Fall detection system based on incremental development model

exposition

Lukasz Marcul

Supervisor: Ph.D. Miroslaw Zoladz

AGH University of Science and Technology
Department of Measurement and Electronics

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Path

1. **Introduction.**
2. Selected components.
3. System overview.
4. Fall detection background.
5. Outcome.

Introduction - Abstract

Goal

Design a **Fall Detector** which should:

- signalize a fall using a sound,
- fit in a pocket,
- have its own supply source.

Additional functions

- motion parameters recording,
- auxiliary application for analysis and processing.

Introduction - Development method

Milestones

1. prepare the measurement system (device and auxiliary application),
2. analyze typical ADL scenarios,
3. develop and implement fall detection algorithm,
4. deploy an alarm feature.

Incremental model

- the product was designed, implemented and tested incrementally: 12 weeks, every week with a new important feature added,
- chosen because of low cost and highly effective delivery.

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Selected components - Detector

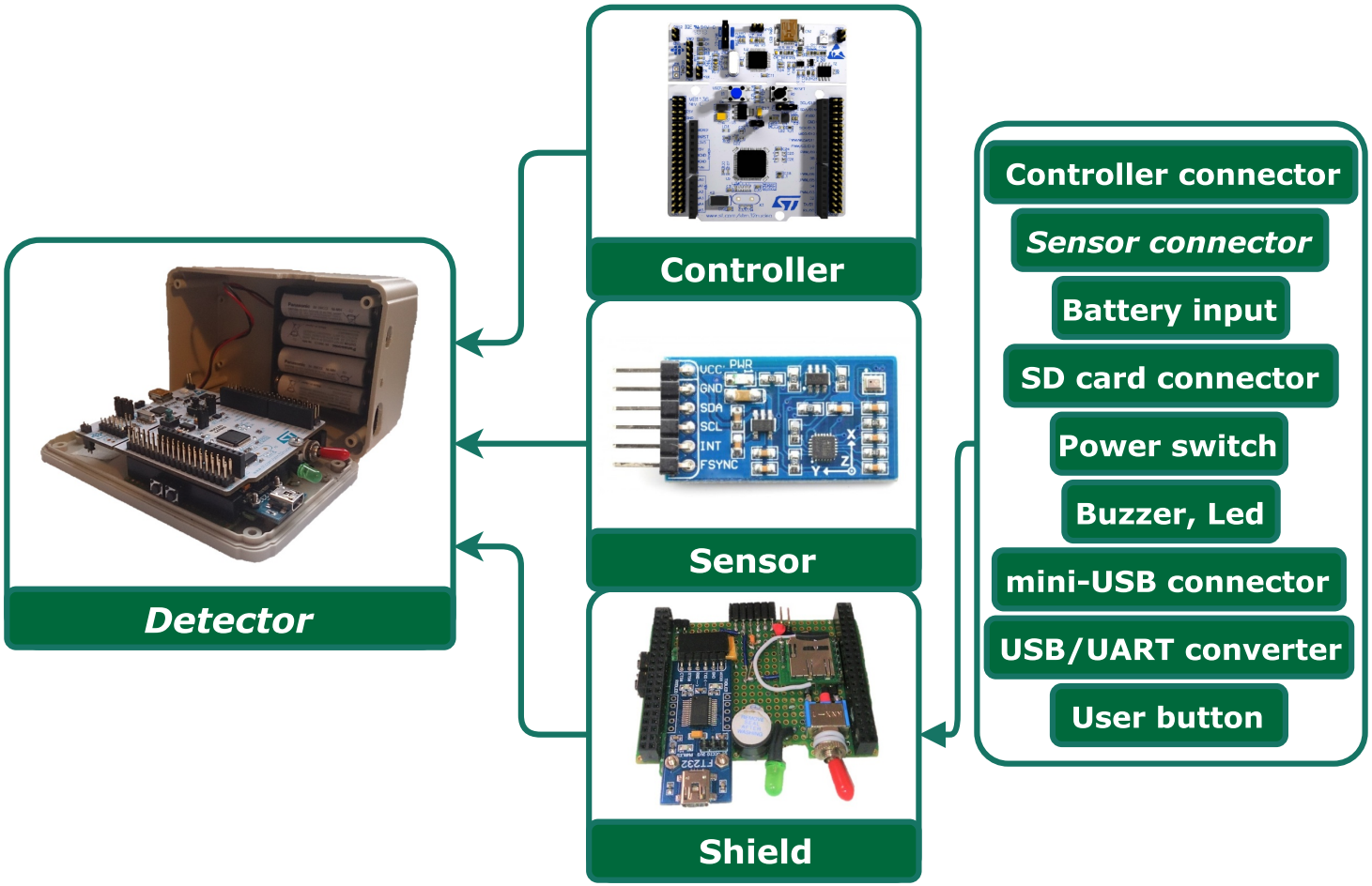
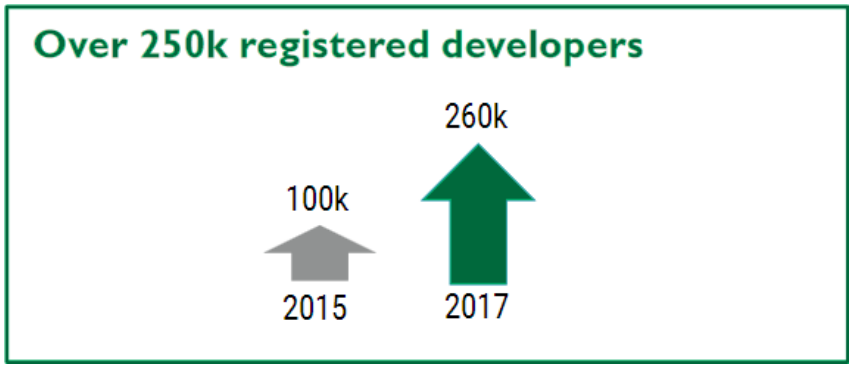
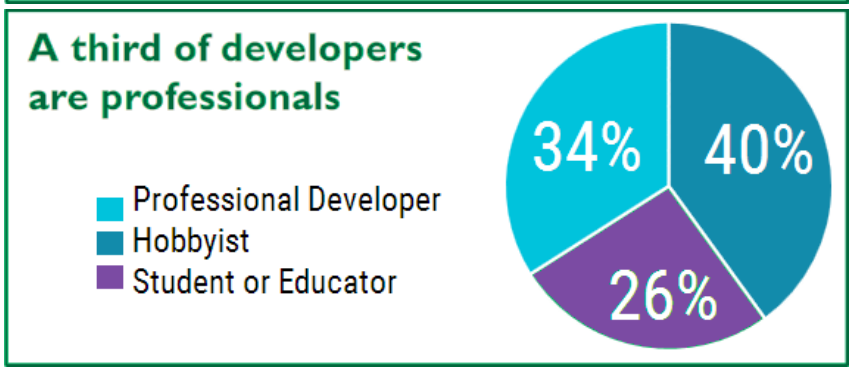
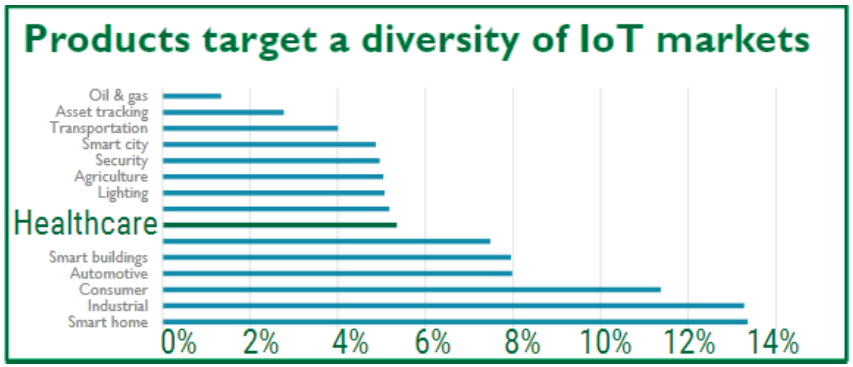


Figure. Hardware components of the detector.

Selected components - Mbed







Chosen because of:

- lightweight driver abstraction layer,
- good C/C++ compiler,
- access to the standard library,
- revision system availability,
- large set of examples,
- clear documentation.

Figures based on ARM mbed Technical Overview [2].

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System overview

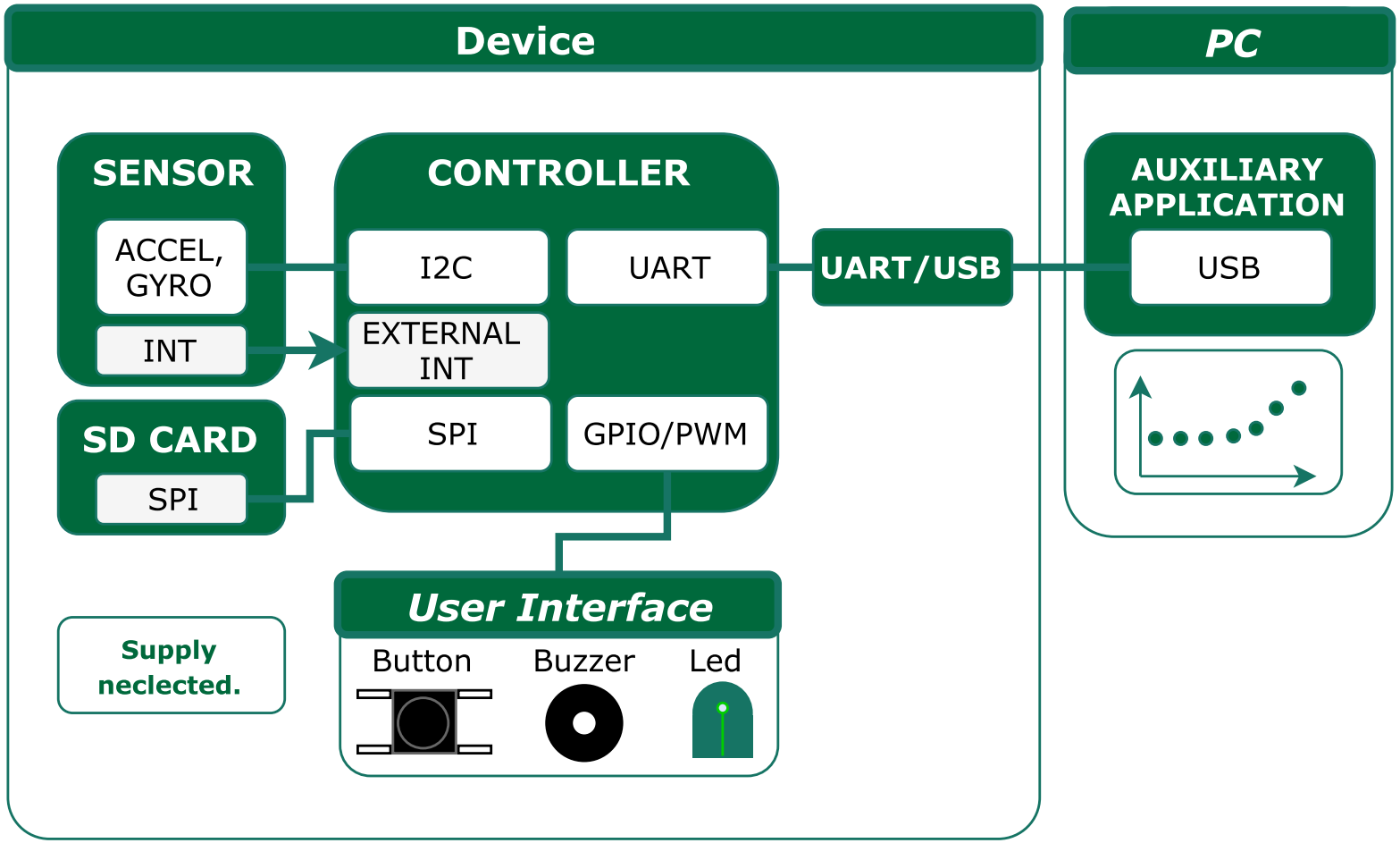

Figure. Distributed system overview.

System overview - Interfaces

Created interfaces:

1. serial command interface (communicate the device and auxiliary application),
2. sensor configuration interface (formatted JSON[3]),
3. data transfer interface (sensor configuration and measurement packet) via serial port.

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Fall detection background - Device location I

Device in the pocket = impact too small to distinguish fall from walk.

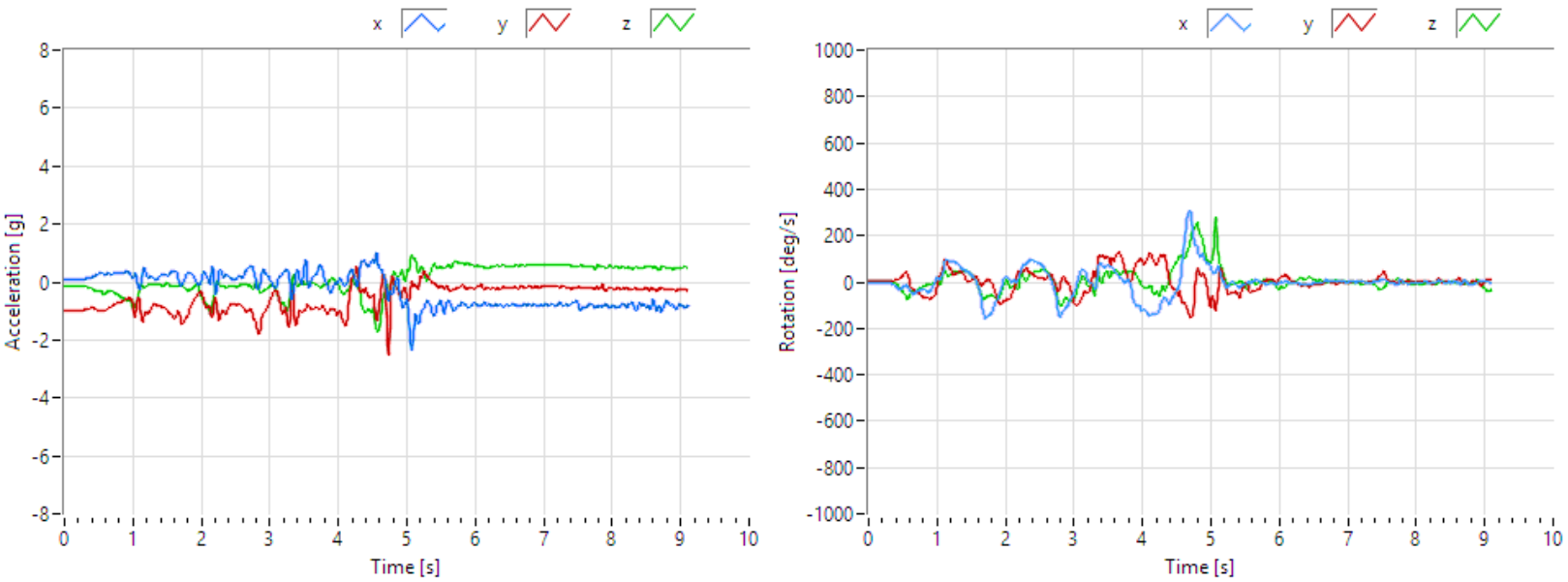

Figure. Fall down after a walk - device in the pocket.

Fall detection background - Device location II

Device beside hand = better exposition on impact.

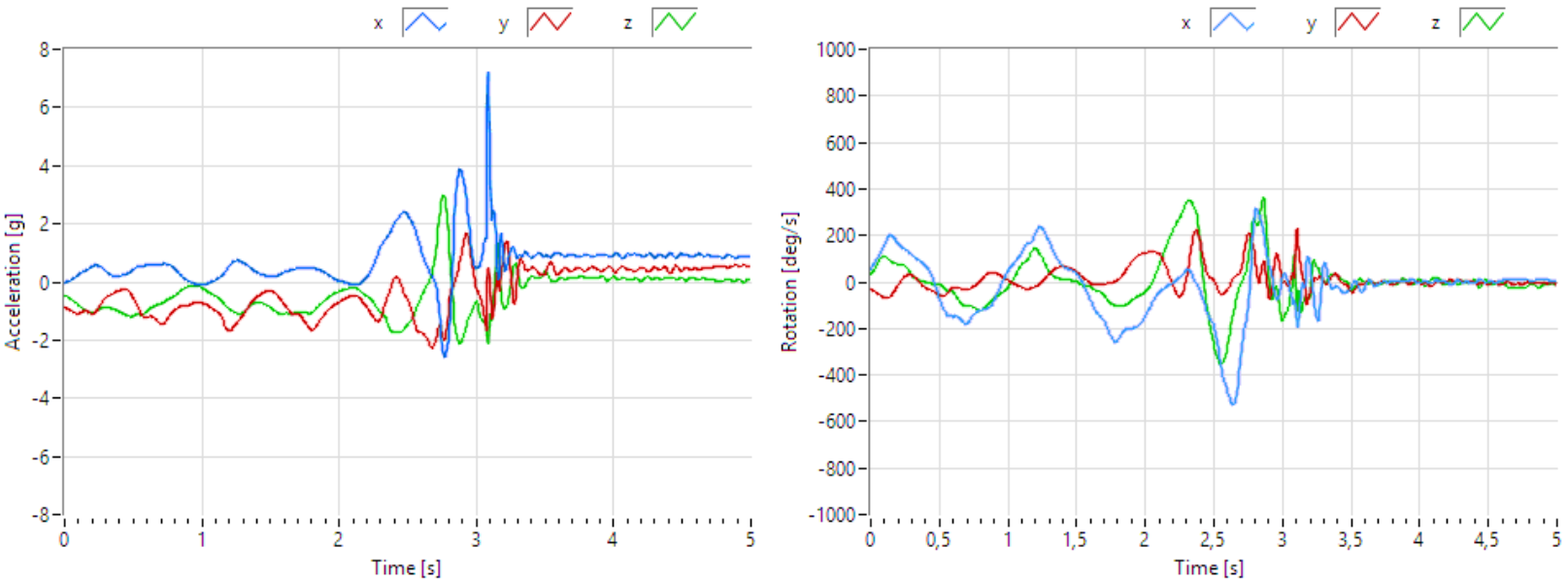

Figure. Fall down after a walk - device hold in hand.

Fall detection background - Activities of daily living I

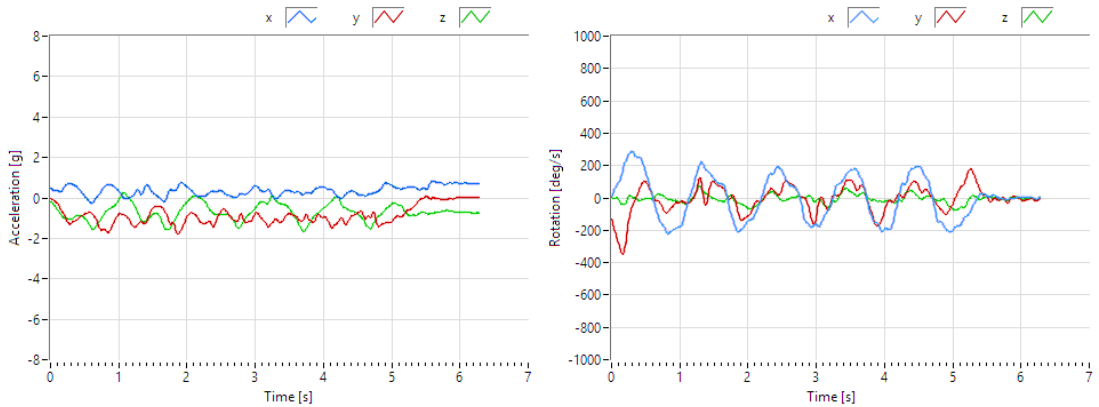

Figure. Walking - record.

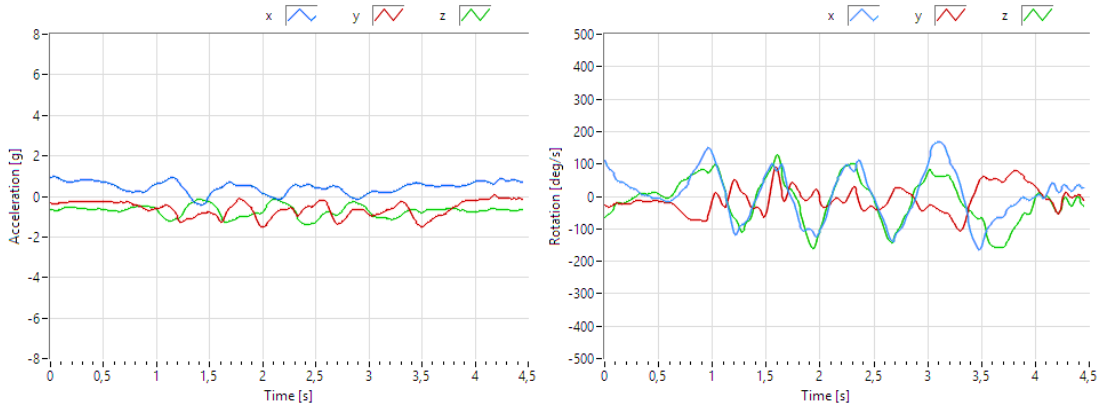

Figure. Walking upstairs - record.

Fall detection background - Activities of daily living II

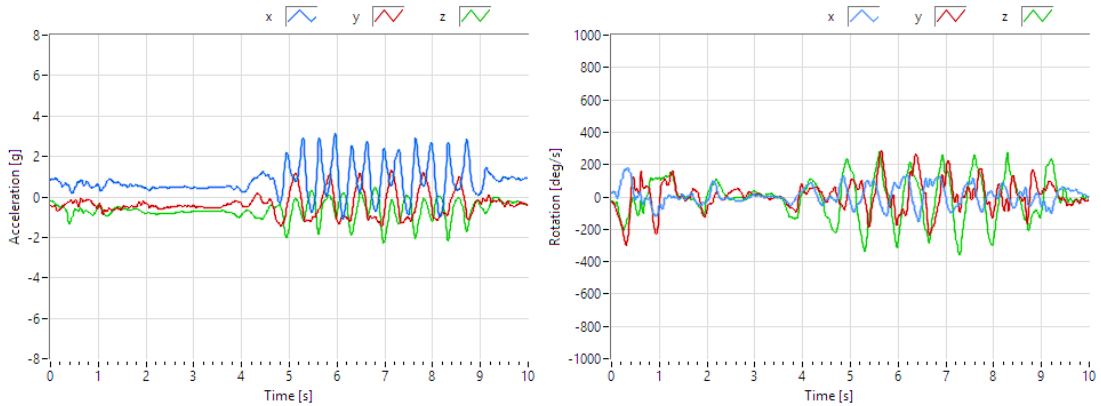

Figure. Running - record.

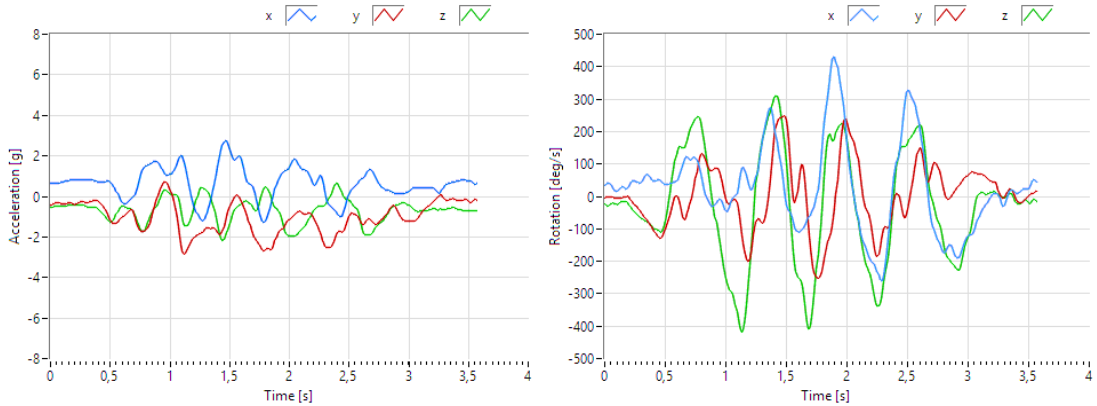

Figure. Running upstairs - record.

Fall detection background - Activities of daily living III

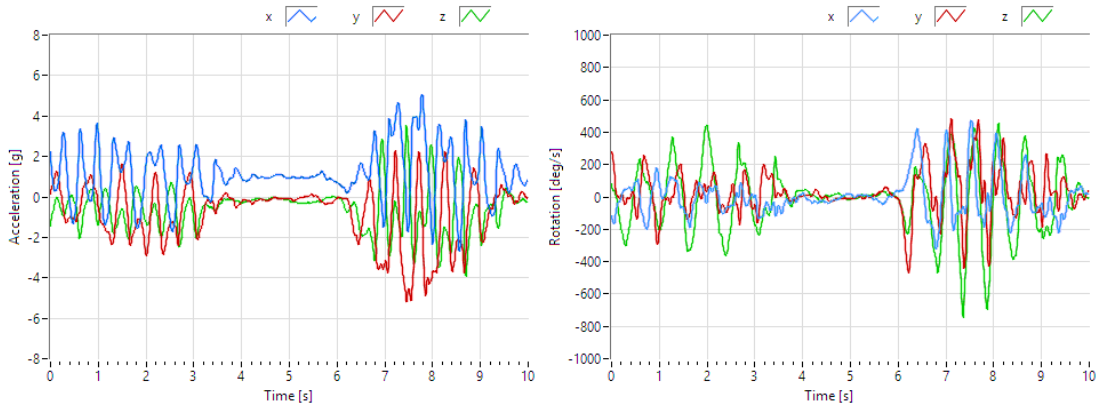

Figure. Sprint - record.

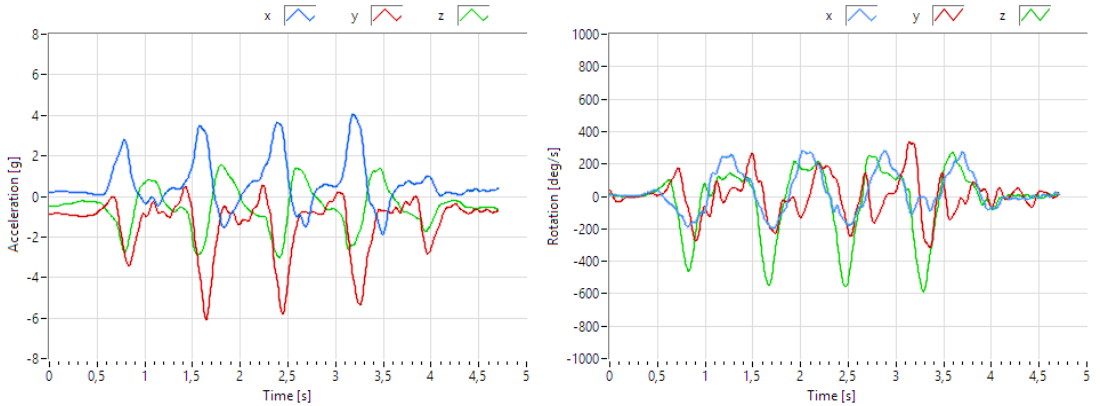

Figure. Jumping - record.

Fall detection background - Falls

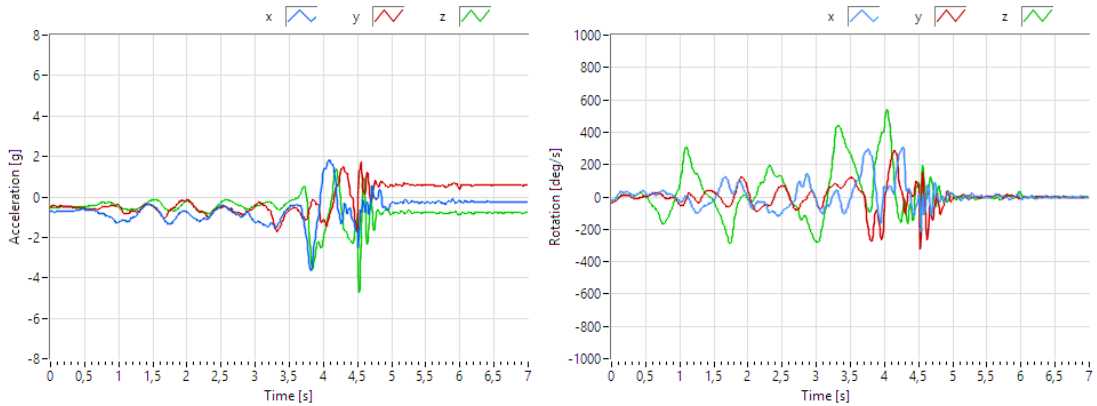

Figure. Light fall (after walk) - record.

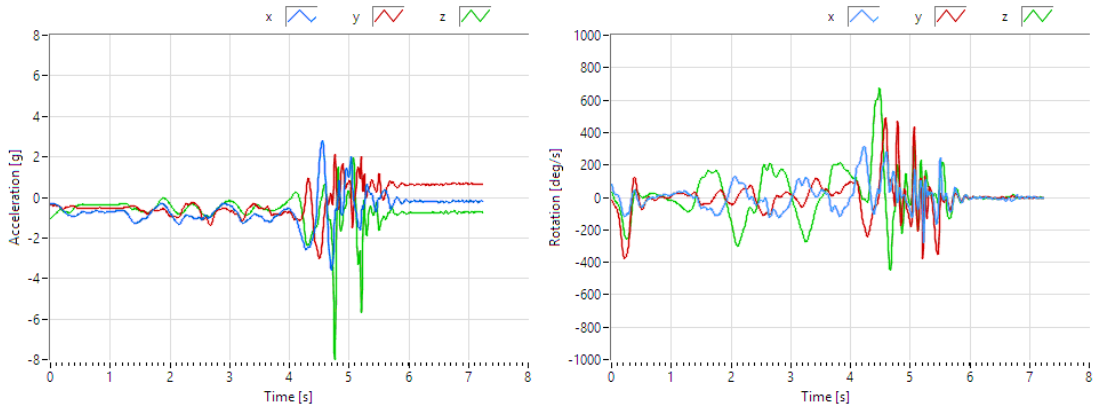

Figure. Severe fall (after walk) - record.

Fall detection background - Algorithm

Algorithm

Let:

- V_{pp} - peak-to-peak amplitude of discrete signal V within the selected time window w,
- AX, AY, AZ, GX, GY, GZ - parts (within the selected time window w) of measured axes of acceleration and angular velocity,
- time window is 50 ms and shifts while data update (every 10 ms).

Then:

$$fall\ detected \Leftrightarrow \exists w : max(AX_{pp}, AY_{pp}, AZ_{pp}) > 8g \vee (max(AX_{pp}, AY_{pp}, AZ_{pp}) > 4.5g \wedge max(GX_{pp}, GY_{pp}, GZ_{pp}) > 150dps).$$

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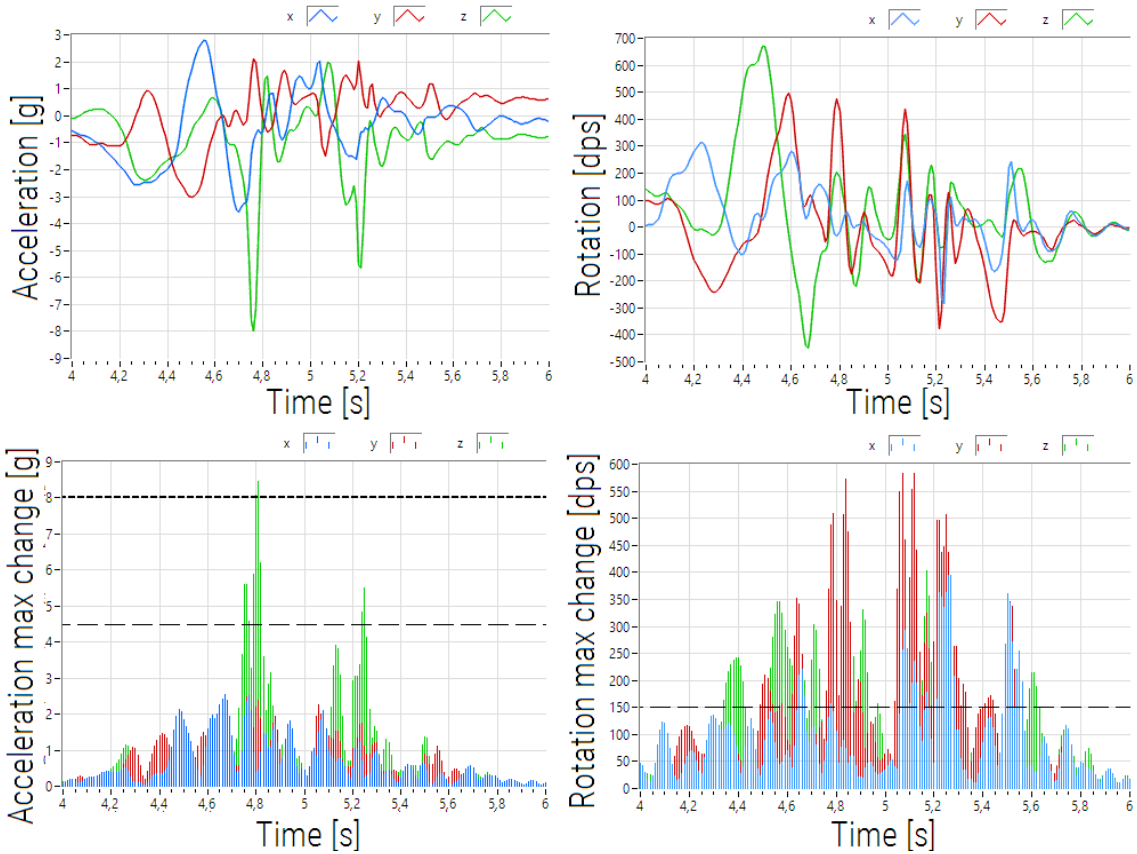
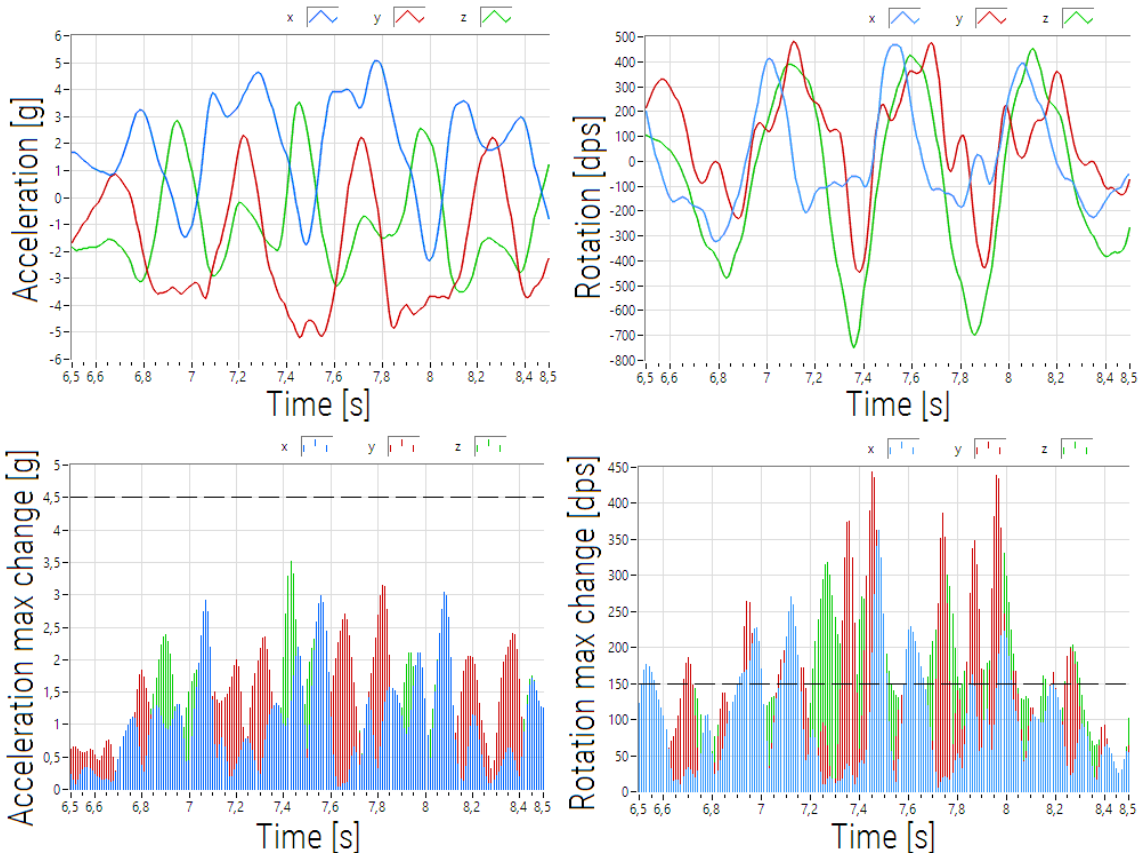
Outcome - Test results I



Fall detected: second condition met at 4.76 s (first met at 4.80 s).

Figure. Fall - event analysis.

Outcome - Test results II



Fall not detected. Acceleration threshold not exceeded.

Figure. Sprint - event analysis.

Outcome - Test results III

TN - true negatives

FP - false positives

TP - true positives

FN - false negatives

Test case	TN	FP	TP	FN	True	All	Efficiency
Jumping	9	1	-	-	9	10	90 %
Sprint	8	2	-	-	8	10	80 %
Fall from standing	-	-	10	5	10	15	67 %
Fall from walking	-	-	12	3	12	15	80 %
Sum	**17**	**3**	**22**	**8**	**39**	**50**	**78 %**

Outcome - Advantages

Advantages:

- motion parameters analysis,
- easily-reconfigurable device,
- storage and export system,
- alarm while falling (78 % of the efficiency),
- long battery life,
- full project history.

Outcome - Critical reflection

Shortcomings:

- 78 % is still below 100 % (limited algorithm),
- performance tested only by the author (human parameters not taken into consideration),
- dimensions.

Outcome - Development prospects

Possibilities:

- implement more professional algorithm (increasing efficiency),
- miniaturize and prepare the device for a mass production,
- deliver automatic ambulance notification,
- integrate application in sport and smart watches.

Let’s examine the device in the action!

References and images

[1] FreePik. Paratrooper falling silhouette: https://www.flaticon.com/free-icon/paratrooper-falling-silhouette_38661.

[2] ARM Ltd. Arm mbed technical overview: https://www.arm.com/files/event/20170628_atf_korea_b2.pdf.

[3] Douglas Crockford. Json: http://json.org/.