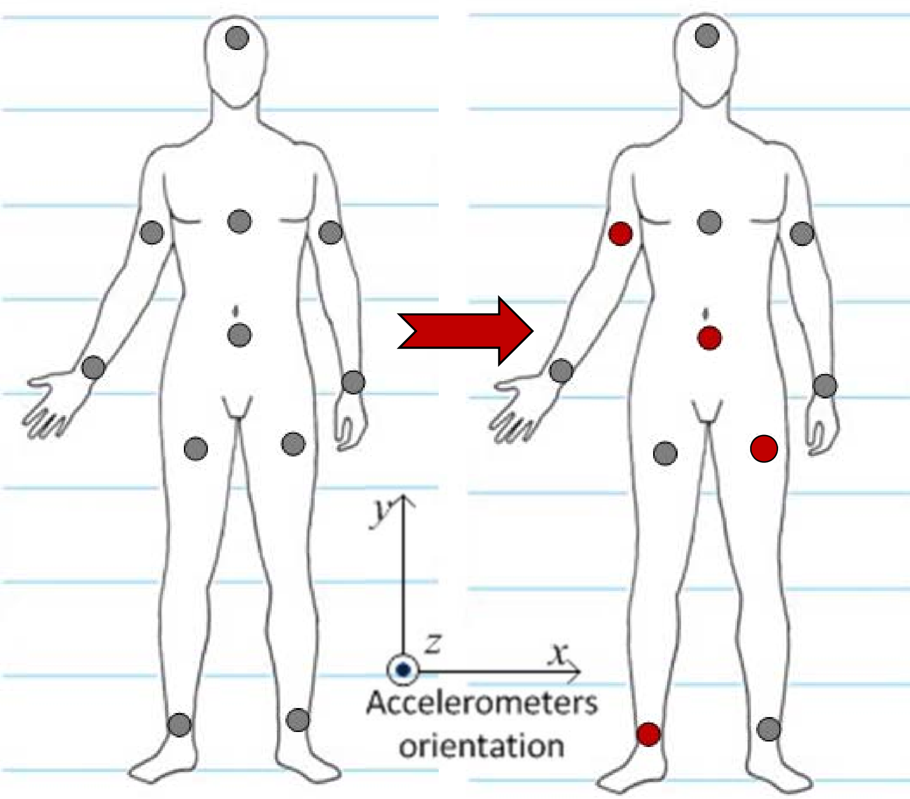
LilyPad Accelerometer (tri-axial, ± 3.6g)



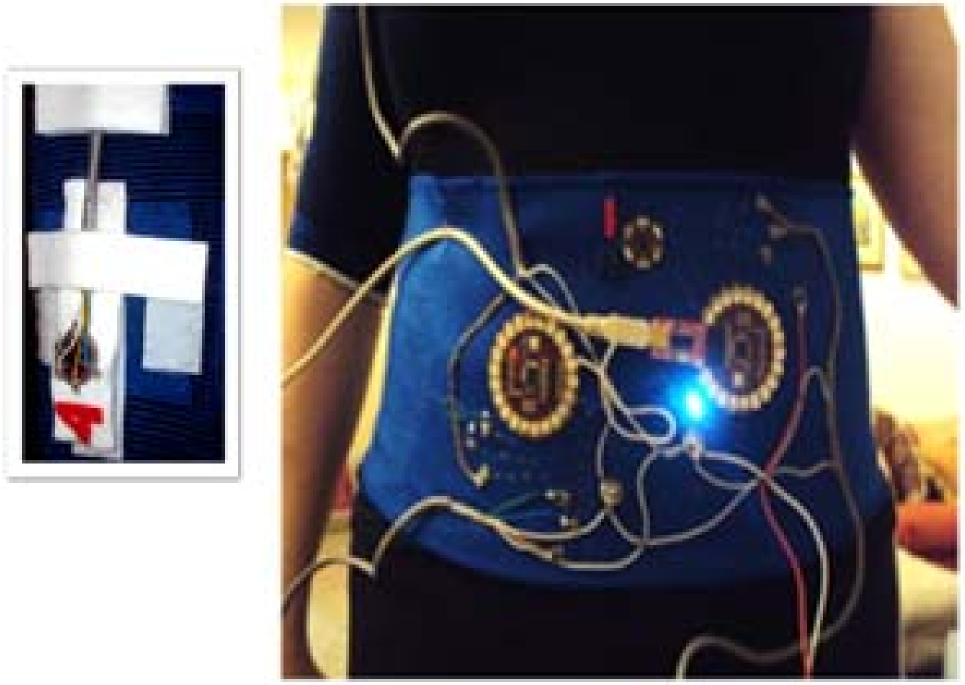
ADXL335
Frequency: 10hz

Building the wearable device

Positioning



User wearing the device



Experimental Setup

- Task
  - Classifying task (multiclass)
  - Output: sitting, standing, standing up, sitting down, walking
  - Input:

```
@AccelX_readings: <x, y, z, m, r, p>

 x, y, z: raw acceleration data from accelerometers

 (m) Module of the acceleration vector

 (r) Rotation over the x axis

 (p) Rotation over the y axis
 @class: nominal
        (sitting, standing, standing up, sitting down, walking)
```

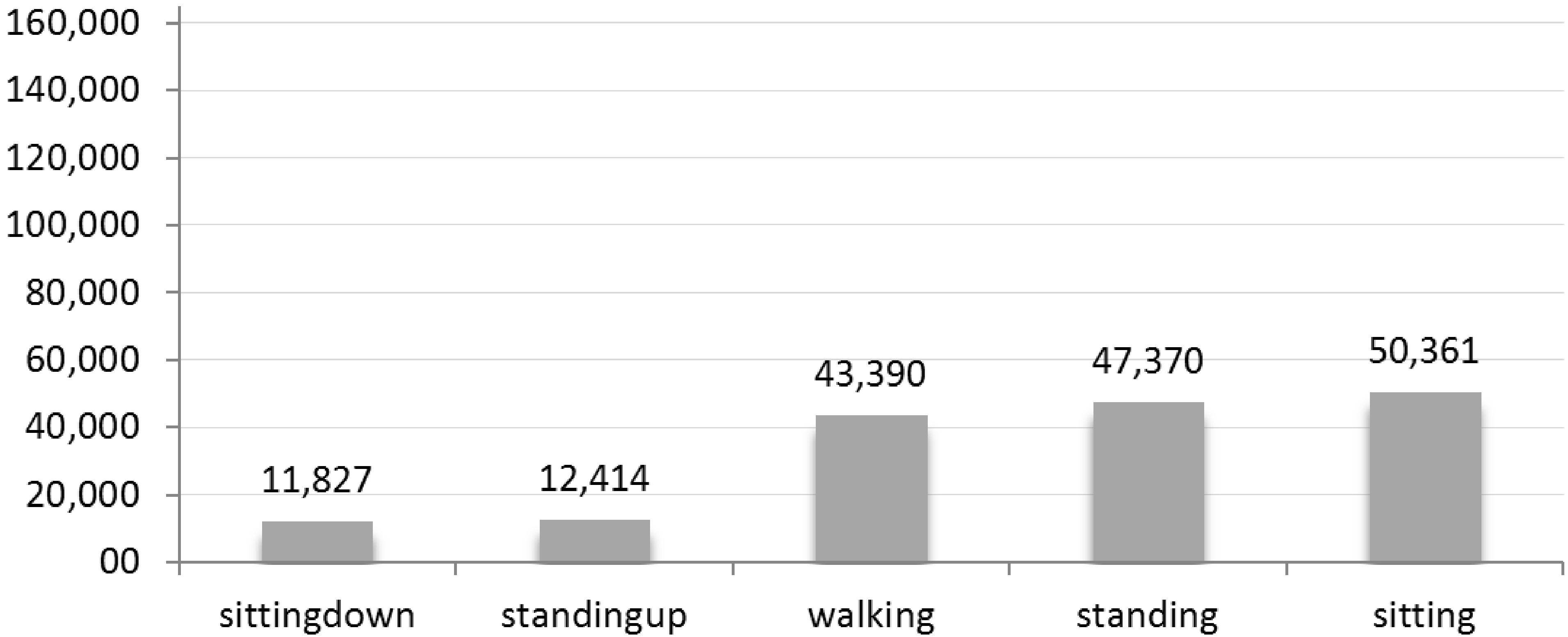
Data Collection

- 8h of activities
- 4 subjects (nearly 2 hours per participant)
- Participants' profiles

Participant	Sex	Age	Height	Weight	Instances
A	Female	46 y.o.	1.62m	67kg	51,577
B	Female	28 y.o.	1.58m	53kg	49,797
C	Male	31 y.o.	1.71m	83kg	51,098
D	Male	75 y.o.*	1.67m	67kg	13,161*

*** A smaller number of observed instances because of the participant's age**

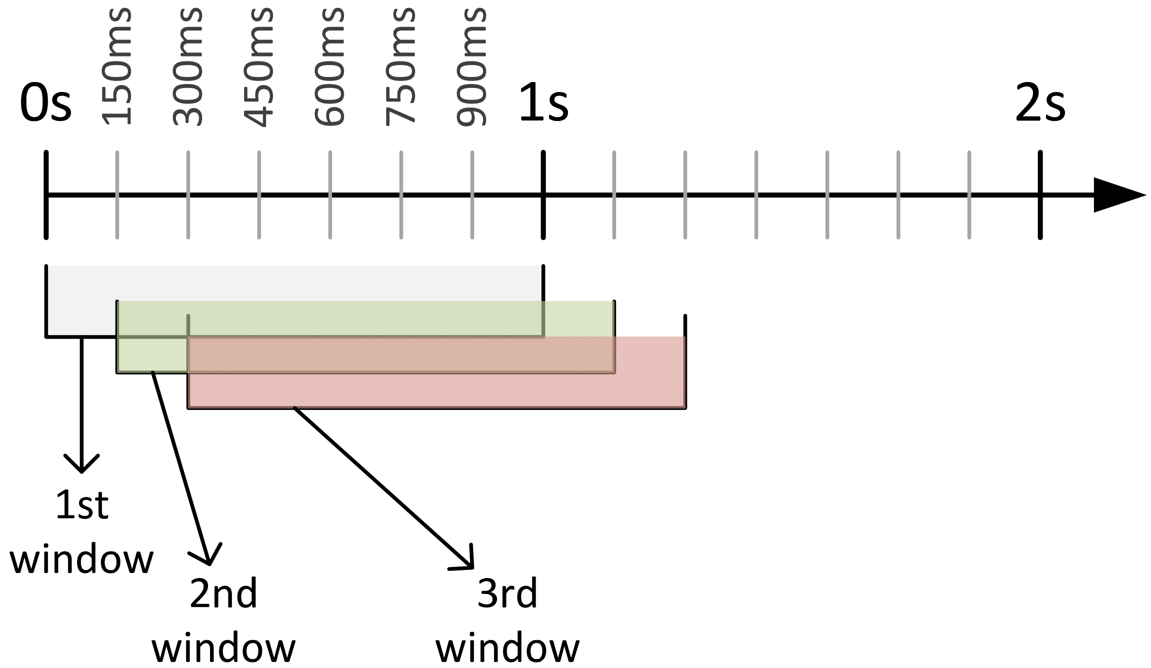
Data Collection



Frequency of classes between collected data

Data Pre-processing

- We defined a time window of 1 second, 120ms overlapping
  - After several experimental tests, we found 1 second more suitable to our list of activities



- Readings inside each window were statistically summarized according the instructions of Maziewski et al. [2009]

Feature Selection

- Mark Hall's algorithm (BestFirst greedy strategy)
- 11 features were selected
  - Accelerometer #1 (waist)
    - Discretization of M1 (module of acceleration vector)
    - R1 (roll)
    - P1 (pitch)
  - Accelerometer # 2 (left thigh)
    - M2 (module of acceleration vector)
    - discretization of P2 (pitch)
    - Variance of P2 (pitch)
  - Accelerometer # 3 (right ankle)
    - Variance of P3 (pitch)
    - Variance of R3 (roll)
  - Accelerometer # 4 (right upper arm)
    - M4 (module of acceleration vector)
  - All sensors (combined)
    - Mean and standard deviation of (M1+M2+M3+M4)

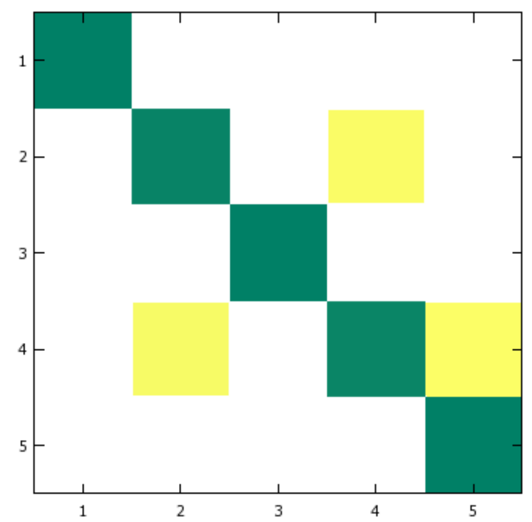
Classifier of Body Postures and Movements

- We tried: SVM, Voted Perceptron, MultiLayer Perceptron (Back Propagation), and C4.5
  - 67 tests!
- Better results: C4.5 and Neural Networks
- Top result
  - Adaboost + 10 C4.5 decision trees (0.15 confidence factor)
- Structured Perceptron + Induction Features method (Eraldo Fernandes, Cícero Santos & Ruy Milidiú)
  - Seems promising as it provides equivalent results of C4.5, but with better generalization (leave-one-person-out results)
  - We tried StrucPerc AFTER writing the paper

Classifier of Body Postures and Movements

Predicted class						
Sitting	Sitting down	Standing	Standing Up	Walking		Actual class
50,601	9	0	20	1	Sitting	
10	11,484	29	**297**	7	Sitting down	
0	4	47,342	11	13	Standing	
14	**351**	24	11,940	**85**	Standing up	
0	8	27	60	43,295	Walking	

Confusion Matrix



Conclusion

- The contributions are
  - From the literature review
    - The state-of-the-art of recent reseach on On-body sensing based HAR
  - From the experimental research
    - A dataset for benchmarking (available soon on our website)
    - A classifier (available soon on our website)

Future / Ongoing work

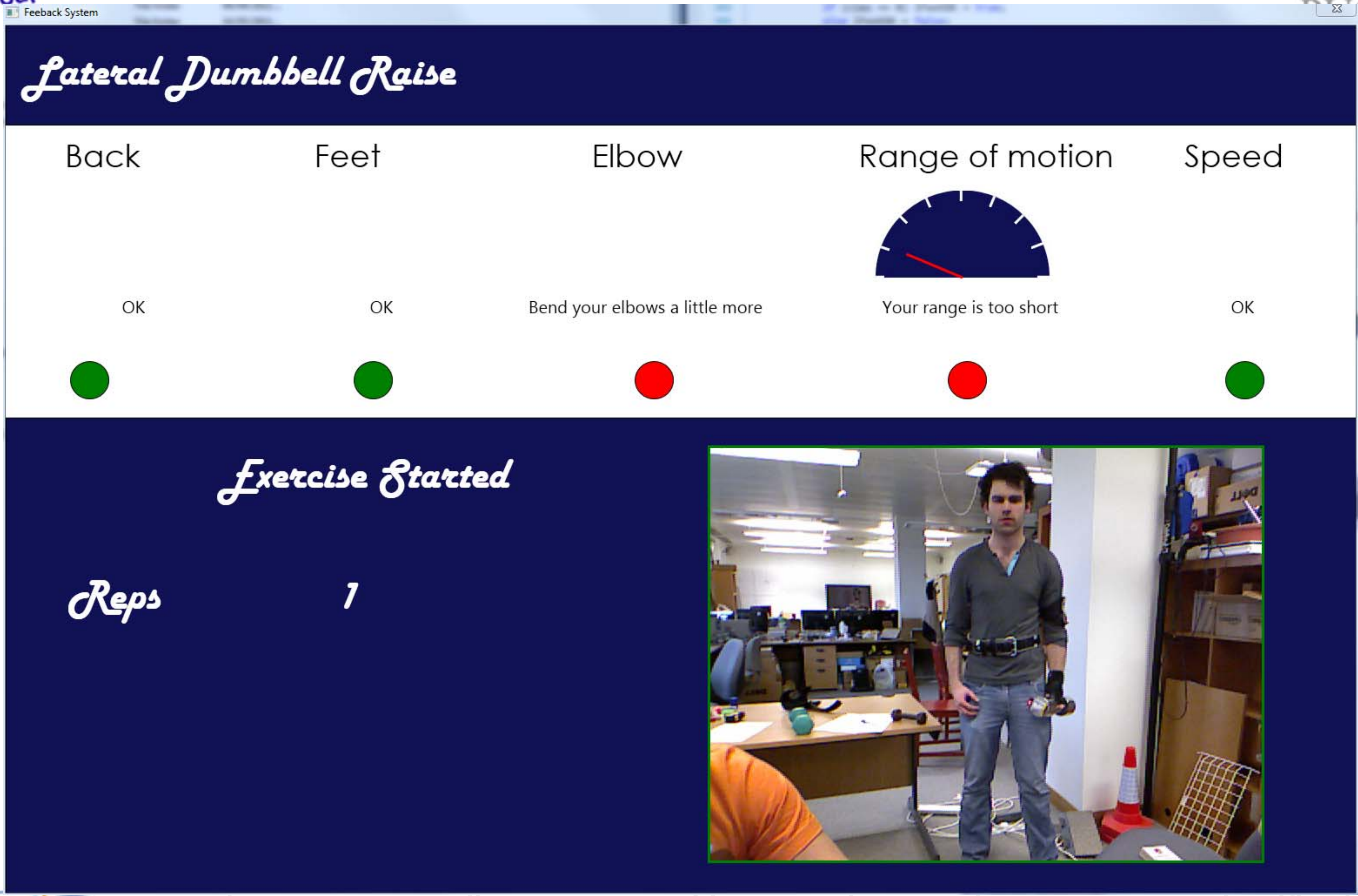
- New wearable (HARwear version 2)

Future / Ongoing work

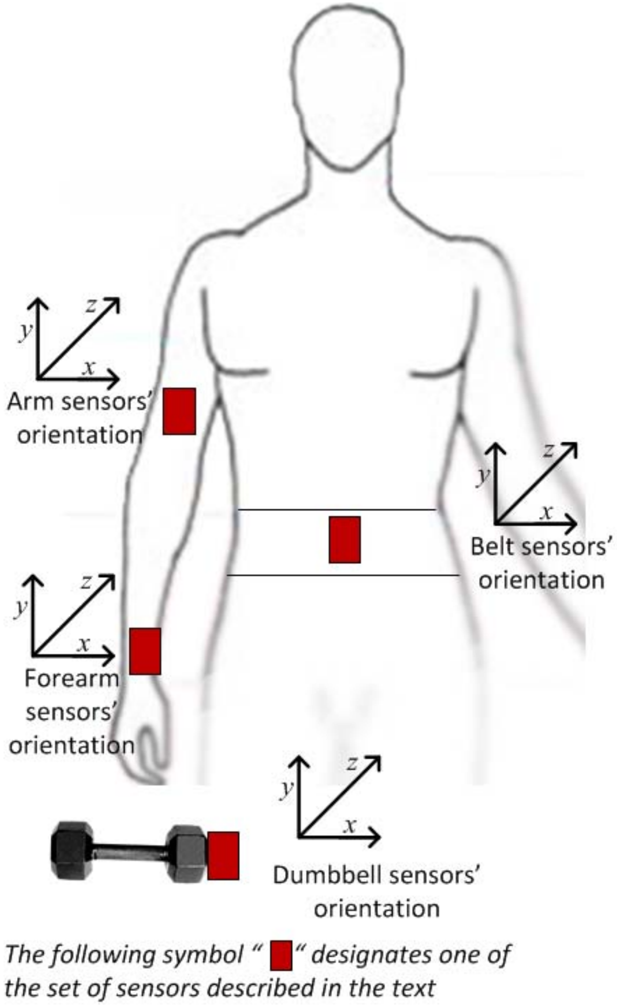
- Data collection with 20 (or more) users
  - Profile: 18-21 years old
  - Body Mass Index ranging from 22-26
  - Male and female subjects
  - Activities comprising weight lifting exercises (for QAR)

- Qualitative Activity Recognition (QAR)
  - Recognize “how well” instead of “what” activity
  - We already collected data with 7 users (similar profile)
  - The task is harder, lower accuracy rate, but still promising

Future / Ongoing work (QAR)



Future / Ongoing work (QAR)



Future works

- Pipeline of tasks?
  - From easier tasks to hard tasks
  - Inspired on the NLL community experience
- Organize tasks (and classes) in a graph?
  - Using ontology to describe and relate tasks
  - Ontology reasoning to select a branch of the graph to apply statistical reasoning on the selected branch
- Investigation of hybrid approaches
  - Ambient Sensing + On-body sensing ⇨ to recognize composite activities and social activities
- Structuring of raw data, adding semantics, sensor identifying, etc,

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