New Telematic Solutions for Improving Safety in Inland Navigation

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Abstract. The article presents practical applications of telematics in improving safety of transport in inland waterway. Presented in the paper new telematic solutions, autonomous system of information about the event on the waters as well as mobile application, enable emergency services to react quickly. This is important particularly in situation where human life is in danger. For the solutions presented in the work it has been proposed a mathematical analysis on the basis of Markov processes.

Keywords: Telematic in inland navigation · Water tourism · Systems modeling

1 Introduction

The modern railway, road and water inland telematic infrastructure allows obtaining high levels of safety, environmental protection, better transport effectiveness and better control over transport means and the transport process. The execution of the functions related to management and control in transport imposes the necessity to ensure reliability indexes of a sufficient degree. The actions leading to establishing them regard a complex analysis of a single element and the entire system. The damage intensity is in this case the primary index. The use of the mathematical apparatus tools and simulations methods additionally allows for evaluating the transport telematics systems and modelling of various damage scenarios and also data transmission interference [1–3]. The transport telematics systems execute various functions and operate in various conditions. Each case of unreliability can generate side effects, including economic or environmental effects. The unreliability of the transport telematics systems can constitute a hazard for human life, which is of the highest value. In such cases, we are dealing with the unreliability of safety of the transport telematics systems.

One of the main tasks of telematics systems related to safety and management in transport is to obtain and process information. This is possible e.g. through the use of transmission standards and processing of information. Obtaining information is possible thanks to two layers, [1]:

– ground layer (IT networks),
– satellite layer (satellite navigation systems).

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The element influencing on the safety of the inland navigation is, apart from the skills of water equipment users, the use of telematics systems to inform about the possibility of a dangerous situation. An example of such a solution is running in 2011 warning system against dangerous atmospheric phenomena (Mazurian Lake District). Before the possibility of danger weather, users of yachts are informed by flashing lights on special masts. 40 flashes/min means that it is expected storm or strong wind, 90 flashes/min alerts to direct danger of the storm and strong wind, [4]. The list of the location of each mast of the system is shown in Table 1.

Table 1. Location data of the masts [1]

No.	The list of masts at the Mazurian Lakes District	Geographical coordinates
1.	Lake Mamry, Skłodowo	21 43 26.55″E 54 09 23.39 N
2.	Lake Mamry, Węgorzewo	21 43 10.08″E 54 11 51.8454 N
3.	Lake Święcajty, Ogonki	21 48 24.05″E 54 10 58.94 N
4.	Lake Ryńskie, Ryn City	21 31 51.83″E 53 55 49.75 N
5.	Lake Roś, Łupki	21 51 34.70″E 53 39 08.10 N
6.	Lake Mikołajskie, Mikołajki	21 37 13.90″E 53 45 53.60 N
7.	Lake Niegocin, Kępa Grajewska (island)	21 47 54.18″E 54 00 20.61 N
8.	Lake Kisajno	21 43 55.36″E 54 02 10.61 N
9.	Lake Mamry, Wysoki Róg	21 40 34.14″E 54 06 07.55 N
10.	Lake Jagodne	21 43 35.43″E 53 56 01.33 N
11.	Lake Boczne, Bogaczewo	21 45 00.05″E 53 57 48.69 N
12.	Lake Łuknajno	21 40 41.04″E 53 47 09.92 N
13.	Lake Śniardwy, Nowe Guty	21 49 11.56″E 53 45 49.40 N
14.	Lake Śniardwy, Niedźwiedzi Róg	21 41 45.05″E 53 43 06.51 N
15.	Lake Bełdany, Kamień	21 33 42.63″E 53 43 21.04 N
16.	Lake Seksty, Jegliński Canal	21 46 52.56″E 53 41 17.70 N
17.	Lake Tałty, Tałcki Canal	21 32 33.66″E 53 51 50.70 N

Component of the system, the mast with lamp, is shown in Fig. 1.

Fig. 1. The mast of warning system [own study]

Besides the above-mentioned solution it is also very important to have tools to quickly reach people in need of help. With regard to inland water transport the time of passing on the information to the emergency services equipped with technical support in the form of rescue boats and coordination with other emergency services are the most important. The notification without specifying the location of the event can significantly delay the time of arrival of water rescuers.

At the Faculty of Transport and Electrical Engineering University of Technology and Humanities in Radom it was designed and built a system dedicated to tourist boat on inland waters, especially for sailing yachts. The system is a part of the telematic solutions which improve the safety. Additionally it has been prepared mobile application for Android system which permit to send messages with the position of need of help.

The solutions presented in this paper are based on the data obtained from the navigation system, and the ground transmission is carried out via cellular network. In the solutions presented in the work, the cellular network is required to send information in the form of the *sms* text message. In the proposed solution dedicated to yachts, transmission is realized by typical GSM/GPRS module integrated with GPS module.

The GPS NAVSTAR (Global Positioning System) is currently the most popular satellite navigation system. Therefore, to sailing yacht system, authors proposed GPS module. The authors also envisage the possibility of using modules receiving GPS, Glonass and Galileo signals (GNSS module). The work of the receiver in many modes will allow for more accurate positioning. The GPS system is owned and operated by United States of America (USA). The system was launched in 1978, but for civilian use it was made available only in 1983 (formally in 1996). The system consists of three segments [1]:

– satellite segment,
– ground segment,
– user segment.

Presented in the paper solutions are the real telematics systems and also an example of the practical use of transport telematics systems.

2 Mobile Application

According to IDC (International Data Corporation) in 2016’ almost 87% of mobile devices in the world worked on Android system, [5]. Due to this fact, at the Faculty of Transport and Electrical Engineering of UTH in Radom, it was created mobile app. that gives the possibility to send an *sms* (Short Message Service) with the call for help, [1]. Initially the application was written for the deaf-mute people, where in case of danger the person may send a request for help, together with the location data. Created application is a tool so versatile that it can be used to inform any rescue services about need for help, also about the event on the waters. In order to write an application it has been prepared the appropriate development environment, which includes, [1]:

– development environment JAVA - Java Developer Kit (JDK). This is a package of tools that allows, among others, to compile programs.

– Android SDK - this is an environment for application development for Android. It also contains useful tools to create or manage virtual devices, in which user-created applications can be checked.
– IDE Eclipse application (Integrated Development Environment), which was used for the mobile app.

The algorithm of the mobile app. is shown in Fig. 2.

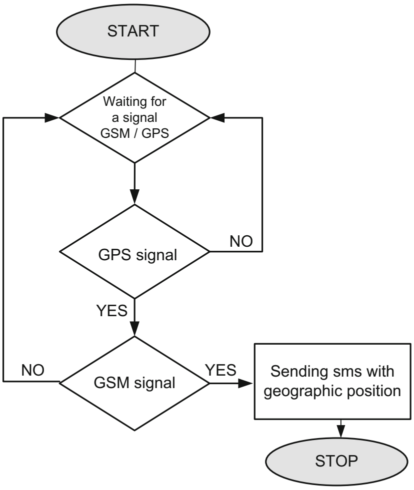

Fig. 2. The algorithm of the mobile app. [own study]

Figure 3 shows the result of mobile app test.

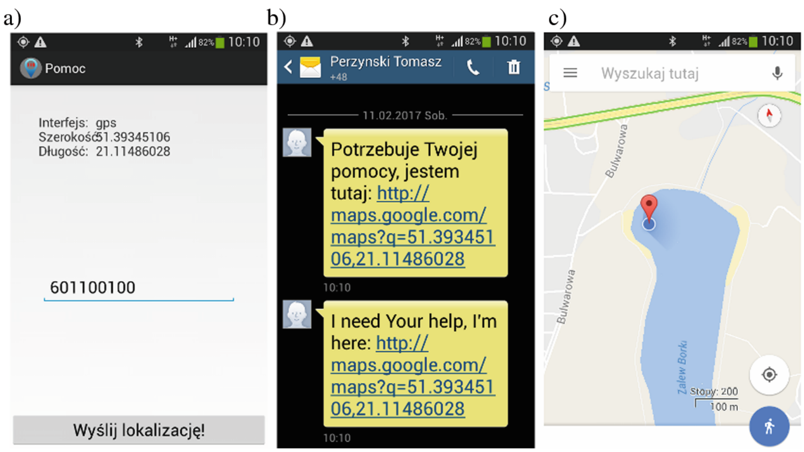

Fig. 3. (a) mobile app., (b) window with sms, (c) Google map with position [own study]

In the application it is possible to enter any phone number. The official phone number to water rescue service in Poland is 601 100 100. In the current version of the application (for testing) in a received text message (Fig. 3b) is automatically entered text: I need Your help, I'm here (pl. - *Potrzebuje Twojej pomocy, jestem tutaj*) and is added the link to the map. In Fig. 3c there is shown the view of Google Maps in open mobile device.

3 Emergency Notification System

Liberal regulations concerning water tourism in Poland cause that there is a real threat to the people who practice this form of relaxation. This applies primarily to people without appropriate qualifications and skills in the safe conduct of yachts. In order to counteract the effects of events on inland waters, at the Faculty of Transport and Electrical Engineering UTH in Radom there has been developed and built the electronic system informing about the event on the inland waters with the working name ENoS – Emergency Notification System, [6]. The ENoS system uses three main electronic components, which are shown in Fig. 4:

- control unit (microcontroller Atmega 128),
- integrated module GPS with GSM-GPRS (Sim908C),
- tilt sensor module.

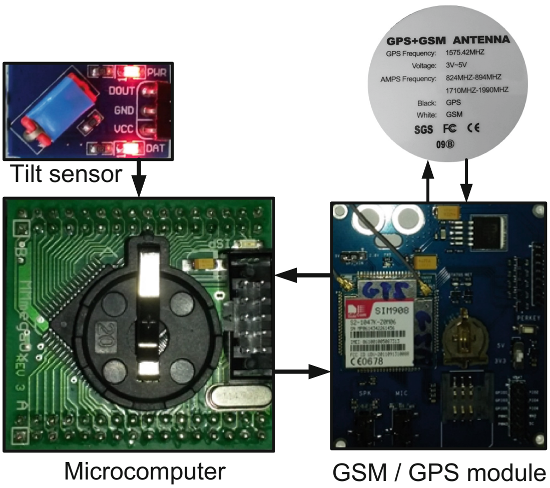

Fig. 4. The components of the ENoS device [own study]

ENoS system is fully autonomic. Sending an SOS (Save Our Ship or Save Our Souls) to the emergency services with a geographical position is automatic. The control unit is equipped with a microcontroller Atmel Atmega 128 and contains RS232 interface. GPS/GSM module also has an RS232 interface. Module control by the control unit is done with using standard commands for modems (AT commands) sent

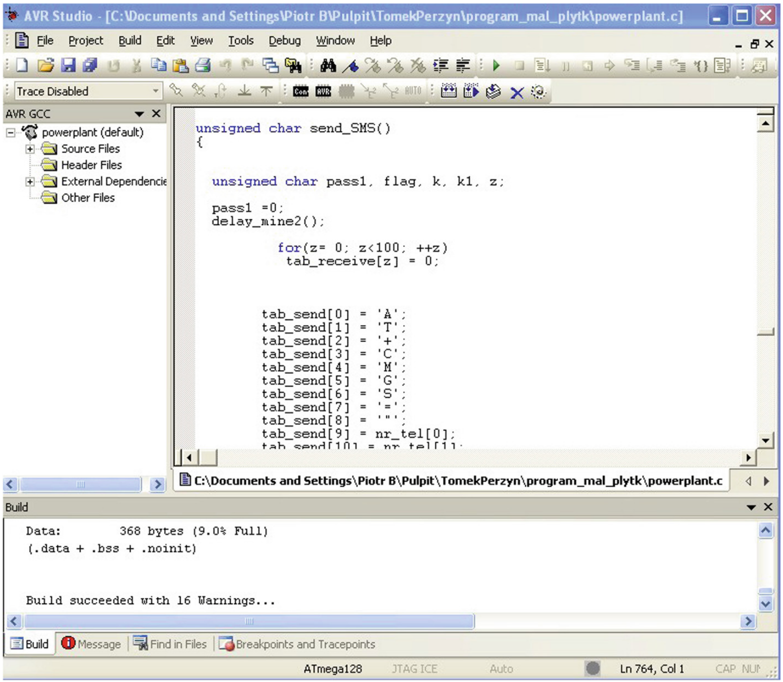

Fig. 5. Screenshot of the control program in the environment AVRStudio v.4.0 [1]

via RS232 interface. Information about the inclination of the yacht is delivered to the control unit by a tilt sensor via a standard digital input.

Software for the control unit is written in “C” for the microcontroller Atmega 128. For this purpose there is used AVRStudio v4.0 environment with compiler “C” for microcontrollers Atmega (GnuC compiler). Figure 5 shows a screenshot of the control environment AVRStudio v.4.0

After turning the device in the first phase it is followed an initialization of the RS232 interface for microcontroller Atmega 128. In this phase there are sets the transmission parameters, such as:

– speed transmission 9600 bit/s,
– stopbit 1,
– no parity,
– sent word of 8 bits.

The next step is conducted to initialize the GPS/GSM module. Initialization is conducted separately for part of the GPS and separately for part of the GSM. After the initialization GPS/GSM module is tested. It consists of sending a test message with the current location of a yacht on the number of recipient. In the case of an error in the operation of the GPS/GSM module the procedure is conducted again starting from reset and initialize the GPS/GSM module. The next step is reading the information about the tilting of yacht from the tilt sensor. If the yacht is tilted for a period longer than 30 s,

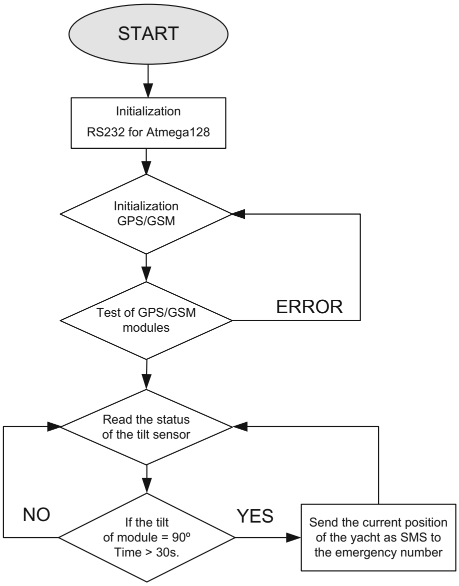

Fig. 6. Block diagram of the control program [own study]

on emergency number there is sent sms with information about yacht current position. In the case of the permanent tilt there are sent only three *sms* with the current position at intervals of 60 s. Figure 6 shows a block diagram of the control program.

Used in the device microcontroller system is programmable and completely autonomous microprocessor system. The device uses 8-bit microcontroller. The microcontroller is managing the device, which is adapted to direct cooperation with various outer devices and sensors without additional peripheral systems. In the future, this will allow to expand the function of the device. The GPS/GSM module system was built on SIM908, which allows connectivity: GSM, GPRS, and a GPS receiver. Communication with a module is via a serial bus. Figure 7 shows the view of the testing stand installed on the pontoon, [1].

a) b)

Fig. 7. The testing stand installed on the pontoon [1]

Fig. 8. (a) Received *sms*, (b) Google map with position [1]

In the testing stand, to allow tilting the ENoS device, there was used the rotary system (360°). Tilt of the device was initiated manually. After switching on and initialization of the GSM/GPS module the device worked in standby mode. The tests of the system was carried out on the waters area Domaniów near Radom. Figure 8 shows the test result (*sms* and a map of the location).

The tests allowed it to check the correct work of the system. Install the ENoS system on the sailing yacht will allow finish the next phase of work on ENoS. Yacht for the test is presented in the Fig. 9.

Fig. 9. Yacht for test the ENoS on Domaniów water area [own study]

In case of Masurian Lake District, the received information with the position of the yacht can be displayed on the TV monitor's map in the headquarters of Aquatic Volunteer Emergency Corps in Giżycko, as shown in Fig. 10. Currently, on the monitor screen are displayed only information with data of rescue boats.

Fig. 10. TV monitor - Aquatic Volunteer Emergency Corps in Giżycko [own study]

4 Models for ENoS System and Mobile App

In order to analyze the presented in the papers solutions, authors proposed Markov processes. In the Fig. 11 there is presented the system model, which includes the possibility of a dangerous situation on the waters. In case of the appearance of dangerous event, it is possible to notify the emergency services using autonomous system installed on the boat (ENoS) or using the mobile app.

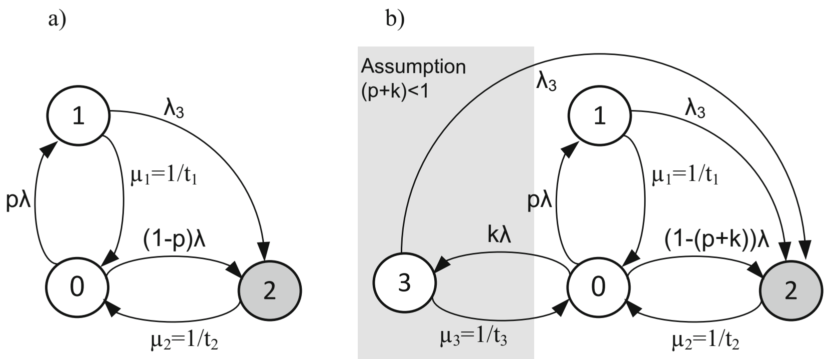

Fig. 11. Markov models, a) only ENoS, b) ENoS and mobile app. [own study]

In the models from Fig. 11, we can distinguish:

0 - state of correct work. No threat.
1 - state of danger. The yacht equipped with a system ENoS,
2 - state of critical danger,
3 - state of danger. The yacht not equipped with the system. Help requested by mobile app.,
p - the probability of equipment yacht in the system,
k - the probability of having the mobile app.

For models in Fig. 11a (1) and b (2) we can write the equation in the form of operators:

$$\begin{cases} s\cdot \underset{0}{\tilde{P}} -1 = -p\cdot\lambda\cdot \underset{0}{\tilde{P}} + \mu_1\cdot \underset{1}{\tilde{P}} -(1-p)\cdot\lambda\cdot \underset{0}{\tilde{P}} + \mu_2\cdot \underset{2}{\tilde{P}} \\ s\cdot \underset{1}{\tilde{P}} = p\cdot\lambda\cdot \underset{0}{\tilde{P}} -\mu_1\cdot \underset{1}{\tilde{P}} -\lambda_3\cdot \underset{1}{\tilde{P}} \\ s\cdot \underset{2}{\tilde{P}} = (1-p)\cdot\lambda\cdot \underset{0}{\tilde{P}} -\mu_2\cdot \underset{2}{\tilde{P}} +\lambda_3\cdot \underset{1}{\tilde{P}} \end{cases} \tag{1}$$

$$\begin{cases} s\cdot \underset{0}{\tilde{P}} -1 = -(p+k)\cdot\lambda\cdot \underset{0}{\tilde{P}} + \mu_1\cdot \underset{1}{\tilde{P}} -(1-(p+k))\cdot\lambda\cdot \underset{0}{\tilde{P}} + \mu_2\cdot \underset{2}{\tilde{P}} + \mu_3\cdot \underset{3}{\tilde{P}} \\ s\cdot \underset{1}{\tilde{P}} = p\cdot\lambda\cdot \underset{0}{\tilde{P}} -\mu_1\cdot \underset{1}{\tilde{P}} -\lambda_3\cdot \underset{1}{\tilde{P}} \\ s\cdot \underset{2}{\tilde{P}} = (1-(p+k))\cdot\lambda\cdot \underset{0}{\tilde{P}} -\mu_2\cdot \underset{2}{\tilde{P}} +\lambda_3\cdot (\underset{1}{\tilde{P}} + \underset{3}{\tilde{P}}) \\ s\cdot \underset{3}{\tilde{P}} = k\cdot\lambda\cdot \underset{0}{\tilde{P}} -\mu_3\cdot \underset{3}{\tilde{P}} -k\cdot\lambda\cdot \underset{3}{\tilde{P}} \end{cases} \tag{2}$$

Using the properties of Laplace transform it was solved Eqs. (1) and (2) and it was calculated the probability of critical $P_2(t)$ for models from Figs. 11a (3), b (4):

$$A_{[Fig.9a]} = 1 - \lim_{t\to\infty} P_2(t) = \frac{(p\lambda+\lambda_3+\mu_1)\mu_2}{(\lambda_3+\mu_1)\mu_2+\lambda(\lambda_3+\mu_1-p\mu_1+p\mu_2)} \tag{3}$$

$$A_{[Fig.9b]} = 1 - \lim_{t\to\infty} P_2(t) = \frac{\mu_2(k\lambda(\lambda_3+\mu_1)+(p\lambda+\lambda_3+\mu_1)(\lambda_3+\mu_3))}{(\lambda_3+\mu_1)\mu_2(\lambda_3+\mu_3)+} \\ \frac{1}{\lambda(\lambda_3^2+k\mu_1(\mu_2-\mu_3)+(\mu_1-p\mu_1+p\mu_2)\mu_3+\lambda_3(\mu_1-p\mu_1+(k+p)\mu_2+\mu_3-k\mu_3))} \tag{4}$$

Assuming the values of rates:

- $\lambda = 0.00685\ h^{-1}$ (60 dangerous situation/year),
- $\lambda_3 = 0.000685\ h^{-1}$ (10% from λ lead to a dangerous situation),
- $\mu_1 = 6\ h^{-1}$, $\mu_2 = 1\ h^{-1}$, $\mu_3 = 6\ h^{1}$, for model with additional application (Fig. 9b),
- k = 0.4,

it was given the results shown in Table 2.

Table 2. The value of availability [own study]

The value of probability *p*	Availability A: Model with ENoS and mobile app.	Availability A: Model with ENoS and without mobile app.
p = 0.1	0.996588242	0.99387339
p = 0.2	0.997268885	0.99455094
p = 0.3	0.997950303	0.99522927
p = 0.4	0.998632497	0.995908373
p = 0.5	0.999315468	0.996588242

5 Conclusion

The solutions presented in the article are a part of the telematics systems, which let to improve a safety. Currently operating in Poland system of warning against dangerous atmospheric phenomena with its coverage covers only Masurian Lake District. However, there are no solutions that can inform about the event on any water. The implemented solutions allow it to send an information to the emergency services, which allows for faster help. At this stage, there is also the possibility of making a voice call at the mobile application. The mobile application after modification can realize tasks similar to ENoS. For this purpose the mobile app will be complemented with the ability to taking an information from the internal accelerometer of the mobile device.

Presented in the paper system ENoS may become standard equipment on yachts on inland waterways. ENoS also can be complemented with additional functions, including the emergency button.

The conclusions of the tests the ENoS device:

- it was tested correct operation of the device during inclination of less than 30 s and greater than 30 s,
- the device does not send a message during inclination of less than 70° and a long tilting,
- during inclination in the range of 70°–80° and time <30 s the system does not send messages,
- an inclination close to 90° and the time <30 s system does not send messages,
- an inclination close to 90° and the time >30 s system worked and sent messages.

The conducted tests confirmed the assumptions from the stage of the concept and construction, [6]. The last phase of the ENoS test will be install system on a sailing yacht to carry out the test in real conditions during sailing.

The paper also conducted a mathematical analysis based on Markov processes, which are one of a lot methods of risk analysis, [7]. Result of the analysis indicates that in the event of a threat on the water using ENoS or mobile app allows for quickly reach water rescuers.

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