Efficient Object Detection through Grasp Intention

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Presentation of the Master Thesis

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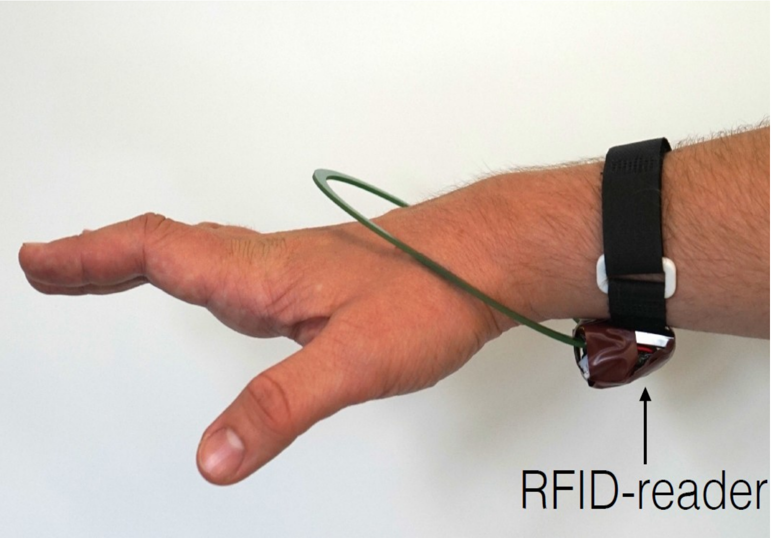
Agenda

- Motivation
- Overview
- Sensors
- Grasp Analysis
- Feature Extraction
- Energy Efficiency
- Grasp Detection

Motivation

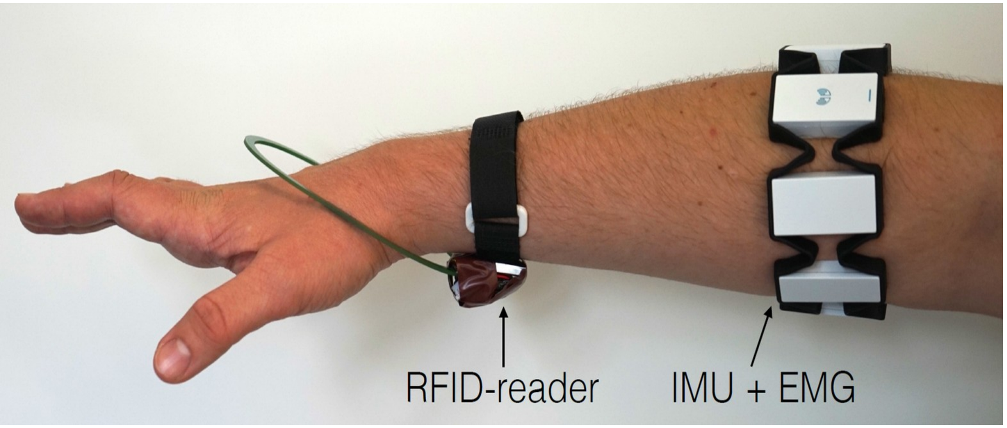
- Detect handled objects

- Applications:
  - Stocktaking [1]
  - Reason about activity [2] (activities of daily living, …)
  - Guidance [3]



- Drawback
  - High energy consuming object detectors [4]
  - ~ 2 h battery lifetime

Overview



- Idea:
  - Only activate object detector when a grasp is performed
- Implementation:
  - Additional grasp detection
  - Additional sensors
  - Prototype split into three subsystems:
    - Object detector
    - Forearm sensor (grasp detection sensing)
    - Assisting standard computer (grasp detection)

Sensors
Object Detection

- Multiple sensors available
  - RFID (used)
  - Camera based
  - Microphone
  - Capacitive and electromagnetic sensing

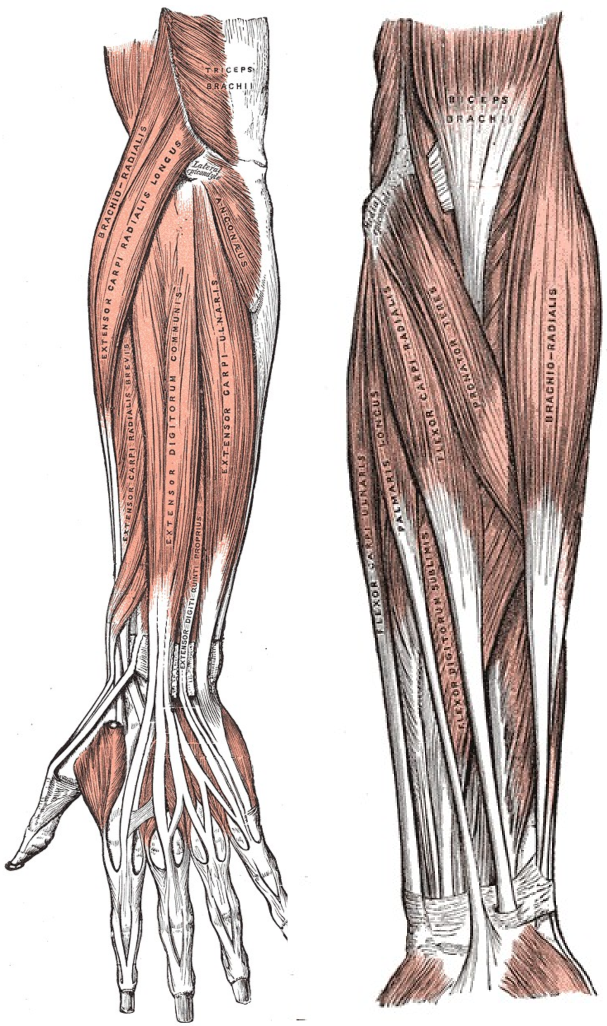
Sensors
Forearm Sensor

- Commercial device: Thalmic Labs Myo

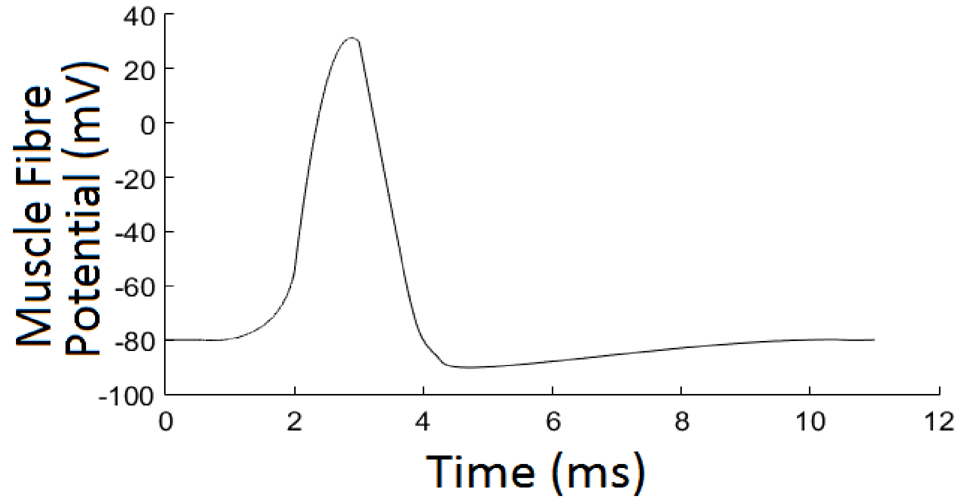
- IMU (InvenSense MPU9150)
  - Three axis accelerometer (50 Hz, ±16 g)
  - Three axis gyroscope (50 Hz, ±2000 °/s)

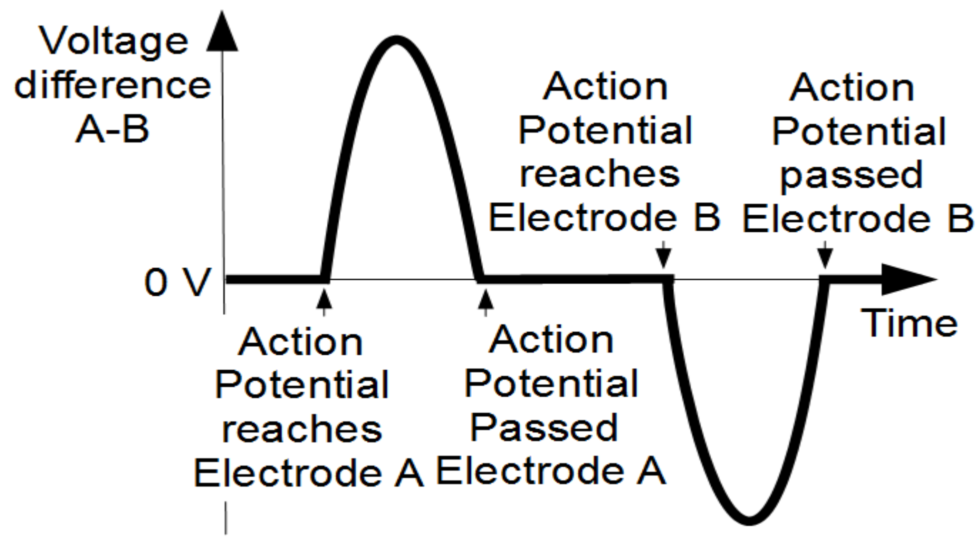
- Electromyographie sensor
  - 8 channel
  - 200 Hz

Sensors
Electromyography



[4]



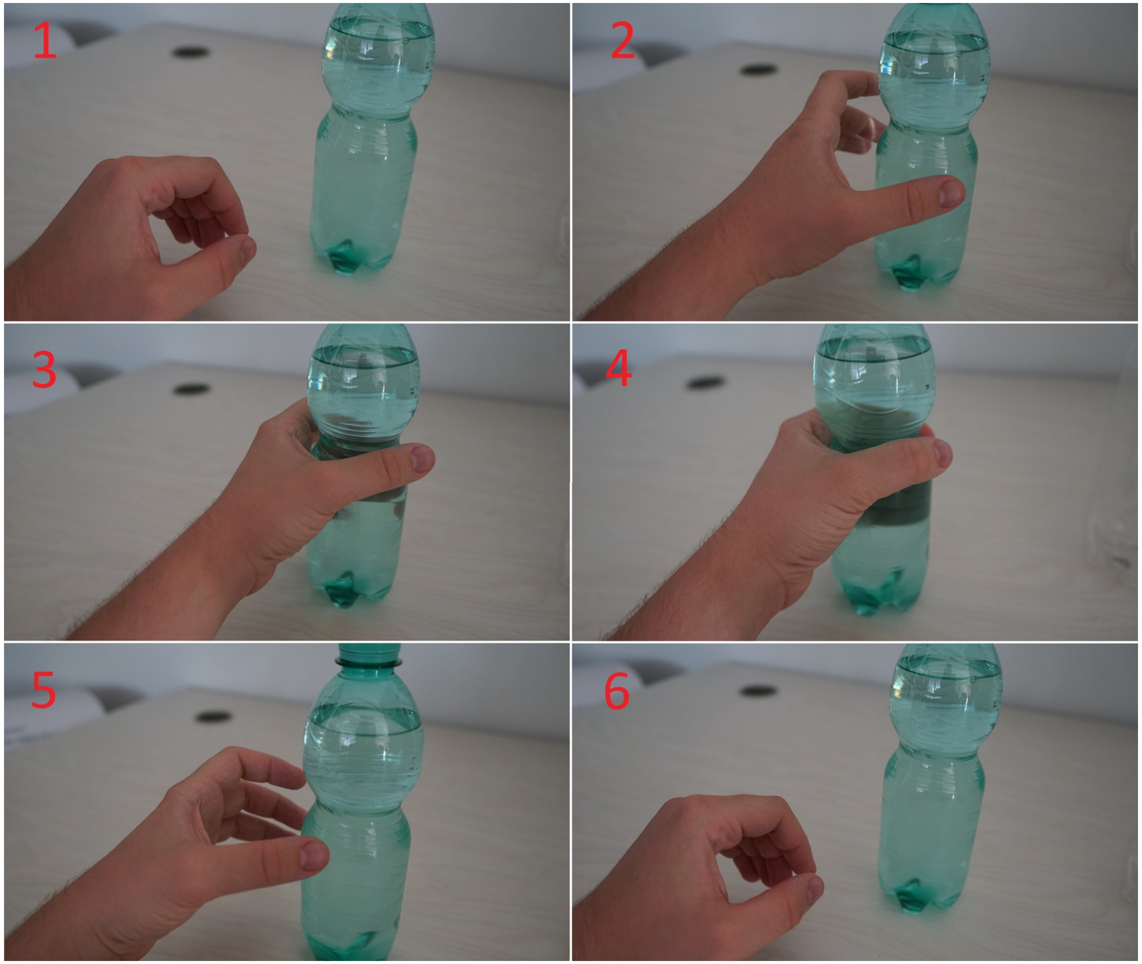


Grasp Analysis
Taxonomy

- Found in Literature [5,6]
- Two different main grasp classes
  - Power grasps (easy to detect)
  - Precision grasps (difficult to detect)
- Object geometry
- Thumb position (adducted / abducted)
- Finger opposition (palm / pad / side)
- Virtual fingers

Grasp Analysis Steps

- Right image: sequence of a grasp
- Grasp divided into five steps (1 and 6: null)
- Similar features per step in different grasps



Grasp Analysis
Three Layer Model - Overview

- Layer 1: base activity detection
- Layer 2: grasp segment recognition
- Layer 3: final grasp evaluation

Grasp Analysis
Three Layer Model – Layer 1

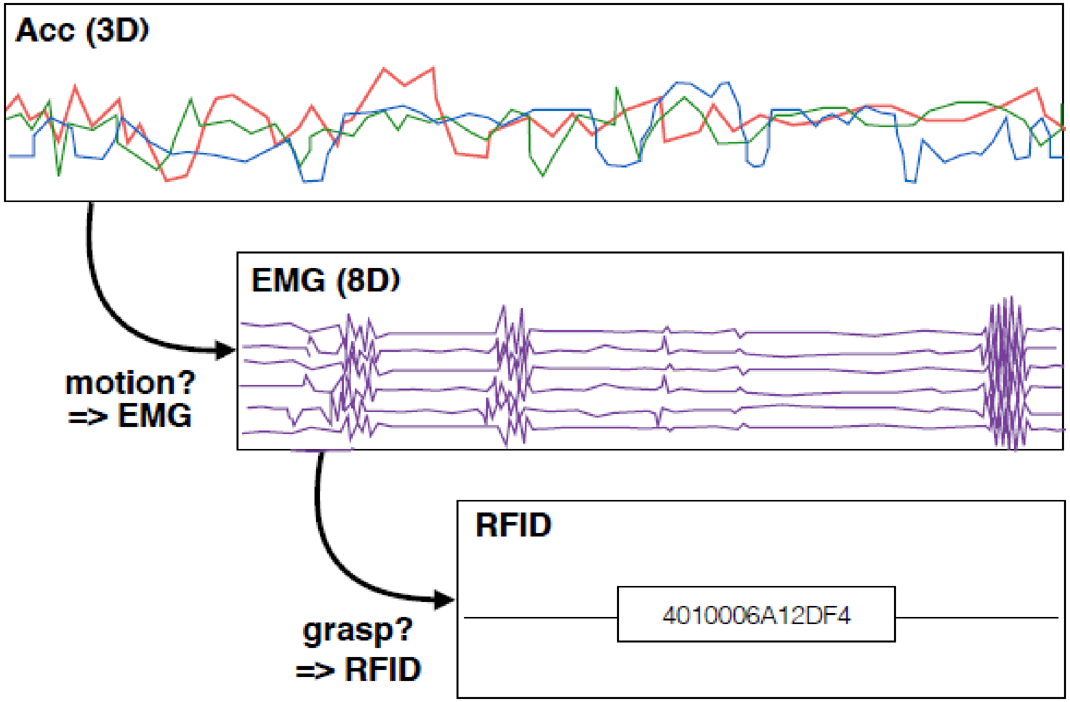
- Detection of the base activity
- Find activities where no grasp is possible
- Implemented activities
  - Rest (no detection)
  - Walk (no detection)
  - Work (detection possible)
- Implemented only on IMU features
- Can disable further processing and sensors

Grasp Analysis
Three Layer Model – Layer 2

- Grasp segment recognition
- Check for grasp related features
- Based on IMU and EMG features
- Adaptive thresholding
  - Is a muscle activity found?
  - No setup normalization necessary

Grasp Analysis
Three Layer Model – Layer 3

- Final grasp evaluation
- Sequencing of the found Layer 2 features
- Controlls starts of object scans



Feature Extraction Methods

- Inspection of data
  - Visualize sensor data
  - Statistical values
  - Principal component analysis

- Knowledge
  - Muscle positions and functions
  - Taxonomy
  - Step sequence
  - Typical grasping behaviours

Energy Efficiency
Sensors

- Grasp detection
  - Accelerometer < 0.2 mA
  - Gyroscope ~ 3 mA
  - 8 channel EMG ~ 8 mA
  - Processing ~ 7.7 mA

- Object detection
  - RFID (full duty cycle) > 60 mA
  - RFID (1 Hz) > 18.2 mA (former study [7]: 65 % of tags detected towards full duty cycle)

Energy Efficiency
Three Layer Model Implementation

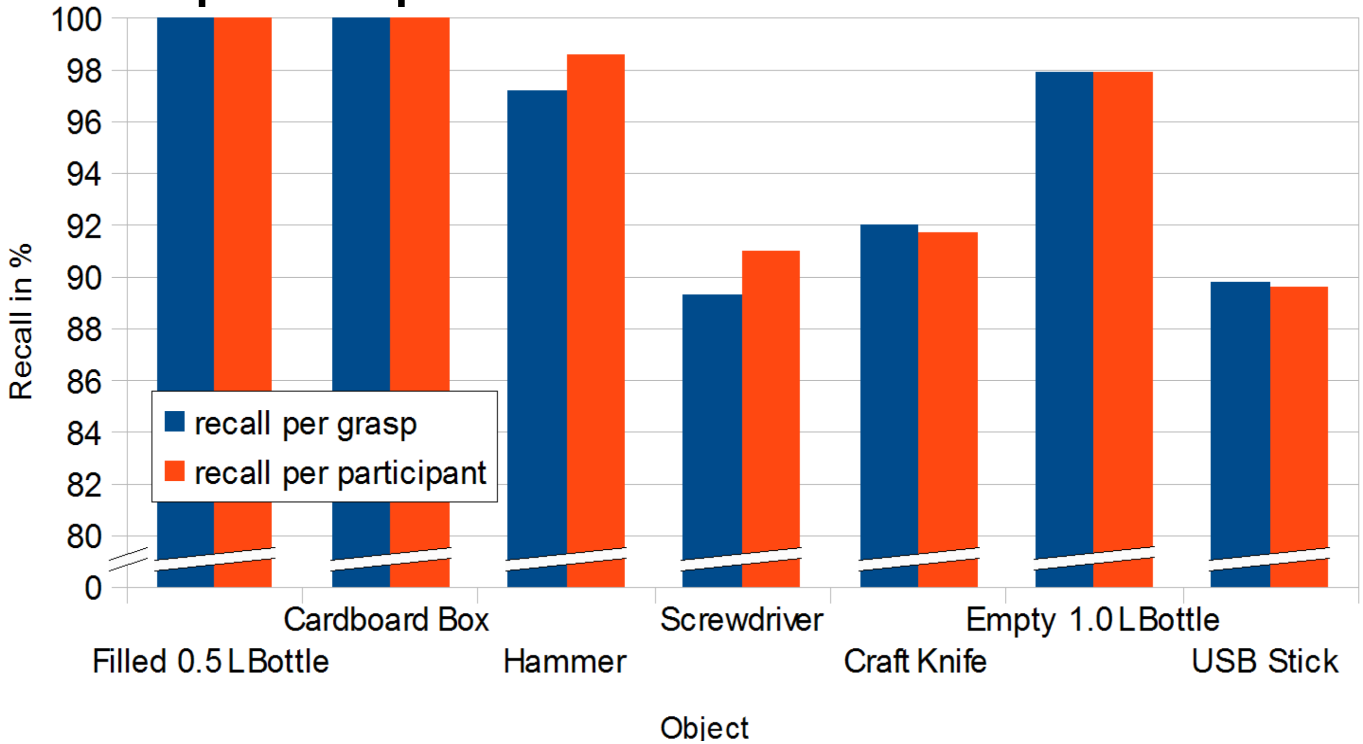
- Processing: 7.7 mA
- Layer 1 (accelerometer only): 0.2 mA
- Layer 2 (additional EMG sensor): 8 mA
- Assuming half time resting and walking activity: total overhead of 11.9 mA

Grasp Detection
Boxtest

- Comparison with former study [7]
- Grasps are free to choose
- Less information to participants
  - No active feedback of grasp detection
  - No information about purpose of the test
  - Participants told tests have been about how they perform tasks

Grasp Detection
Boxtest Results

- 95.5 % recall at start of grasp
- Better results with power grasps
- 5 of 12 participants: 100 % recall



Grasp Detection
Realtime Analysis

- Test with detection feedback to participants
- Active plotting of sensor data
- No test script
- Participants informed about test purpose
- Performed with random participants
  - 20 years celebration faculty of engineering
  - Wearables sensor laboratory presentation
- Results:
  - Untypical behaviour
  - Feedback used by participants

Grasp Detection
False Positive Grading

- Used to get a number of false positives
- Similar to grasp gestures for false positves:
  - Scratch head
  - Use light switch
  - ...
- Crosscheck recall on boxtest's objects
- False positive rate 78.5 %, recall 82.3 %

Grasp Detection
Object Detection

- Same setup as boxtest
- Many misses (RFID range too short)
- 32 of 94 objects missed completely
- 1 of 94 objects missed by grasp detection
- Tight set with less pauses
  - 0.94 detections per second
  - 0.02 not task script related detections per second, also including grasps

References

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End

Thanks for listening.

Questions?