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A MOTION ACTIVITY MONITOR

MONITOR POHYBOVÉ AKTIVITY

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Summary: The paper deals with motion and vital activity monitoring of person in the case of dangerous environment (rescue team member) or in the case of possible damage or injury threat (e.g. engine driver). Special attention is paid to modern INS MEMS components use.

Key words: motion monitoring, vital activity monitoring, MEMS, accelerometer, .

Anotace: Článek se zabývá způsobem monitorování pohybové aktivity osoby v případech, kdy je vystaven nebezpečí (záchranář, hasič), či na jeho bdělosti závisí jiní lidé nebo majetek (strojvedoucí), a to se zaměřením na využití moderních prvků INS MEMS.

Klíčová slova: monitorování pohybové aktivity, monitorování bdělosti, MEMS, akcelerometr.

INTRODUCTION

The paper presents discussion of some well known methods of motion and vital activity monitoring first. In the scope of view there are methods usable for ambience-noninterfering monitoring using only a minimum equipment to be worn and minimum equipment to be installed in the monitored area. In the term „motion and vital activity monitoring“ we mean monitoring of normal human vitality unaffected by possible dangerous environment conditions (high temperature, smoke, darkness, building damage) and absence of vitality signalling. The aim is to find a method suitable for monitoring of the mentioned conditions and for detection and signalling of situation of an asleep person. In the next part of the paper we try to describe our experience with modern MEMS (Micro Electromechanical System – mechanical components integrated on silicon chip together with integrated circuit) components. In the tests we use demonstration kit STEVAL-MKI062V2 from STMicroelectronics (7). The third part depicts our experimental motion detector with wireless connection to the base station made as student's bachelor work. In the last part of this paper we discuss our experimental detector together with MEMS tests results and propose further improvements.

1. THE MOST KNOWN MOTION DETECTION METHODS

Nowadays, the state-of-the-art methods are based on digital signal processing and picture analysis and (face) recognition. Face recognition allows individual person monitoring

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– there are camcorders equipped with a function of focus and exposition measurement for a selected person from the group of people. But picture recognition has limitation in a space with limited visibility (smoky) and it is necessary to install one or more cameras what is unacceptable in the case of rescue team members monitoring. Therefore it is not useful for our aim.

The second commonly used method is a passive infrared sensor (PIR) based on infrared detector and Fresnell lens. It is used in automatic doors opening, automatic lighting or in protective systems to detect gate-crasher in property. PIR sensor is hardly configurable to detect a person at a sufficient distance and simultaneously not detect small animals (cats) or flying big insects (hawk-moths for example) as is often seen in the case of an automatic lighting. Clearly - the PIR sensor is not able to monitor more than one person, it detects any movement. Therefore it is not suitable for our aim. In (2) PIR detector is used in combination with doors light gate, each PIR detector is equipped with ZigBee transceiver and data is sent to the central station. The ZigBee network transceivers in cooperation with the ZigBee transceiver of the monitored person are utilised as RSSI (Received Signal Strength Indicator) to distinguish positions of monitored persons in the area of interest. It seems it is suitable for elderly people health care as it is described in (2).

The third method represents an ultrasound detector. It is similar to PIR with the same disadvantage: it needs hardware mounted in the monitored space, it does not distinguish between one or more moving objects and it does not distinguish between a monitored person movement and any other movement.

Next, apart from the above solutions and solution based on electromagnetic waves let us have a look at the solution in (3). The authors used two inertial sensors (IS, one-axis accelerometers) mounted on two parts of a monitored person body – one on the chest and the second on the thigh. In the experiment they record data from both sensors and record video. A monitored person was in a room equipped with a chair, a table, a bed, books, food, a treadmill and a TV set and asked it to do its usual daily activities. There were five classes of activities to be detected from records: lying, sitting, standing, dynamics and others. The recorded signals contained both a movement acceleration component and a gravity component. Comparing the signal analysis results and a video record the authors got about 10.7 % wrong classified movement classes.

The second example is described in (4). They used one three-axes waist mounted accelerometer. The authors presented classification tree and algorithm capable to distinguish 15 classes of human movement with very good accuracy. The waist mounted accelerometer gives good and useful information about a human body movement. It is free of signal from knocking accelerometer against another object and free of signal from swinging. Unfortunately, the algorithm is not able to distinguish (find the signal difference) between a sitting and a standing position.

As we can see in (5) it is possible to distinguish between sitting and standing even using 3-axes accelerometer. The matter is simple – we must classify signals not only from static point of view but we must take into account sequences of „signal events“. Some of those signal events are presented. For example, the difference between transition from standing to sitting and fall is apparent from graphical representation of signals (5): both responses have visible descent of gravitation signal component but in the first case (sitting) it is less and longer than in the second case. In the first case after this descent some time interval is visible with the gravitational component going to the normal level followed by peak acceleration (sitting). In the second case (fall) there is no time interval with near the normal gravitational component – the descent is in a short time followed by a big peak value of acceleration. Similarly we can distinguish between going upstairs and downstairs. The first is accompanied by a peak acceleration upwords and in the second case we can see first a descent followed by a peak. Article (5) is an application example of a new programmable MEMS accelerometer with an additional intelligence. For further details see (6).

2. THE EXPERIENCE WITH A NEW MEMS

In the previous chapter we have meant some methods of movement detection and activity classification and we found useful an inertial component – an accelerometer. Gravitational component of accelerometer signal seems to be useful for our purposes, too.

We have got demonstration kit STEVAL-MKI062V2 (STMicroelectronics, iNEMO: iNErtial MOdule) which consists of 3-axes accelerometers, 3-axes gyroscopes and 3-axes magnetometers with pressure and temperature sensors to provide 3-axes sensing of linear, angular and magnetic motion, accompanied with temperature and barometer/altitude measurement (7). The kit can be connected to a PC via a mini USB connector and by means of PC application (GUI) it is possible to make some initial test measurement. First of all we wanted to know noise levels of all sensors and their drift due to temperature and time. For this test we first left the kit lying on the table of about 10 minutes to settle the temperature of all components to the room temperature and after it we connected the kit to PC and immediately started data recording. We recorded data for 8 minutes. The first picture (Fig. 1) shows accelerometer data. The kit was

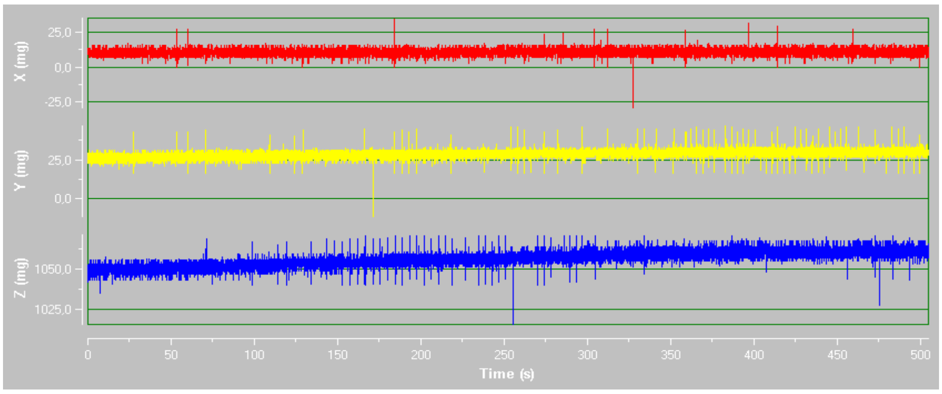

Fig. 1 –Accelerometer data record -8 minutes

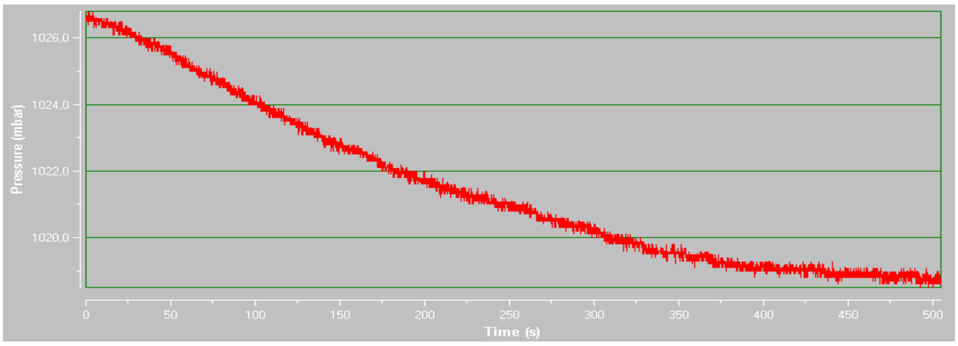

Fig. 2 – Barometer data record - 8 minutes

oriented horizontally, it means that the Z-axis (blue) was in vertical direction and contains the most of the gravity component (about 1000 mg, not calibrated) and some change of the output value can be seen on this axis. The red line (X-axis) has constant value and Y-axis contains some drift. There was no visible drift for 8 minutes in gyroscope outputs and very small drift was in magnetometer outputs. But surprising result came from barometer (Fig. 2) and temperature sensors (Fig. 3). The difference between first and last value from barometer was 9 mbar. In small levels 1 mbar corresponds to 8 meters in vertical direction. The difference between the first output value from thermometer and the last after 8 minutes was 8 degrees. Actual room temperature was 18.3 degree Centigrade. The results evoke an idea that very small sensor chips heat themselves though they have a small consumption. Thus, next measurement was

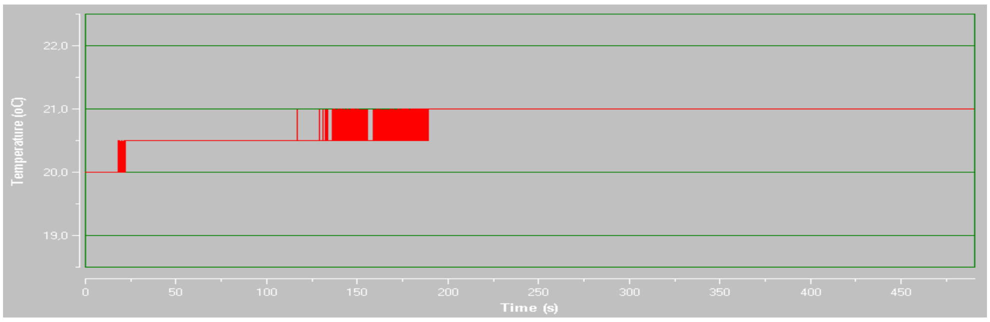

Fig. 3 – Thermometer data record - 8 minutes

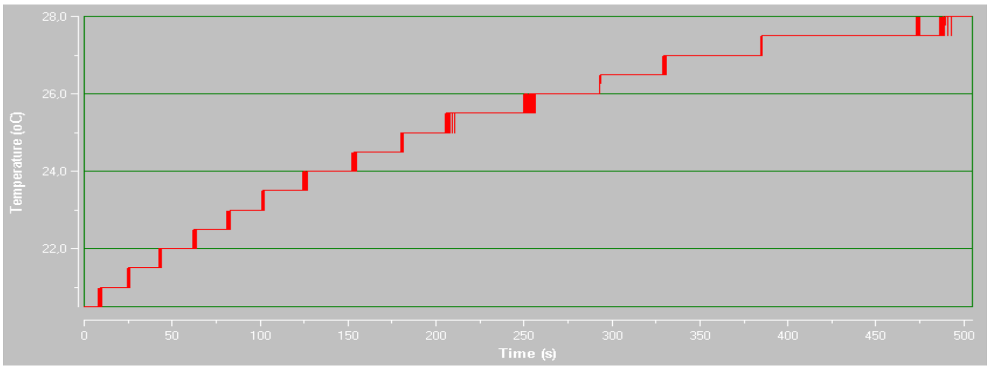

Fig. 4 – Barometer in airflow data record - 8 minutes

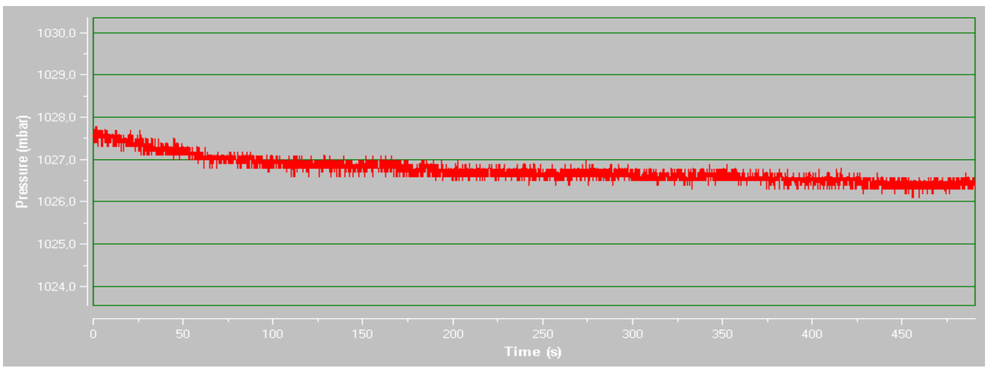

Fig. 5 – Thermometer in airflow data record - 8 minutes

done – exposing kit to an airflow from a hair-dryer without heating. In this case the 8-minute drift nearly disappears. See the figures 4 and 5.

From the Fig. 2 to the Fig. 5 follows that it is impossible to use of data from the thermometer to compensate a temperature dependence of other components on the kit board without any further changes in the thermal coupling among them.

The fig. 6 demonstrates practical unusefulness of current kit configuration for barometrical measurement. It represents a barometer data record during 3 times repeated use of the lift from the ground floor to the eighth floor. The kit was powered up just before the record was started and temperature drift is comparable to the measured value of the pressure difference corresponding to 24 m.

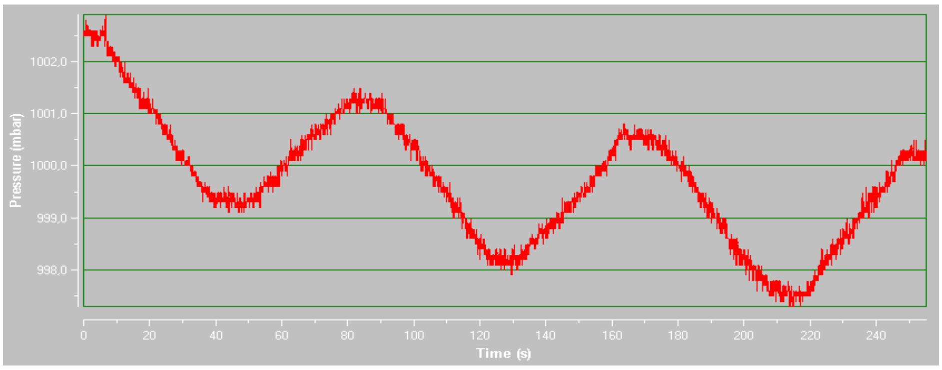

Fig. 6 – Barometer data record – 3x from ground to the eighth floor

The further data record presented in the fig. 7 appeared useful: the kit was fixed on the top of the head and we record walking upstairs one floor and then back downstairs one floor. The kit was oriented with Z-axis up and X-axis in the direction of walking. There was a landing in the middle of stairs. The record consists of two different parts. The first half of the picture represents a walk upstairs interrupted by a few steps at the landing. Each step begins with a peak in Z-axis (blue curve) arising from the movement upword. In the second part each step begins with moving downword and a corresponding decrease in the Z-axis is apparent. The figure 7 (Z-axis - blue curve) shows very good accordance to (5).

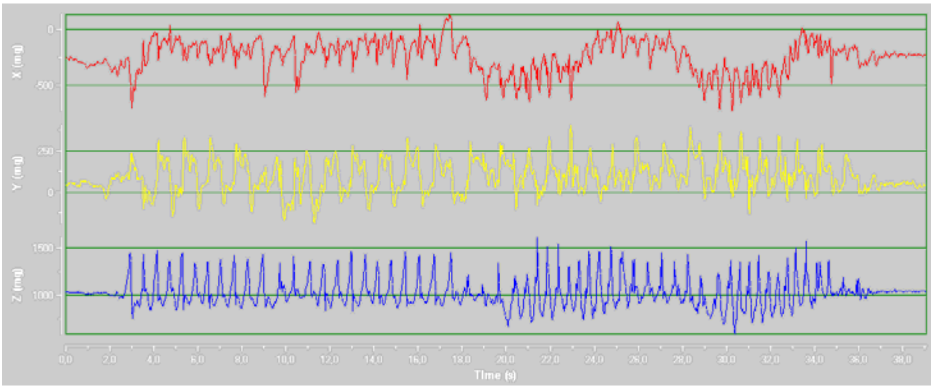

Fig. 7 – Accelerometer data record – upstairs and downstairs one floor

3. THE MOVEMENT ACTIVITY INDICATOR (MAI) – A PRACTICAL EXAMPLE

The movement activity indicator was a subject of the bachelor work (1). The task was to design and to make a personal movement activity indicator (MAI). It should signalize a person nonactivity if it lasts more than selected time interval (in seconds). The information (signal) transfer to the base station should be wireles. Student has used a two-axes accelerometer with an analog output (MMA6281QT – Freescale Semiconductor), a microcontroller, a RF transmitter module for the ISM band and a small switched power supply. These components together with 2 AAA cells forms a mobile module (see fig. 8) the spotted person wears. The best place for it is a body (waist). The base station contains a compatible receiver and indication LEDs.

The application of the two-axes accelerometer means that there is one dimension not sensitive to the movement. The accelerometer is in a small flat package and its Z-axis is oriented perpendicularly to the top of the package while X-axis is parallel to the package plane.

The algorithm inside CPU is simple. The samples are taken 10 times per second. Eight consecutive samples are averaged and the result is compared to the average of the next eight samples. This eliminates the gravitation component. If the consecutive averages differ of more than the noise level some moving activity exists. The mobile part sends information every second. If the base station receives no data then no indication occurs.

In the case of waist mounting it is necessary to place MIA oriented by its X-axis up and to avoid horizontal X-axis mounting. Following this rule MIA works reliably and indicates walking and other body moving. The problem arises when person is standing or sitting – the waist mounting is not sensitive to only hands activity.

4. THE MAI AND INEMO EXPERIMENTS EVALUATION

The functional tests of MAI verify its practicability. But it is not perfect. Problem is to detect only hands activity or in the case when spotted person is standing and holding something. While the person is active it does not move anyway and the absence of a corresponding (alternating) signal from accelerometers cause no activity state to signalize.

Before we suggest a new approach to detect activity in above mentioned case let us show the next result from iNEMO tests.

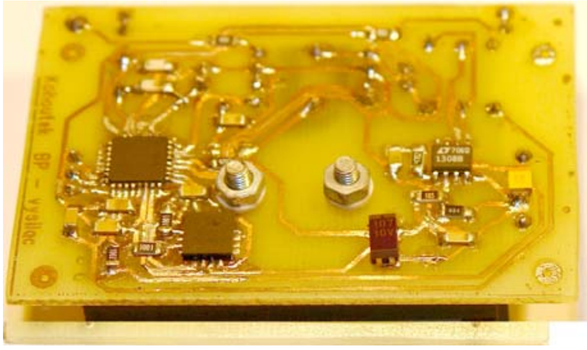

Fig. 8 – MAI, bottom view, CPU and accelerometer

iNEMO kit contains an integrated 3-axes accelerometer with a 3-axes magnetometer. The magnetometer is capable to indicate orientation against the magnetic field around. We were interested in capability and sensitivity to a power line electromagnetic field. The two further pictures describe magnetometers data in a lift (Fig. 9) and a near a house power switchboard (Fig. 10).

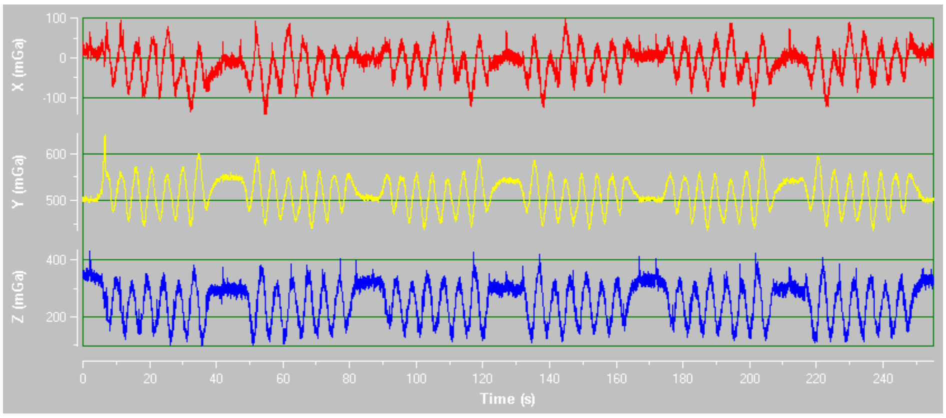

Fig. 9 – Magnetometer data record – in lift, from first to eight floor and back three times

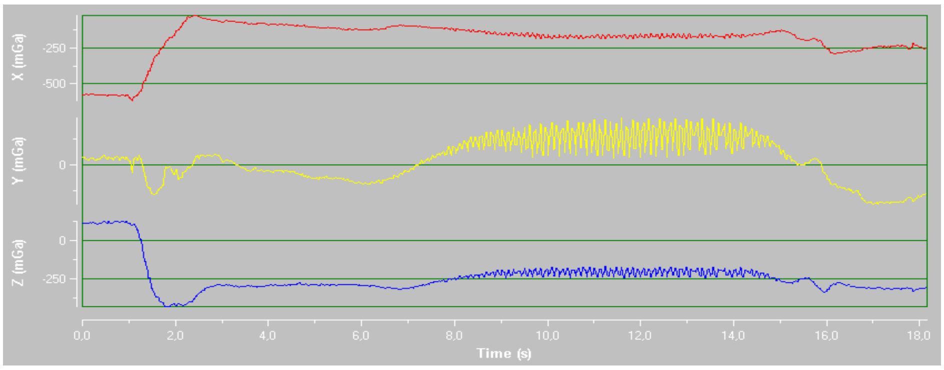

Fig. 10 – Magnetometer data record – 2 m to 10 cm from a house switchboard – interference begins in distance of about 20 cm

Both pictures show that magnetometer can be easily affected by an electromagnetic field from power lines and therefore it is not reliable as a source for movement detection. The magnetic field of the Earth is relatively constant and it promised a fixed point (line) for space orientation. Unfortunately it is often covered by other (electro) magnetic fields.

There is another constant field – gravitational. Inertial accelerometers detect it (see fig. 1, the blue curve shows value about 1000mg [mili dží], thousandth of normal gravitation). In the INS solution (Inertial Navigation System) the gravitation annoy us because it causes no velocity. But it is useful for tilt measurement. The last figure (fig. 11) presents data record when the iNEMO kit was fixed on the top of the head. There were four position of the head monitored. A transfer of the gravity component to the other axes is very clear. Then we can use the Earth gravity to measure a tilt of a human head and a body. We can detect the following positions: forward, back, to the left and to the right - all meant "down". Why down? Normal healthy position of a human head (partially of a body) is upstanding.

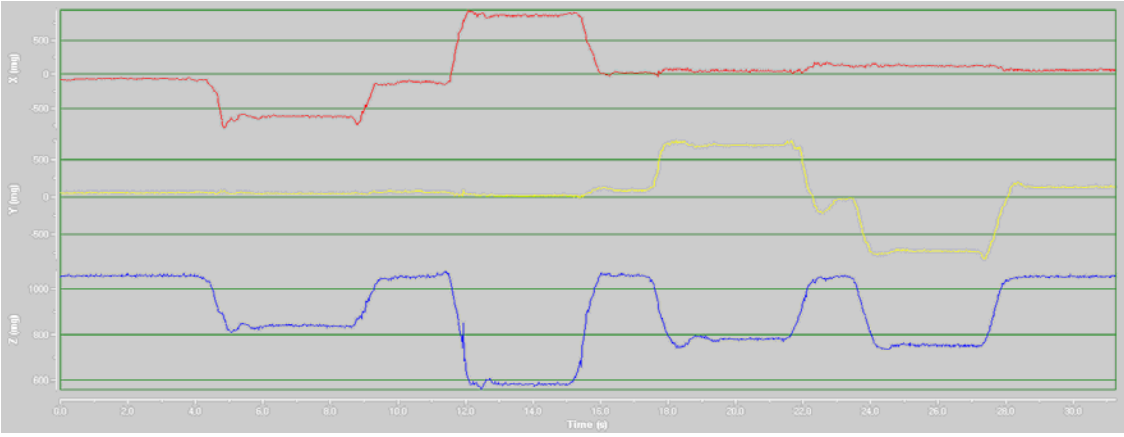

Fig. 11 – Accelerometer on the top of head – head moves forward, back, left and right

As a result of the described experiments and the discussion we suggest an algorithm for movement and vital activity monitoring to contain: 3-axes any movement detection, fall detection as described in (5) and detection of an abnormal head and body tilt to avoid false nonactivity signalling.

5. CONCLUSION

The progress in MEMS technology is very promising. The MEMS inertial components are small and become cheep and easy to use.

The discussion of known methods of the motion and the vital activity monitoring and the experiments resulted in the recommendation of an algorithm for the activity monitor.

6. ACKNOWLEDGEMENTS

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REFERENCES

[1] KOHOUTEK, A.: *Detektor pohybu sledovaného objektu* Bachelor work University of Pardubice, Faculty of Electrical Engineering and Informatics, Pardubice, 2010

[2] ČERNÝ, M.: *Movement Activity Monitoring of Elderly People* [online] http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05445689 [cit. 2010-11-16]

[3] AMINIAN, K.: *Physical activity monitoring based on accelerometry: validation and comparison with video observation* [online] http://www.springerlink.com/content/053x41h3mu2236x5/fulltext.pdf [cit. 2010-11-16]

[4] MATHIE, M., J. et al.: *Classification of basic daily movements using a triaxial accelerometer* [online] https://www.bsl.unsw.edu.au/docs/2004/fulltext.pdf [cit. 2010-11-16]

[5] NING J.: *Human Fall Detection Using New MEMS Accelerometer Technology* [online] http://www.ecnmag.com/Articles/2009/12/human-fall-detection/ or http://www.analog.com/library/analogdialogue/archives/43-07/fall_detector.html [cit. 2010-11-16]

[6] ADXL345, Analog Devices, datasheet [online] http://www.analog.com/static/imported-files/data_sheets/ADXL345.pdf [cit. 2010-11-16]

[7] STEVAL-MKI062V2, iNErtial MOdule V2, demonstration board [online] http://www.st.com/internet/evalboard/product/250367.jsp [cit. 2010-11-16]