Platform for exploring the possibilities of creating an intelligent elevator system

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Abstract – **In recent years heavily were discussed problems related to elevator equipment – their reliability, modernization and accident-prevention techniques. In this paper an autonomous data collecting platform for lifts movement parameters analysis is presented. As it consists of multiple sensors – acceleration, gyroscope, magnetometer, temperature, doppler and distance – a variety of parameters can be collected thus providing the grounds for a vast research in prevention of accident. Included are wireless communication modules, power independence and non-volatile memory - further eases research efforts by remote data collection, local-based storage for off-the network locations, script-based analysis algorithms and power-loss prone system.**

Keywords – **Lift, accident, prevention, sensor platform, lift equipment, data collection, data analysis.**

I. Introduction

In recent two years problems related to elevators emerged – as several different generations of lifts are in operation - relay, electronics and microprocessors based. Apart from some being obsolete, depreciated, started to break down due to poor, maintenance and deliberately inflicted damage. Most human involved elevator accidents leaded to injuries and some of which with lethal end - are mainly caused due to technical deficiencies in construction, human errors , improper operation, etc [1].

Due to SAMTS, 98000 are the known and registered elevators in Bulgaria. Up to December, 2016, 7063 lifts were technically reviewed, 299 discontinued work, and more than 4000 had technical issues. In 2013 there were 20 official signals for accidents – 20 with material damaged, 20 people were injured and 3 leaded to deaths. In 2014 – 25 accidents, 5 with material damages, 13 injured people and 3 deaths. In 2015 – 18 accidents, 5 with material damages, 10 injured and 2 deaths [2].

Most of those were due to missing or non-functional load control devices, misaligned elevator cabin to floor, worn friction discs and sleight, broken operational buttons, oil leakage [1]. Most of which can detected by monitoring cabin movement. In order to limit injuries and human panic in case of an accident, all elevators were equipped with phone based devices for direct conversation with support team [3]. Nowadays all elevators have some kind of intercom system usable only after an accident occures. Still, in case of major accident a direct connection to 112 is not available. The eCall standard, related to traffic and vehicle crashes, implements such functionality, and thus is implementable in lifts as well. To minimize the risk of an accident, a system that predicts and warns for such an event is needed. The first step is to build a data collecting system that will enable us to "see" what is going on in life of an elevator by develop lift movement analysis algorithm.

Purpose of this paper is to describe a microcontroller based platform for algorithm synthesis and development related to lift movement analysis (using multiple sensors - doppler radar, accelerometers, magnetometer, temperature-humidity sensors, gyroscopes, distance sensors, etc.) to predict and prevent accident in the near future. If conditions for such and event are in place – a warning shall be send to support team to take appropriate precaution measures.

II. Overview of the System

On fig. 1 a block-diagram of elevator-monitoring platform is presented.

Hardware may be divided in three main subsystems. The first one is power supply unit. It provides the required voltages for the system. Power may come from the grid or from an 12V battery. In case of an power outage, the system shall continue its work.

The microcontroller is the brain of the system. It analyses data from the sensors, constantly monitors the health status of elevator and in case of an emergency, a message is sent to support team using either Wi-Fi, GSM call or 3G network. During its run, data is also collected and stored in non-volatile memory, as to be accessed at anytime by developers and engineers. In this case Atmel SAM3X8E Arm Cortex M3 processor is used with micro SD card support, a Wi-Fi, LoRA and GSM/3G modules.

To collect data multiple sensors are available to the system:

- Compass sensor – compass sensor is used in calibration process to determine the initial orientation of the device – which way is "UP", where is "NORTH" etc. HMC5883 is used – a 3 axial magnitoresistive sensor with 12 ADC and I2C bus.

- A DHT22 sensor is used to collect temperature and humidity data alongside with MLX9061. It is used may be used for compensation, error correction and fire recognition.

- MPU6050 is accelerometer with build-in gyroscope – both 3-axial. Its main purpose is to monitor for vibrations while the lift travels up and down, constantly monitoring for any

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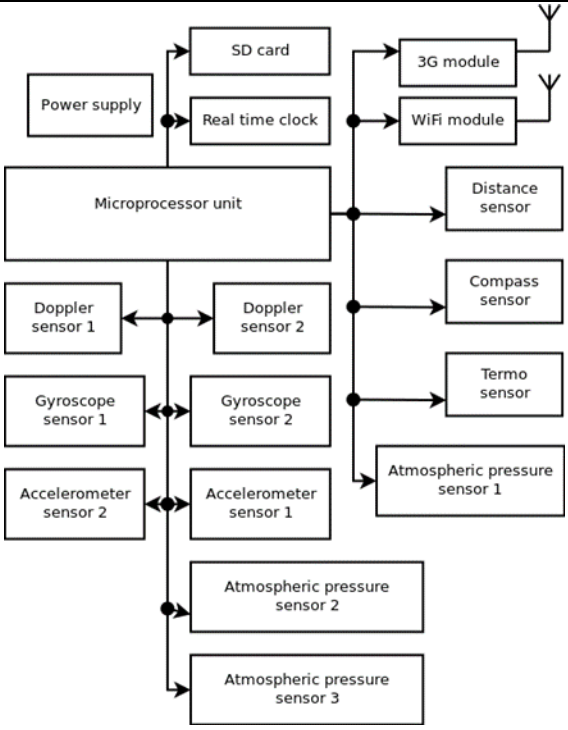

Fig. 1. Hardware block diagram

upcoming failures, thus preventing any accidents. Two of it are used – for error correction algorithms.

- Doppler sensor – a microwave radar HB100 alongside with laser distance meter and atmospheric pressure are used to detect speed, movement, direction and elevation of the lift carriage. Again data is collected from multiple sensors to allow development of failure-detection and prevention techniques.

III. Software algorithms

Following are examples of algorithms, implemented using presented hardware features. The first and most important step is to gather initial statistical data.

A. Calibrating initial data

Elevator engineer should check for any problems. If is satisfied with lift's condition the system is initiated and enters in Initial data calibration mode. This is done for the algorithm to "exam" and "learn" what is a "normal condition" for the current elevator.

The first step is to determine the orientation of the platform itself. This is done while the cabin is stationary and there are no people inside. First "down" direction is determined by detecting Earth's acceleration. Used sensor MPU6050 is 3 axial linear accelerometer which detects 9.8 m/s2 on corresponding axis. X and Y axis, used for interpreting gyroscopic data, are determined by compass sensor. The procedure is shown on figure 2.

After phase one is completed, the system should learn the "normal" way of travel. This is done by collecting statistical data while the cabin travels from the lowest to the highest and in reverse. This procedure is repeated twice more – with stops at each floor . In this way, system also "learns" how the elevator stops – accelerations, vibrations etc.

After all initialization steps completed, system is ready to collect data. It is stored on an external micro SD card as well to be used for development of new algorithms, emergency rules, warning conditions, etc. Using Internet access it is accessible any time by support team. LoRa connectivity allows new remote sensors to be attached to the system and collect data from them too.

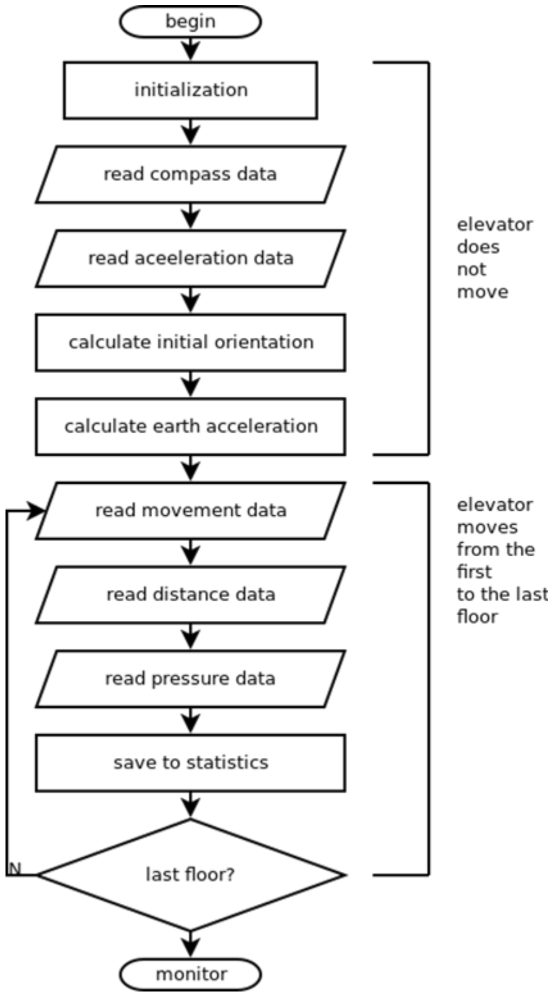

Fig. 2. Software diagram for initial data calibration

B. First floor recognition algorithm

One of the algorithms that may be accomplished with such system, that is vital for the proper functioning" is recognition of first floor. This is shown on figure 3. Using data from pressure sensors it is quite easy to determine where the cabin is located. An algorithm is shown on figure 3. To accurately detect the first floor, no movement should be registered. This is

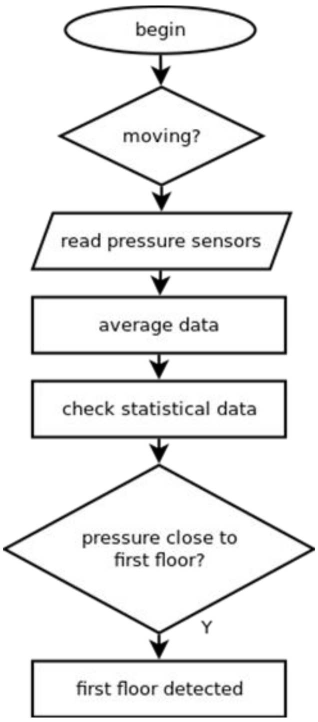

Fig. 3. Software diagram for detecting first floor

done by using doppler sensor.

If no movement is detected all pressure sensors are sampled. To reduce sensor errors a moving average algorithm is used, where windows seize equals previously determined by the operator number. This smoothen value is compared to any values stored in controller's memory (previously learned in calibration mode). Closest one is selected and the floor is recognized.

This would be an ideal situation if the weather and pressure were constant. As the pressure changes over time difference between current one and that stored in statistics for the corresponding floor varies as well. If the margin reaches predetermined value (for example 20 per cent) value in statistics is corrected. All recorded pressure values for the rest of the floors are recalculated and corrected if needed.

C. Free fall recognition algorithm

A free fall recognition algorithm may be realized, but first a closer look into acceleration data should be taken. On figure 4 is shown data collected from Z axis of an accelerometer.

In first couple of milliseconds lift cabin is stationary. Sensor is linear thus reads 9.8 m/s2 – Earth's gravity acceleration is not compensated. When free fall starts, measured acceleration reaches 0 m/s2. On figure 5 an algorithm for recognizing free fall is shown. First calibration data is read. Microcontroller constantly reads data from both acceleration sensors and calculates average value. Finally a Moving average is applied for filtering purposes. Free fall condition is detected when 0 m/s2 is read for more than 250ms. According to relation

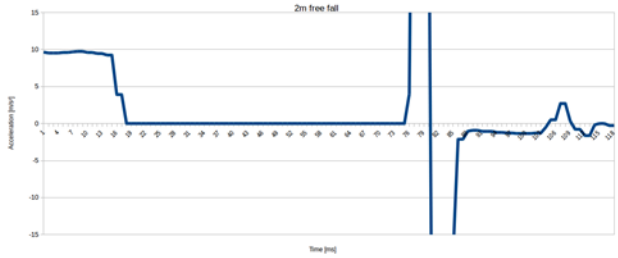

Fig. 4. Free fall data accelerometer MPU6050. X axis – time; Y axis – acceleration m/s^2

between acceleration and distance (formula 1) the cabin would have fallen with approximately 30 cm. This is necessary do filter out vibrations, jumps, etc. In such case an warning shall be sent to support and rescue team.

In addition if multiple vibrations are detected – this would be sign for an abuse and property damage. Again support team shall be called.

$$S=0.5at^2=0.5*9.8(0.25)^2=0.30625m \quad (1)$$

ADDITIONAL REMARKS

Described algorithms are an example of the capabilities of the proposed platform and cover a parameters, collected during general usage of elevators. They may be modified.

This prototype is still in development phase. As a platform, it shall provide ability for researchers to develop many new algorithms that will prevent disasters and save people's lives.

IV. CONCLUSION

Proposed platform is a great tool to help scientists to investigate, research and develop new life saving and disaster prevention techniques. A working version of the prototype shall be available in the following months. More information and measured data will be provided to all institutions, research centers, developers and students interested in this project.

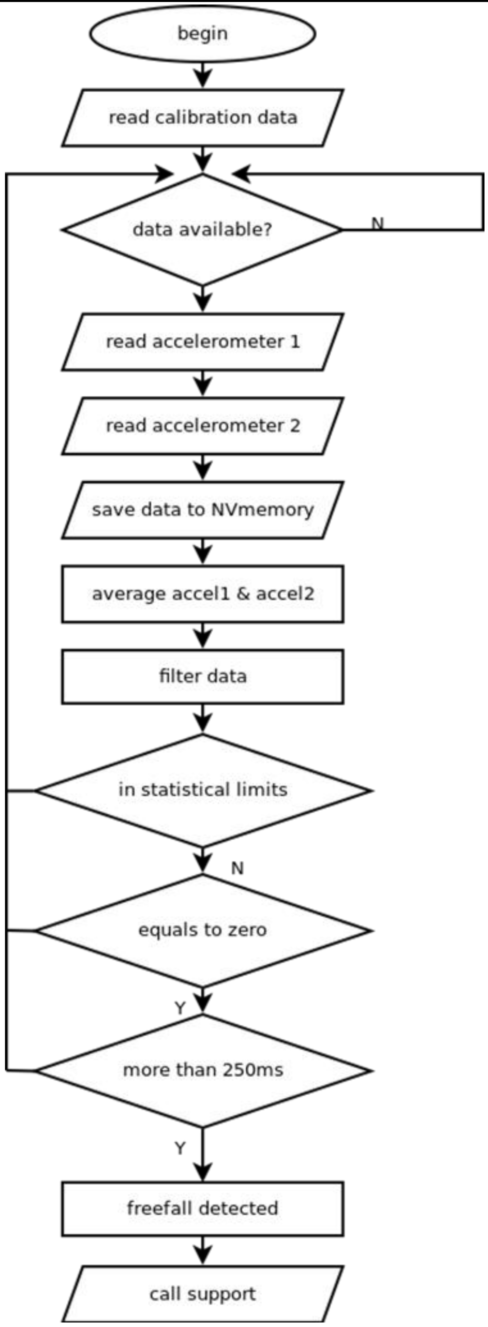

Fig. 5. Free fall data accelerometer MPU6050.

X axis – time; Y axis – acceleration m/s2

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