Construction and implementation of a magnetometer as a learning platform for marine survey

Negoiţă Sorin Gabriel

Maritime University of Constanţa

Abstract

The paper presents the construction of a relatively simple fluxgate magnetometer and its adaptation for marine magnetic surveys; the purpose of it being to map large ferromagnetic objects on the sea bed, that could pose a danger to navigation and/or the environment. Among various types of magnetometers used for magnetic surveys, the fluxgate ones are the most convenient in terms of cost and complexity of construction, providing also adequate performance for the stated purpose. The constructed device constitutes also a learning platform for persons interested in acquiring the skills of performing a marine survey, without much of the constraints imposed by a larger system.

Introduction

Magnetic surveys at sea have been employed successfully for mapping ferrous objects (1) on the sea bed, for mapping geological features of the sea bottom, and for mapping archeological structures (2). For the purpose of this paper we will focus on large ferrous targets on the sea bed that could pose a hazard for navigation and the environment. Such targets are recently sunken vessels, lost or thrown cargo at sea (containers, barrels), other large underwater iron based structures

Magnetometers are devices that can measure the magnetic flux density of the Earth. In SI (international system of units) the magnetic flux density is expressed in Tesla (T), or in practice in nanoTesla (nT = 10^{-9} T). For example the Earth's magnetic field has an average value of 50,000 nT, while a small permanent magnet can easily surpass this value by over 2000 times. Magnetometers can signal the presence of ferromagnetic objects (iron, steel, nickel, cobalt, etc.) because they disturb the value and direction of Earth magnetic field. The most common types of marine magnetometers in used today are the fluxgate and proton precession ones (3).

The fluxgate magnetometer is based on the transformer effect (4). As in a transformer there are two separate windings on a high magnetic permeability core. An alternating electric current passes through the primary coil, driving the core into an alternating state of saturation: saturated, unsaturated and inversely saturated. When an external magnetic field is present and the core is in a highly permeable state (unsaturated), the external magnetic field induces a secondary current in the sense coil whose strength is proportionally to the intensity of the external magnetic field. This second signal is extracted from the sense coil, converted into direct current voltage, and processed by specialized circuitry into meaningful information (magnetic flux density).

The proton magnetometer uses as a base for its function the precession movement of protons. Protons particles contained in a fluid oscillate at a speed whose value depends only on the value of the ambient magnetic field (5). Normally the precession movement is not synchronized between protons and thus a canceling effect occurs. In a proton magnetometer a proton rich fluid is magnetized with the help of a coil, which stops their procession movement and orients them in the same direction. When the magnetization stops all protons resume their normal precession movement but in the same direction for a short period of time (a few seconds). The combined effect of all protons produces a small electrical signal in a sense coil. This signal is amplified, it frequency measured and used to determine the value of Earth's magnetic field intensity.

Proton magnetometers can provide better resolution than the fluxgate ones but require high precision frequency measurement electronics and this makes them harder to build for the non-professionals. For our build we chose to use fluxgate sensors as they are commercially available, affordable and provide sufficient resolution for the purpose we intend to follow.

The main components of a marine magnetometer system are the tow fish that contains the magnetic field sensing sensors, and the control unit where the signal processing electronics are held. The tow fish is towed behind a boat, connected to the boat by a nonmagnetic tether line, long enough so that the magnetic signature of the boat is not pick-up by the magnetic sensors. Usually the tether line length is controlled with the help of a winch that is remotely operated by the magnetometer operator. He monitors with the help of sonar, the see flor depth in front of the tow fish, in order to avoid hitting it with the tow fish. The control unit houses the signal processing electronics, the data logger, the GPS receiver, and the computer output ports for real time mapping. The GPS receiver has a real time offset equal to the distance between the location of the GPS receiver on the boat and straight length to the position of the tow fish.

The goal of this paper was to adapt a rather simple fluxgate magnetometer for conducting marine magnetic surveys in order to map large ferromagnetic targets that could constitute a hazard to navigation and , or the environment. Moreover due to its ease of construction and low cost it is also suitable as a learning platform towards more complex magnetometers systems.

Construction

In what follows there is presented the construction and implementation of a fluxgate marine magnetometer intended to be used for mapping large ferrous objects on the coastline seabed and as a learning platform towards more complex marine magnetometer systems.

The basic design used in this marine magnetometer is borrowed from an article written by John Becker in the 2004 July edition of Everyday Practical Electronics (6) magazine from United Kingdom. The design uses two commercially available FGM 3 sensors from Speake and Co, in a gradiometer arrangement. For the purpose of our project we will use the sensor arrangement in a horizontal position. The sensors operate from a 5 volt power supply, with the output giving a 5 volt rectangular pulse whose period is directly proportional to the field strength (giving a frequency which varies inversely with the field) (7). The circuit provided by John Becker uses a PIC16F877-20 operated at 20 MHz by and external crystal. The microcontroller is used to monitor the output frequencies of the sensors and store the values to a non-volatile serial memory, from where they can be later downloaded to a personal computer for analysis and graphical display. An alphanumeric crystal display output is also provided for monitoring in real time the values detected by the sensors. A GPS feature is also available for recording the geographical location at the start and at the end of each recording session although with today's advances in the accuracy of global positioning system it would be more desirable to associate the GPS position to each of the readings. The basic electronic design chosen for this magnetometer provides sufficient flexibility in order to adapt it to marine surveys but also to upgrade it with better specification parts and software.

Figure 1

In figure 1 it is shown the control unit, on the left side the main printed circuit boards and on the right side the front panel whit the control switches. The second PCB from the top of the housing is that of a secondary power supply for the LCD backlight. Between the two printed circuit boards there is the battery holder. We used a three cell Li-Ion, 1000 mAh, rechargeable battery. For the connection of the magnetic sensors we used a multi-pin microphone type connector, a serial nine pin socket for the computer connection, and an USB connector for the optional external GPS unit. On the front panel we have the alpha numeric display, all the standard switches from the original design, and 2 LED's (rate led- indicates the frequency whit which the microcontroller takes samples from the magnetic sensors and rec led – indicates when the record function is active) The recorded the data can be downloaded and visualized as a magnetic map whit a free of charge software, written under visual basic 6; the software although not recently design can be made to work under Microsoft Windows 7.

Figure 2

In figure 2 there is shown the sensor assembly in a horizontal position as it will be secured in the tow fish. In order to achieve maximum benefit from the two sensors they have to be aligned whit each other as precise as possible. If they are not precisely aligned, they will not sense the same value of the magnetic field and they will be direction sensible it rotated around there own axes. The materials used in the sensor assembly have to be totally non-magnetic otherwise the functioning of the sensors will be disrupted. For the described construction we have used right angled aluminum section as it also provides good rigidity and convenient alignment. The distance between the two sensors is approximately 0.5 meters. Screened cable was used in between the two sensors, in order to avoid the signal from the bottom sensor interfering with the response of the top sensor. Four-way screened cable was also used to connect the sensor assembly (tow fish) to the control unit. Each of the sensors is provided with local decoupling. The right angled aluminum section is to be mounted inside a small (20 mm internal diameter) PVC pipe for added rigidity the later will be housed inside the tow fish. Due to the fact that the towline and consequently the signal cable is very long, there will be considerable signal strength loses that will prevent the control unit receiving any usable signal from the sensors in the tow fish. This requires that the signal from the magnetic sensors to be amplified in order to overcome loses due to cable length. A separate signal amplifier has to be housed and powered from inside the tow fish. Moreover the sensors themselves have to be powered from inside the towfish.

Figure 3

Shown in figure 3, is the actual tow fish constructed to house the sensor assembly described above. It is mostly intended to be used in shallow water (no more than 50 meters in depth). The exterior shell is manufactured from heavy duty PVC pipe with an external diameter of 75 mm and a working pressure of 16 bars. Overall length is 1.15 meters. At the back of the tow fish we have three stabilizing fins mounted at an angle of 90 degrees of each other. On top of the tow fish there is installed a hook-up rail with multiple connecting holes for obtaining the best horizontal balance when towed. At the left end of the hook-up rail is located to cable strain through which the signal cable will pass and go alongside the towline to the control unit in the boat. All the materials used in the construction of the tow fish are also non-magnetic.

Implementation

In order to test the reliability of the magnetometer system (tow fish and recording unit) a test grid (figure 4, not to scale) was surveyed for two times on Lake Siutghiol from Constanta, Romania. The dimensions of the survey grid were 20 meters length by 12 meters wide, with a total of 7 survey lines. The magnetic measurements were taken with the magnetic probe orientated in west-east direction; this was done in order to minimize the influence of Earth's magnetic field on the recorded readings. For testing the first magnetic reading was taken with the grid perimeter clean of any significant ferrous target. For the second magnetic reading, a ferrous target was introduced in the grid perimeter. This method helped in determining if the magnetometer probe was able to detect the anomaly produced in the Earth's magnetic field by a a medium test target (standard oil barrel) in shallow water (4-5meters). The sensor assembly was towed behind a boat following the grid pattern shown in figure 4, at about 5 km/h. For precise positioning a GPS unit was connected to a laptop on the boat running Google Earth software. A secondary set of virtual lines was used to determine the position of the tow fish by taking into consideration the length of the tow line. At the beginning of each new survey line the record function was switched on, and switched off at each line end, this mode of operation signaled to the recording unit when a survey line begin and ended.

Figure 4

In figure number 5 there is shown the tow-fish being prepared for deployment, and in figure number 6 there is show the tow-fish being towed behind the boat.

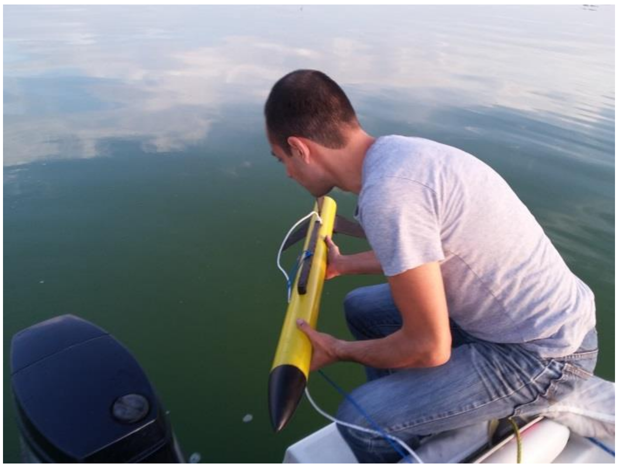

Figure 5

Figure 6

After each set of recorded data was saved, it was converted in order to be graphically displayed. For this purpose I used third party software GeoSurveyer2dowloader for saving the data from the recording unit and GeoSurveyer2 (8) for graphically displaying the data. Below in figure 7 and figure 8 there is presented the graphical interpretation of the scanned area. From left to right the image without test target and the image with the test target. The intensity of the magnetic field is colored in increasing order from dark blue, light blue, green, light green, yellow, orange and red. In figure 8 by comparison to figure 7 there is clearly visible in red a magnetic peak resulted from the presence of the test target. In both pictures there are various low intensity magnetic anomalies, mostly highlighted in yellow; one reason for some of these parallel anomalies could be a slight yaw of the tow fish.

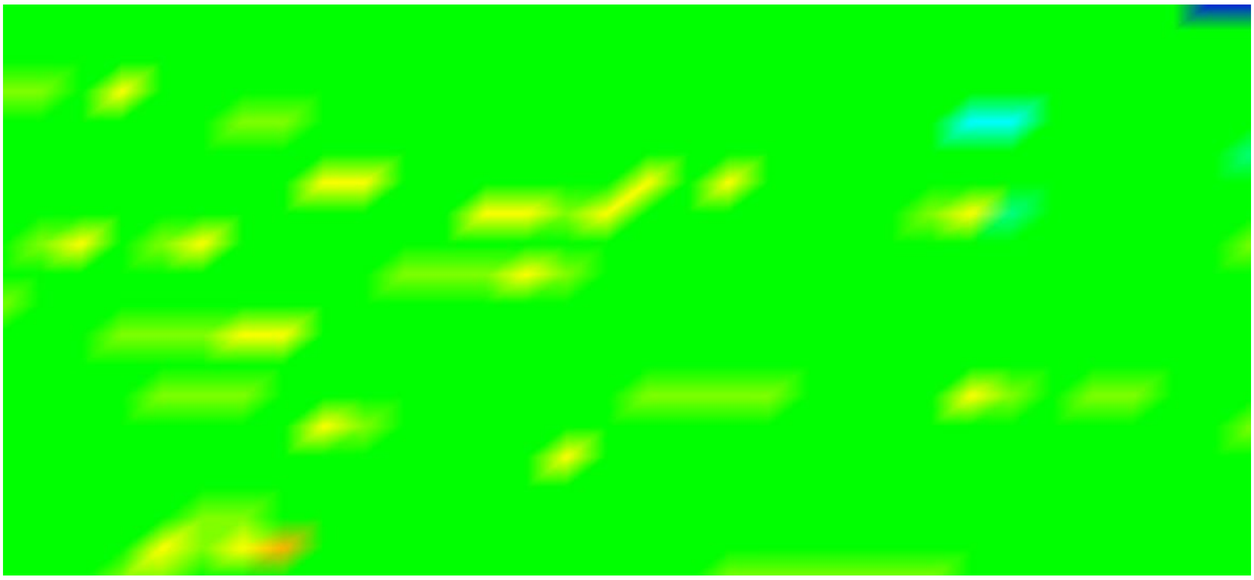

Figure 7

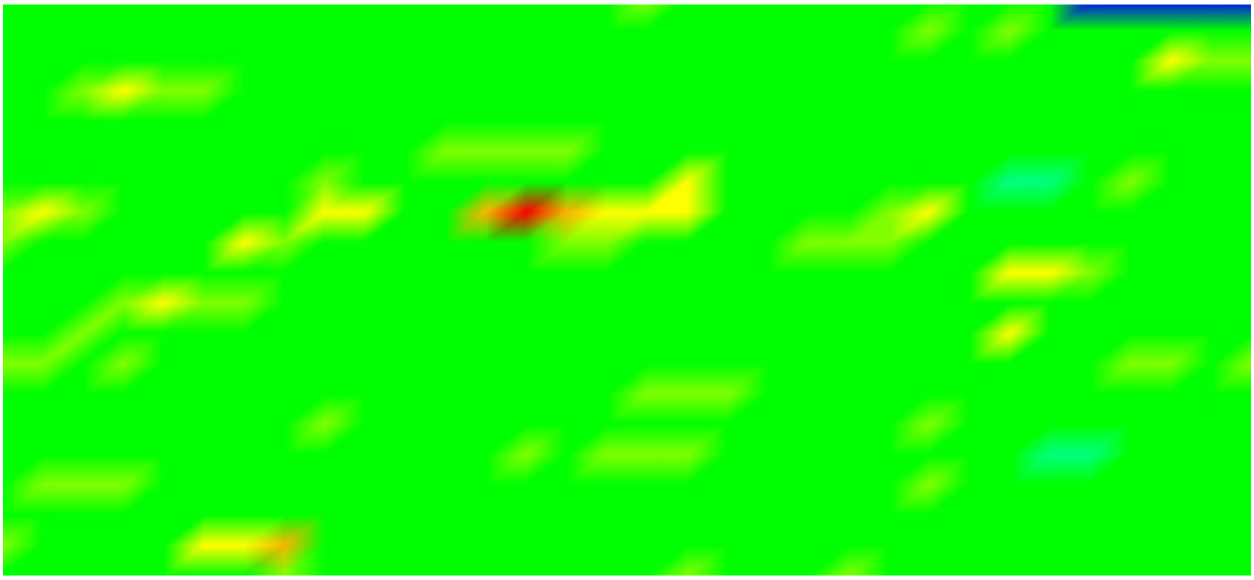

Figure 8

Final thoughts

I believe that the described magnetometer has a good potential to be used for the purpose of learning magnetic marine survey and to be a stepping stone towards more advanced marine magnetometers. For the moment I will continue to experiment with the unit presented in this paper, in order to obtain best performance from this setup. As improvements I'm already thinking of adding an onboard power supply for the tow fish in order to permit the usage of longer towing cables and to implement an "in the field" method of sensor alignment. Moreover during the tests it was observed a slight yaw movement of the tow-fish when being towed by the boat; this is very likely due to improper positioning of the center of gravity and center of pressure.

This project is yet to be finished and will still require some work until I will have gained enough experience in order to move towards more advanced projects like a proton magnetometer, but overall I'm pleased with the results obtained.

Bibliography

1. Pozza . M; Hrvoic. D; Priddis. K – Mapping marine ferrous targets using the seaquest gradiometer system. Marine Magnetics Corp. 2003, www.marinemagnetics.com.
2. Boyce. J; Reinhardt, E.G. – Marine magnetic survey of a submerged roman harbor, Caesarea Maritima, Israel. International Journal of Nautical Archeology 2004 , p. 122-136
3. Breiner. S – Applications manual for portable magnetometers – Geometrics 2190 Fortune Drive, San Jose, California, USA 1999, p. 3
4. Ripka; Pavel – Magnetic sensors and magnetometers. Arthech House Publisers. p. 494
5. Bayot. W – Practical guidelines for building a magnetometer by hobbyists, part1: Introduction to magnetometer technology, 2008 p. 8
6. John Becker – PIC magnetometry logger, Everyday Practical Electronics Magazine, July 2004, p.469-476
7. Speake and Co Llanfapley U.K.– Application Notes - Magnetic field sensors. p.1
8. http://www.imaginglocators.com/gems_installation.html

Scientific research (Life rafts survival tests)

Michał Rataj, dr Andrzej Molisz, dr Katarzyna Nowicka-Sauer, Krzysztof Mocarski

Gdynia Maritime University, Poland
Medical University of Gdańsk, Poland

Abstract: A group of students from Gdynia Maritime University and Gdynia Naval Academy participated in a life rafts survival tests. Volunteers stayed in life rafts, which were towed by a stern of SAR vessel: "Kapitan Poinc". They were supplied in primary life raft equipment food supplies, water supplies and pyrotechnics. The purpose of survey was enduring 12 hours in conditions very close to being a survivor.

Key words: *Life raft, survival, SAR,*

1. Introduction

A Group of students from the first, second and third year of navigation from Gdynia Maritime Academy and Polish Naval Academy would like to check, how they, future officers, can handle with situation hard situation, where all means fail and they will have to save their lives escaping to the life rafts. For this purpose we gathered the group of 18 students, 10 men and 8 women which would like to participate in the scientific research.

The main goal of experiment was to check how students, who have theoretical knowledge about rescue procedures at sea will use it in real threat situation.

We would like to know their mental, psychic condition and their own opinion after 12h in the life raft.

2. Technical description

We had two life rafts. First was CSM company, second one STOMIL company, their capacity were 10 persons. Life rafts had equipment according to the SOLAS convention. STOMIL life raft was open at the ship deck, so that everyone can see how this procedure looks like. We decided to divide group of students into a Male and Female rafts. Women took place in STOMIL life raft and Men in CSM life raft.

The Basis of our research was SAR vessel m/s “Kapitan Poinc”, which crew took care of us. M/s „Kapitan Poinc” performs service moored in the Port of Gdynia, ready for rescue ships and persons 365 days, 24 hours per day. It’s length is 49,8 meters, width 13,6 meters, drought 4,6 meters, engines 2 x 1920 horsepower, maximum speed 13 knots, basic crew 11 persons, can pick up 272 survivors, ice class 1L.

During the scientific research air temperature was thirteen Celsius degrees, water temperature eight Celsius degrees, state of the sea three to four in the Beaufort scale.

3. Research plan

- Labyrinth examination and Cardiograph examination were realize by Dr Molisz before and after being at the life,
- Putting on immersion suit and customize to the body
- Jump into the life raft or into the water and swim to the life raft
- Adapt into the life raft and ta king comfortable position in it
- Using a radar reflector according to the manual
- Using Hand flares, Parachute rockers, Floating smoke
- Simulation swimming using paddles to the person in water
- Pick up unconscious and conscious person to the life raft
- Rain simulation

4. Scientific research process

After leaving Port of Gdynia, students were examined by doctor. Next each of participants had to put on immersion suit and check is it all his equipment. Next step was to open a STOMIL life raft and look inside to make sure that all needed things that SOLAS convetion required are in. Both life rafts were launched and students due to instructions SAR vessel “Kapitan Poinc” get in. After taking their position about 400 meters far from the ship we start an observation. Two hours later first three women said that it’s over for them and they would like to go out, due to sea sick. Students were asked to use a radar reflector, task was finished fully succeed and we can see them in the ship radar. Crew simulate the attendants raining weather by activate fire water cannon at the ship. After four hours next women said that she want to go out from life raft.

After five hours four man said that due to sea sick they also want stop research and go out. After five and a half hours next three women and two man would like to leave the life raft complaining of malaise. We decide to move last women from the life raft to the men life raft, where were still four men. At the CSM life raft are now 5 persons (four men and one woman). Next students were informed that in the water is something similar to the human body, their task was to swim there, using only paddles. They struggle with his exercise for about an hour, because of strong wind and high waves. After half an hour since last task they were ask to use pyrotechnics material. Each of it was used correctly and visible from a far. Last exercise was to pick up unconscious and conscious person to the life raft. Two beholders put on immersion suits, jump into the water and after getting close to the life raft, the students have to pick up them. Participants manage easily with this task. After about seven hours last students resigned from the research due to bad mental and physical condition, and were took on board

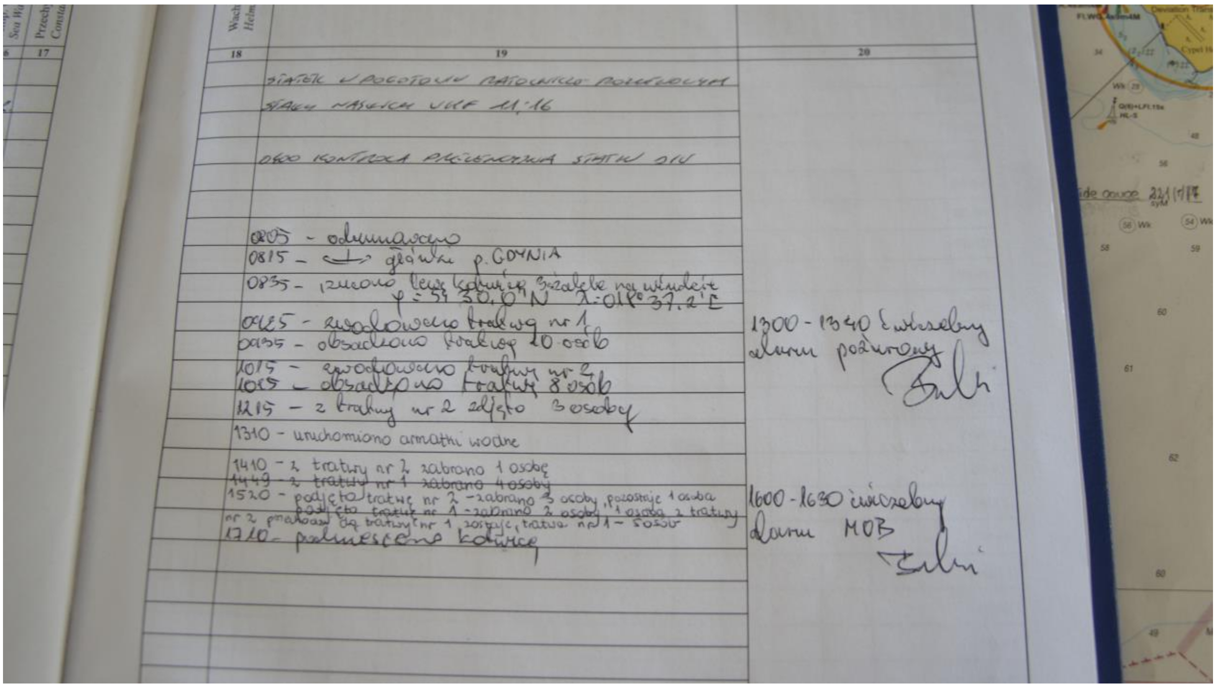

Photo 1. Vessel Logbook, where crew wrote time when each of the students take on borad from life raft

5. Observation behavior of the participants

The crew and beholders notice some serious mistakes which students made during the research:

- Getting off immersion suit during test (mainly gloves and hood),
- Mental unpreparedness to spent twelve hours at sea,
- No idea what to do during experiment
- Drinking not enough water
- Mental resignation
- Closing the life raft (no air circulation inside)

However we see a lot of assets.

- Support each other
- Teamwork
- Dealing with the knowledge how to use equipment

Additionally after research we asked participants to tell us what was the most positive and negative aspects during the test.

Positive aspects:

- Atmosphere
- Check theoretical knowledge in practice
- Sunny weather
- Jumping into water
- Taking care of colleagues in worse condition

Negative aspects:

- high waves
- rocking the life raft
- fear
- smell of the rubber inside
- cold
- seasick

6. Medical results

The examination included questionnaires, vestibular testing and examination of the cardiovascular system. Cardiovascular parameters such as pulse, stroke volume, blood pressure, were evaluated with impedance cardiography (ICG). On the life rafts intensity of seasickness was evaluated with MSAQ (Motion Sickness Assessment Questionnaire.
We can see cardiovascular parameter changes, which appeared due to seasick, stress and hypothermia

Table 1. Cardiovascular parameters measured with impedance cardiography (ICG). Statistically significant differences ($p<0.05$) are **in bold**.

Parameter	Before life rafts	After life rafts	P value
Heart rate	**78.6**	**70.1**	**0.002**
Systolic blood pressure	123.6	123.5	0.973
Diastolic blood pressure	73.7	74.2	0.768
Mean arterial blood pressure	85.2	85.6	0.863
Systolic volume index	**55.6**	**60.5**	**0.003**
Cardiac output index	4.3	4.2	0.230
Systemic vascular resistance index	1505.0	1567.1	0.145

Table 2. Correlation between results of MSAQ and cardiovascular parameters from impedance cardiography. Spearman's rank correlation coefficient is presented. Statistically significant differences (p<0.05) are **in bold**.

Parameter	Overall	Gastrointestinal	Central	Peripheral
Heart rate	-0.273	-0.249	**-0.478**	**-0.711**
Systolic blood pressure	-0.354	-0.370	**-0.532**	0.100
Diastolic blood pressure	0.299	0.173	0.283	0.140
Mean arterial blood pressure	0.184	0.101	0.113	0.189
Systolic volume index	**0.525**	0.347	0.419	0.365
Cardiac output index	0.411	0.305	0.180	-0.113
Systemic vascular resistance index	-0.176	-0.167	-0.082	0.442
Pulse pressure	**-0.476**	**-0.579**	**-0.584**	-0.008

7. Conclusion

For each participant this life raft survival test was first confrontation theoretical knowledge of lifesaving with reality. The purpose of the research, survival twelve hours at the life raft was not succeed, due to hard weather, students mistakes and lack of practical prepare for survival at the life raft. However fact, that they decide to challenge themselves in this kind of event is very satisfied and we make sure that if any of them find out in serious danger they will know what to do. Medical results are interesting, because we can see that even short period of time affect the human body. What's important participants during event deal perfectly with pyrotechnics, fast put on immersion suits and rescue survivals from water, therefore we are sure that students know how to keep alive at the life raft and correctly use equipment at it.