Telematics
Computer Systems

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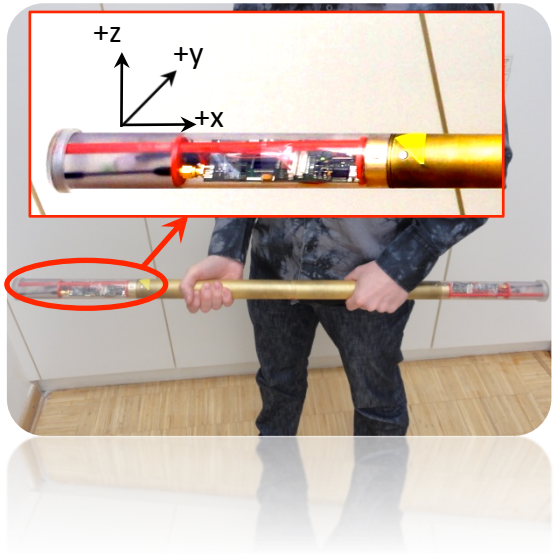
Ideen zünden!



Integration of Distributed Event Detection in Wireless Motion-Based Training Devices

Norman Dziengel, Marco Ziegert,
Martin Seiffert, Jochen Schiller

Freie Universität Berlin

{dziengel, ziegert, seiffert, schiller}@inf.fu-berlin.de

Georg Wittenburg

INRIA
LIX, École Polytechnique

georg.wittenburg@inria.fr

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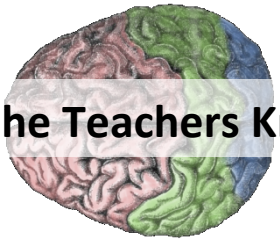
Typical scenario in YOUR life

- Imagine, your Stick-Fight Master is for tee.
- You have to train during his absence.
- If you make a mistake, you may get used to it.
  - ➢ It would help to have an intelligent Fighting Stick

Traditional Fighting-Stick

+



Part of the Teachers Knowledge

=

Wireless Motion-Based Training Device

Motivation / Goal

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Motivation

- Computer based Sports, Games and Medical Aid gain in importance
- Immediate feedback is often needed without contact to any kind of base station
- Learn from devices which are a priory trained by teachers or therapists

Goal

- Intuitive devices with embedded intelligence
- Real-World usability
- High accuracy during event detection

Wireless & motion-based applications

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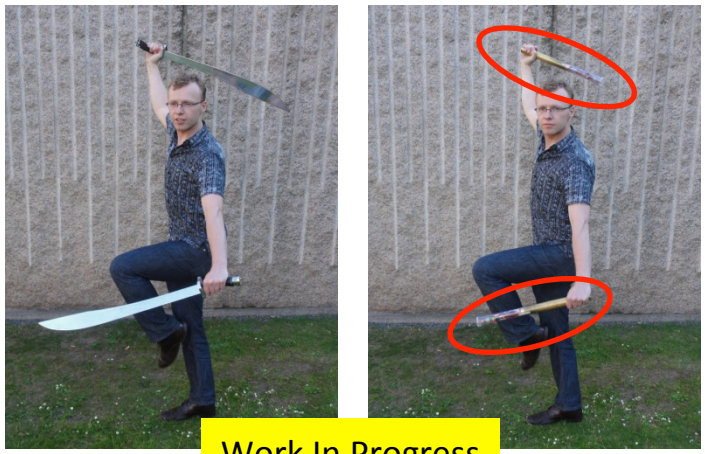
1. Fence Monitoring AVS-Extrem

Done

2. Coupled Training Device

Done, Focus Of This Talk

3. Decoupled Training Device



Work In Progress

4. Rehabilitation

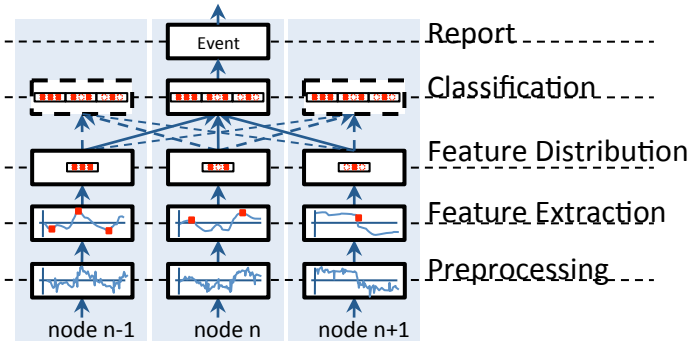
Future Work

Design Challenges

1. Sensor Node Platform
   - Energy awareness
   - Communication issues
   - Sensor (acceleration)
   - Flexibility

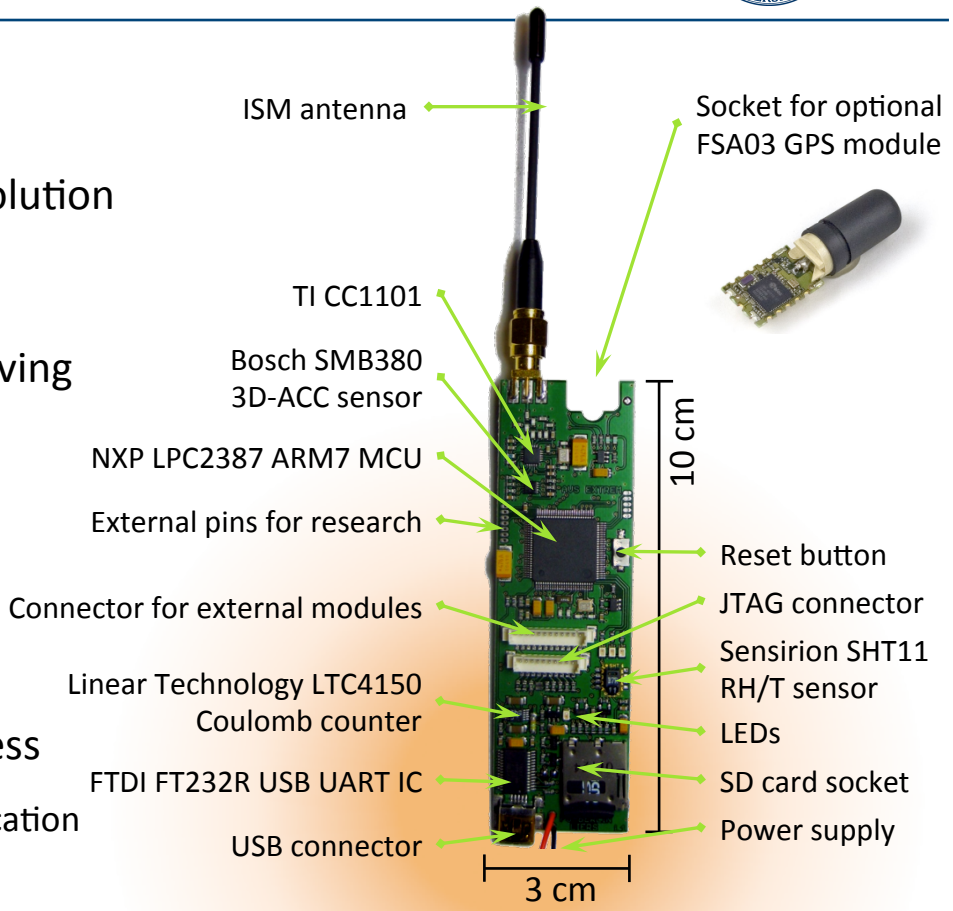
2. Housing
   - Look & feel and usability
   - Thin housing
   - Integration of PCB-Shape & energy supply

3. Event Detection
   - Decentralized pattern recognition
   - No dedicated infrastructure



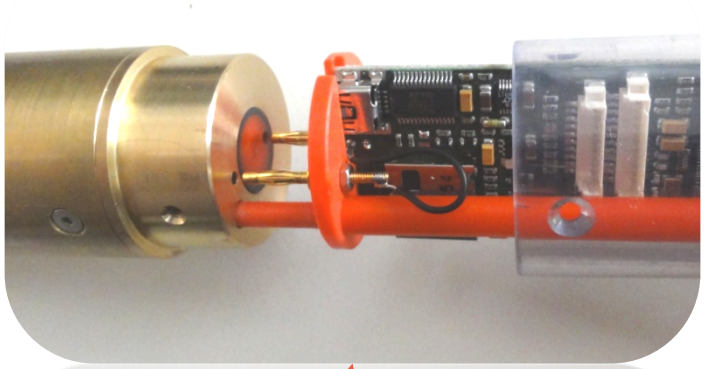
Hardware and Software Platform

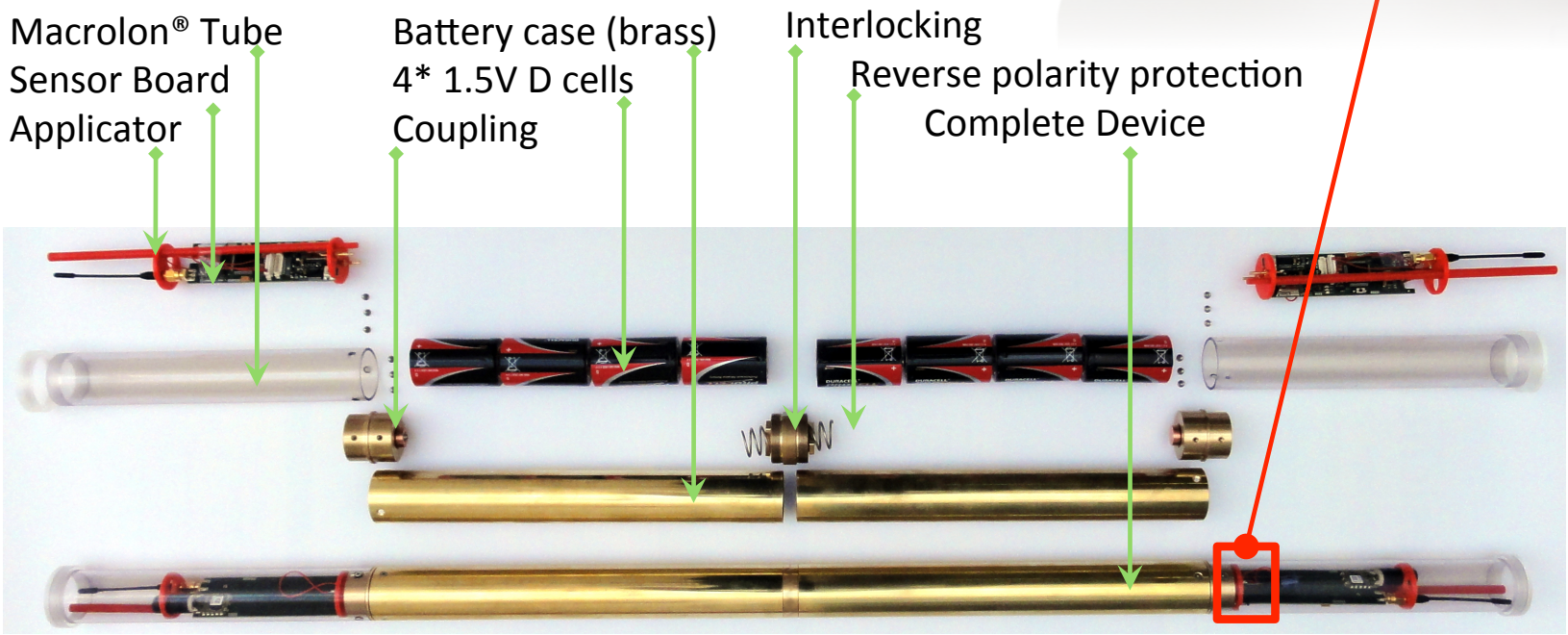
- ARM7-MCU based architecture
- 3D-Acceleration sensor (±2g, ±4g, ±8g), 10bit resolution
- 868 MHz CC1101 transceiver
- Interrupt driven OS FireKernel supports power saving
  - Wake On Radio for transceiver
  - ACC-Logic wakes up MCU **only** if necessary
  - IDLE-mode (int. Int.), Power Down (ext. Int.)
  - D cells : 16 days training / 250 days standby
- ACC-Data is buffered to enable time-delayed access
  - e.g. for varying algorithms for event analysis or classification
  - allows higher priorities for communication and routing
- Integrated Distributed Event Detection
  - Pattern recognition and in-network evaluation
  - Freely trainable system



Housing

- Simple integration of sensor node
- Reverse polarity protection
- Splash proofed and robust housing
- Alternative power-supply possible
- Capacitor to bridge power supply with spring

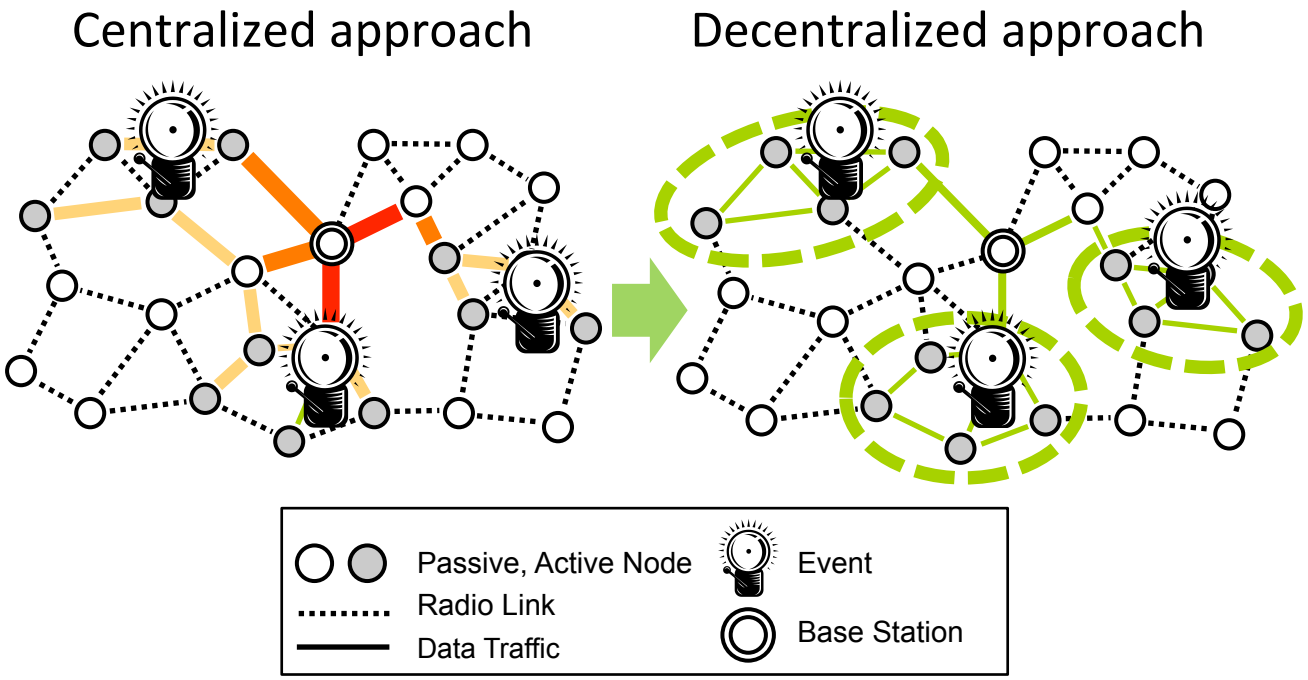




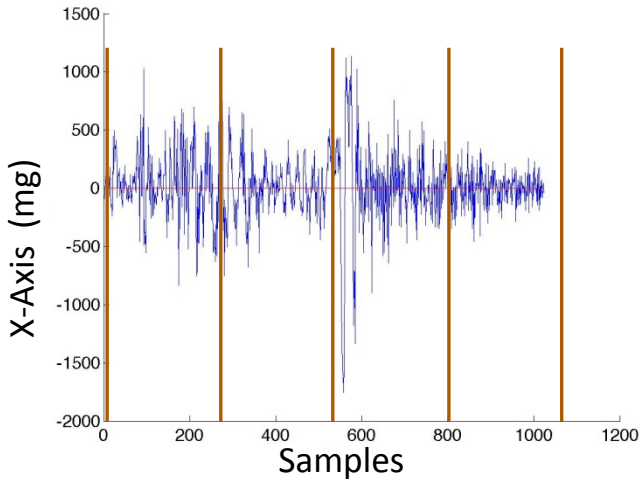
Unassembled & Assembled Device

Distributed Event Detection

- *In-network data processing* is a key feature of Wireless Sensor Networks (WSNs)
  - **Time**: In-network evaluation of condensed data, transmitting results ONLY if needed => In-network decisions are possible
  - **Energy**: Reduce communication with base station => Extend network lifetime



Orientation & Strength Features

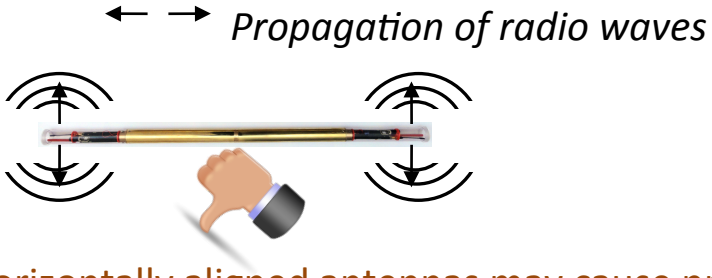


- Building of *n* intervals with *k* acceleration samples
  - ACC-Values of all axis (x, y, z) are combined in a vector $\vec{v}_i$ in Euclidean space IR³.
  - All vectors $\vec{v}_i$ of an interval are summed to the interval vector $\vec{v}_{int} = \vec{v}_1 + \vec{v}_2 + .. + \vec{v}_k$
- Orientation Feature $\vec{o}_{int} = \frac{1}{||\vec{v}_{int}||} * \vec{v}_{int}$
  - Describes physical orientation of all axis within a certain interval
- Strength Feature $||\vec{v}_{int}|| = \sqrt{\langle \vec{v}_{int}, \vec{v}_{int} \rangle} = \sqrt{x^2 + y^2 + z^2}$
  - Describes the strength a person induces into the device

Leading Questions

- Latency/ Packet Delivery Ratio
  - Problems in communication due to horizontally aligned and omnidirectional antennas

vertically aligned antennas



horizontally aligned antennas may cause problems

  - If latency is too high, uninterrupted training is not possible
  - Does antenna alignment..
  - Does moving the stick..
  - Does the environment..
  - Does Wake On Radio..

..influence latency or PDR?

- Accuracy
  - Teacher and student are different persons, is detection still working?
  - Is there a training effect?

Latency / PDR: Experimental Setup

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- Real-World experiment: transmit data between both nodes of device
- Measure RTT between embedded sensor nodes
  - RRT used to avoid focusing on MCU clock drift
  - 800 packets
- Varying parameters:
  - Moved device vs. steady device
  - Indoor vs. outdoor performance
  - Standard Receiver Mode vs. Wake On Radio
    - CRX: constant receiving mode ON
    - WOR: 542ms sleep, Wakeup 1ms

Latency / PDR: Experimental Results

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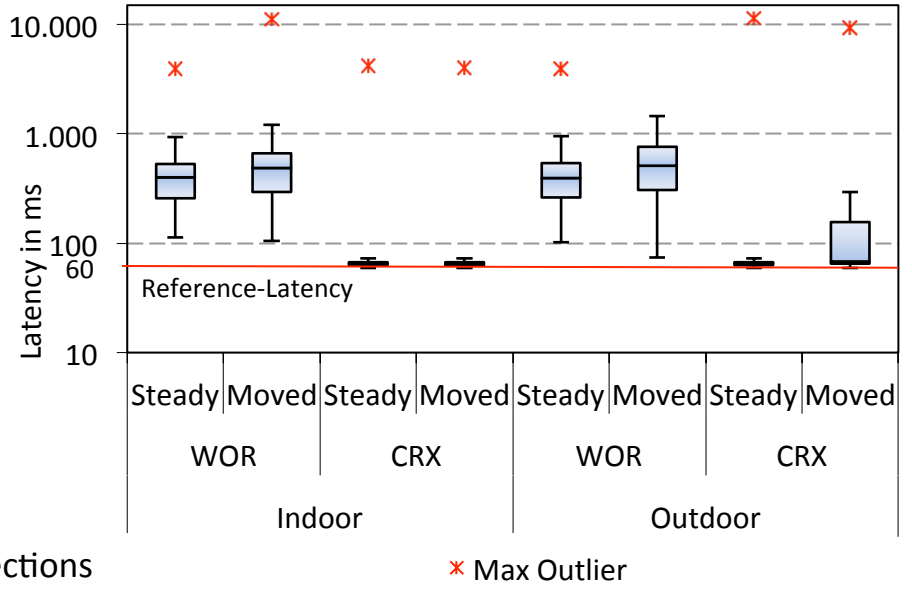
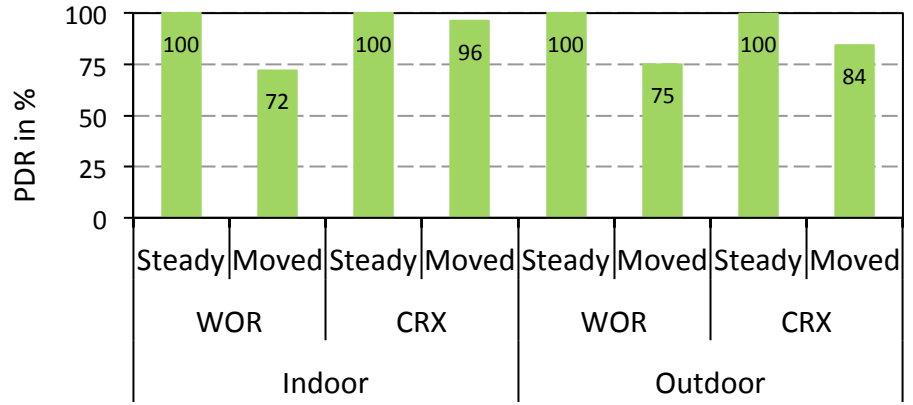
Latency

- Horizontally aligned antennas increase latency by 10 ms
- Movements increases latency by 130-230 ms
- WOR increases latency by 400-500 ms
- Outdoor application increases latency slightly
- Indoor application decreases latency because of more reflections



Packet Delivery Ratio (PDR)

- Movements cause packet loss
- In general: very high PDR
- CRX optimizes communication in indoor and outdoor areas



Movement Detection: Experimental Setup

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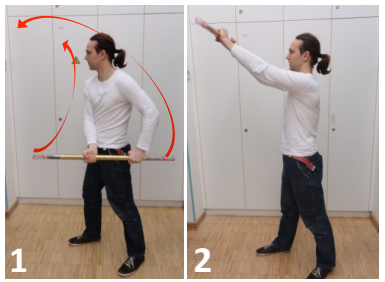
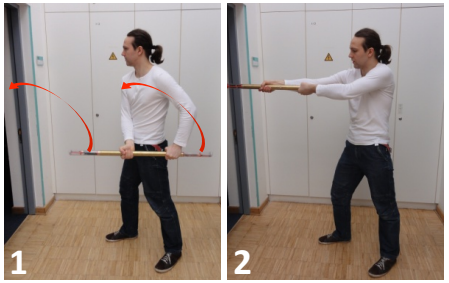
- Training-Device trained by teacher
  - 20 times per technique, at 8g, 100Hz
- 6 techniques are trained (3 Strikes , 1 Block, 1 Stab, 1 Spin)
- Another person imitates the techniques about 50 times each
- LEDs give immediate feedback of performance quality

Strike a)

Strike b)

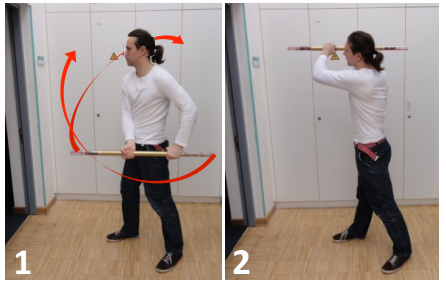


Block c)



Stab d)

Spin e)



Strike f)

Green = Technique ok
Red = Technique wrong/bad
Blue = Sequence finished

Movement Detection: Experimental Results

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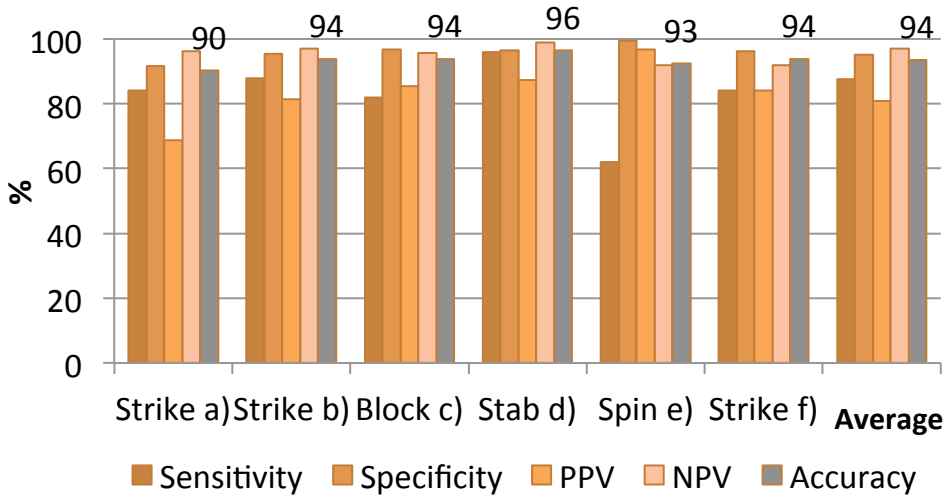
- All events reach an accuracy above 90%
  - Strike a) has low PPV: too many Strike a)
  - Spin e) has low Sensitivity: too few Spin e)
  - Strike b), Block c), Stab d) and Strike f) deliver high accuracy of at least 94 %
- Average accuracy of about 94%



- Principal diagonal is well-marked
  - Strike a) has good characteristics but classifies itself as all other classes at least once
  - Spin e) is often classified as Strike a)
- Detection accuracy is also user-dependent
- Errors can easily be detected by the motion-based training device

Classes to detect

Classes detected	Strike a)	Strike b)	Block c)	Stab d)	Spin e)	Strike f)
Strike a)	42				19	
Strike b)	1	44	4			5
Block c)	1	1	41	2		3
Stab d)	1	5	1	48		
Spin e)	1				31	
Strike f)	4		4			42

Confusion matrix

0 classified events 50

Conclusion / Future Work

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Conclusion:

- Distributed Event Detection enhances training devices to supervising and independent devices
- Activating WOR and performing training outdoors increases latency and decreases PDR
- Communication is stable and suitable by applying CRX at indoor environments
- Training device improves user skills, as errors are detected
- Training with device simply makes fun => it motivates

Future Work:

- Housing made of Krüpax
- New application scenarios
  - Decoupled devices
  - Rehabilitation
  - Surveillance of buildings (bridges, skyscraper…)

Watch Demo:
http://cst.mi.fu-berlin.de/projects/AVS-Extrem