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CONTENTS

APPLICATION OF GNSS TECHNOLOGY FOR HIGH SPEED BOATS TRACKING AND COLLISION AVOIDANCE

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ABSTRACT. *Since each country with access to the seacoast is an interesting tourist destination, additional facilities are built in such countries to attract tourists. In addition to the usual rental offer of a variety of sea vessels, boats, yachts and sailboats, an increasingly popular trend of adrenaline sport is introduced in the form of high speed boats. They are also called Jetski and present a fast growing rental business in the area of adrenaline sports.*

In this paper possible solutions to detection and prevention of collisions will be analysed in order to raise the level of safety of sea traffic. The research is motivated by the fact that renting of fast boats is done mostly to amateur drivers. They are usually searching for vacation fun with little experience of manipulating high speed boats. Several implementation difficulties due to the high dynamics of these speed boats will be examined. The driving style of these boats which includes very quick change of speed and direction of movement is an additional challenge. Proposed embedded system is based on the Atmel AVR family of processors, and SIMCOM SIM908 GSM and GPS system. Proposed system was tested in real world scenarios during the touristic season on the Adriatic coast. Significant amount of GPS position data for collision detection analysis were collected including tourist behaviour data to test the earning reports generation module.

KEY WORDS: *collision detection, GNSS, speed boats, remote control*

1 INTRODUCTION

Rapid development of GPS and GSM-based embedded computers, their popularization and falling prices opened new areas of application in monitoring, supervision, and control of road and sea traffic. One of the applications is rental of speed boats popularly known as JetSki scooters (Figure 1). The owners of such rental companies have the need for supervision of the current speed boat's position and driver behaviour because drivers are mostly inexperienced amateurs. Additionally, owners have the requirement to obtain earning reports for each speed boat. Such monitoring requires a person that oversees the speed boats from a nearby coast. During the speed boat rental time it can be necessary to shut the boat down or to alert the driver of his wrong actions [1]. Rapid development of embedded computers that are aware of their position, speed, acceleration and movement direction made it possible to execute these tasks and further increase sea traffic safety by setting a geo-fence. This advanced surveillance application requires the boat's geo position inside of a geo-fence area. It enables an automated restriction of the driver's movement outside a certain area. Establishment of such a geo-fence results with prevention of boat alienation; prevents the drivers to enter an area reserved for swimmers; and prevents approaching the coast in a dangerous manner. As rental owners regularly have several fast boats it is very usual to find them at the same time in the same sea area. To increase sea safety as part of such a system speed boat trajectory analysis, collision detection and prevention is required [2].

Figure 1 Speed boats popularly known as JetSki

Proposed embedded system for monitoring and tracking of speed boats is based on the Atmel AVR family of processors [3], Analog Devices ADXL343 3-axis Digital Accelerometer [4], and SIMCOM SIM908 GSM and GPS system [5]. The same system is used for monitoring and tracking of road vehicles in [7] and is for this application upgraded with a waterproof housing, geo-fence functionality and real time software abilities.

The developed boot-loader software allows remote modification of the embedded computer main program using the Hyper Text Terminal Protocol and GPRS communication network [6, 7]. Main program is based and developed on the assumption that a permanent GPRS state-full TCP/IP connection to the server is available. The purpose of the server is to analyse the GPS and speed data received from the embedded system and to store it in a database for additional off-line analysis. Developed TCP/IP server is a socket daemon which enables multiple concurrent connections, collision detection between boats and message relaying for real time remote boat control. Remote speed boat control is enabled in the form of a mobile phone equipped with an appropriate application. The application connects using a permanent state-full TCP/IP connection to the socket server which relays commands to the boat if necessary. It has the ability to turn the speed boat's engine off and warn the driver of his dangerous actions or a possible collision situation.

In order to maintain demanded level of safety of sea traffic, and the fact that speed boats are rented mostly to amateur drivers without driving licenses, the law for companies engaged in the rental of speed boats (Jetski) requires remote control. In this way companies' experienced employees can oversee inexperienced drivers from a shore base and remotely stop them if necessary. At the present day there are many accessories on the market available for speed boat rental. They are mostly based on a simple remote control technology using analogue or digital radio waves with a limited range of a transmitting. But on the market available systems do not even remotely met the needs of companies in the speed boat rental business. There is a need for a device with more technological advancement that includes features like: automated control over boats speed outside a defined geological area and in the vicinity of the coast line, safety systems to prevent boat theft, collision detection and prevention capable of monitoring multiple speed boats rented in the same geological area, automated generation of financial reports of rented speed boats, etc.

2 JETSKI RENTAL BUSINESS REQUIREMENTS

To identify the needs of Jestski rental businesses, an analysis among the related companies has been done. Results of the analysis revile that there exist the need for supervision of the current speed boat's position and driver behaviour because, as mentioned, drivers are mostly inexperienced amateurs. The required advancement of systems available in this area is to enable remote control on larger distances. Remote devices with a transmitting distance limitation of a few hundred meters aren't suitable for this application. Possible alienation and grand theft presents a significant risk and concern for the boat owners. Additional automation in monitoring of inexperienced drivers is required as current technology has a significant disadvantage: monitoring a driver that is located over 500 meters away from the coast with binoculars requires very good skills and focus for the employees. As these rental companies have more than one speed boat on one location, the monitoring gets more and more challenging.

A few employees to supervise this very dynamic situation aren't enough anymore. The employees have to pay attention if someone is driving to close to the coast or to the beaches reserved for swimmers since both is prohibited by law. Additionally, employees have to monitor if someone is driving too far away into the open see since this could end in boat theft. And when there are two or more boats in the water at the same time, the possibility of collisions and driver injures increases significantly. Boat theft and alienation isn't possible only during the day while the boats are rented. It is also possible during the night when the boats are left unprotected in the sea or at the coast. This presents an additional expense for other employees like security guards so an overnight automated security system is required.

Automated supervising of the employees' financial (generated revenue) reports is a main interest for these rental companies so it is also required. Current technology limits the owners of the companies to rely on the honesty of their employees and earning reports written manually by employees on site. Proposed GNSS based device can fulfil almost every task found by this case study:

- Remote control of the boat's engine remotely by an experienced user on the coast;
- Automated control over the boat's speed outside the geo-fence and near the coast line;
- Automated or manual control to prevent boat theft;
- Automated collision detection and prevention for all currently rented speed boats;

- Automated generation of financial reports for employees supervision;
- Overnight automated security to prevent boat alienation.

This advanced surveillance application requires the current speed boat's geo position and enables automated restriction of driver's speed and movement outside a certain geological area usually called geo-fence. Establishment of a geo-fence result with prevention of boat alienation prevents the drivers to enter an area reserved for swimmers and approaching to the coast in a dangerous manner. As rental owners regularly have several speed boats it is very usual to find them at the same time in the same sea area. To increase sea safety speed boat trajectory analysis, collision detection and prevention is required also.

Additionally, by logging all geo-position data new analysis opportunities arise. For example, such data can be used later for generation of many reports or for any online real time calculation. Such real time calculations can be used to take the control over a speed boat in case of possible wrong driving actions. Furthermore, collision detection and prevention or prevention of driving to close to the shore can also be implemented. Report generation could be used for later creation of income reports like the one in Figure 2.

	Ime	start	stop	Vrijeme	Min	Br Osoba	Cijena
1	JET1	11.07.2012. 14:58:57	15:12:35	00:13:38	15	N/A	250.00
2	JET1	11.07.2012. 15:47:48	16:02:24	00:14:36	15	N/A	250.00
3	JET1	11.07.2012. 16:07:03	16:19:19	00:12:16	10	N/A	200.00
4	JET1	11.07.2012. 16:24:01	16:25:01	00:01:00	free	N/A	0.00
5	JET1	11.07.2012. 16:28:16	16:41:53	00:13:37	15	N/A	250.00
6	JET1	11.07.2012. 16:46:28	16:48:59	00:02:31	free	N/A	0.00
7	JET1	11.07.2012. 16:56:21	17:11:37	00:15:16	15	N/A	250.00
8	JET1	12.07.2012. 10:43:32	10:59:19	00:15:47	15	N/A	250.00
9	JET1	12.07.2012. 12:31:23	12:43:14	00:11:51	10	N/A	200.00
10	JET1	12.07.2012. 14:28:04	14:43:15	00:15:11	15	N/A	250.00
11	JET1	12.07.2012. 15:18:40	16:31:48	01:13:08	60	N/A	780.00
12	Ukupno:			03:08:51	170	0	2.680,00 kn

Figure 2 Automated generation of financial report

Source: Made by authors according to [8]

3 BOAT TRACKING SYSTEM ARCHITECTURE

Rapid development of embedded computers that are aware of their position, speed, acceleration and movement direction made it possible to execute required tasks and further increase sea traffic safety. Safety is increased by the automated supervision of driver's actions. The automated supervision can be implemented simple as just a geo-fence control or more complex like a collision detection system. Complete block diagram of the proposed system architecture is presented in Figure 3.

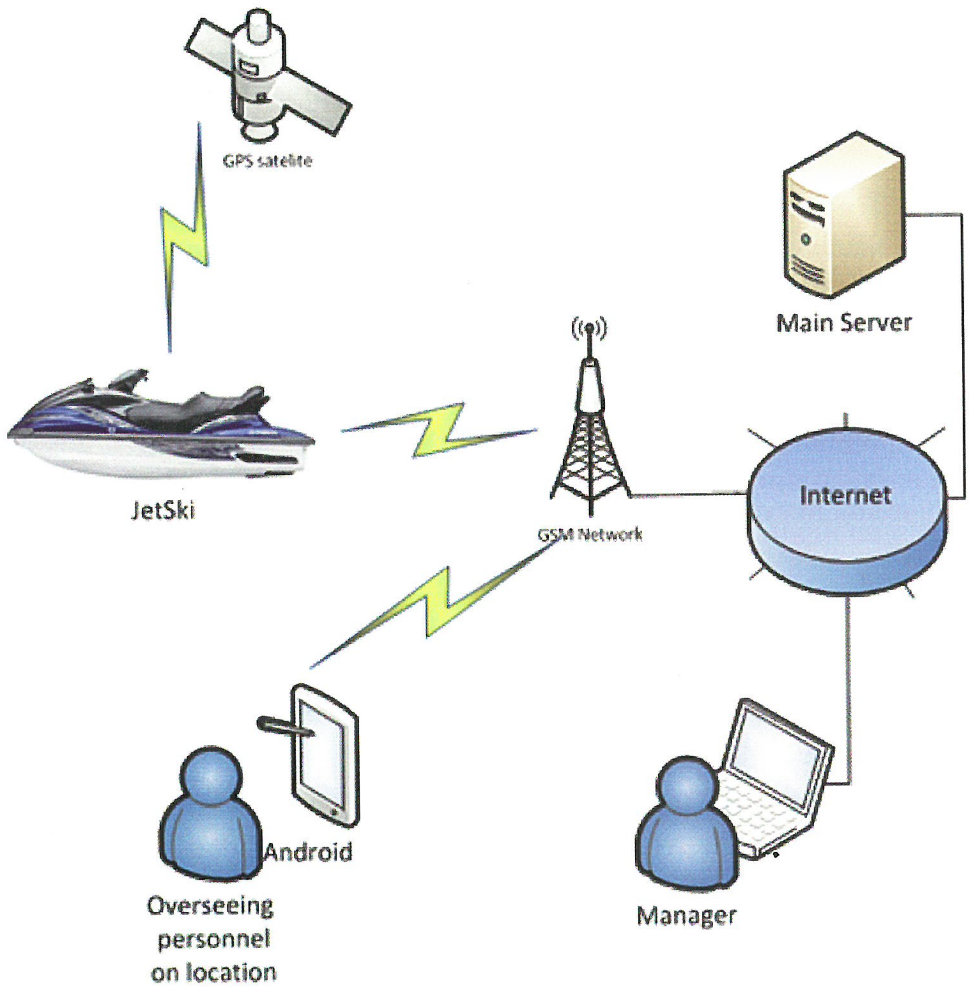


Figure 3 Block diagram of tracking system architecture

A GNSS capable device installed in the boat, with the knowledge of the boat's geological position and connected to the main server over a GPRS TCP/Ip statefull connection, can be used to report its position periodically to a central server and to perform server's or owner's commands. Saved geo-position data can be used for later creation of reports, studying of the boat's dynamics and analysis of the driver's behaviour. Additional remote device like a Smartphone with an appropriate application (Figure 4a) is required by the employee so he can read various reports and issue commands to the boats using the main server. The commands can be issued whenever the device in the speed boat is online. There are also some special requirements on the device enclosure and housing for device instalment inside of the speed boat and the interconnection to it. The device should be installed in a plug and play manner with a simple plug into the fabric formwork of the boat. Additionally, the device has to withstand high temperature, mechanical shocks, humidity and salty air as well as contact with sea water.

The system used for monitoring and tracking of road vehicles described in [7] is modified for this application and upgraded with a waterproof housing. Its remote software upgrade ability over GPRS network is required for rapid software changes and development of a main programme capable of fulfilling tasks found in the Jetski rental business requirements case study. This ability helped the authors to develop and test the proposed system on real world locations during the summer touristic season time while the speed boats were rented. Developed GNSS device is presented in Figure 4b and Figure 4c.

Geo-position calculation and analyses are done partly on the embedded system for geo-fence and sent to the server. Received GNSS data include course and speed data. They are stored in a database for deeper analyses on the server. The data can be also compared to the data received from other boats' embedded systems. Stored data in the database could be used for additional off-line analysis and report generating. But the real time analysis of the data is crucial for collision prevention and other automated tasks.

Developed TCP/IP server is a Linux's based socket daemon which enables multiple concurrent connections, simplified collision detection and message relaying for real time boat remote control. Remote speed boat control is enabled in the form of a Smartphone equipped with an application that connects over a permanent state-full TCP/IP connection to the socket server which relays commands to the boat if necessary. It has the ability to turn the speed boat's engine off, limit its speed and warn the driver of his dangerous actions or a possible collision situation. It can also put the embedded system in a security mode or a night mode to prevent theft of speed boats during off duty periods. Overnight security mode is used in two modes while the boat is in the sea, or

a) b) c)

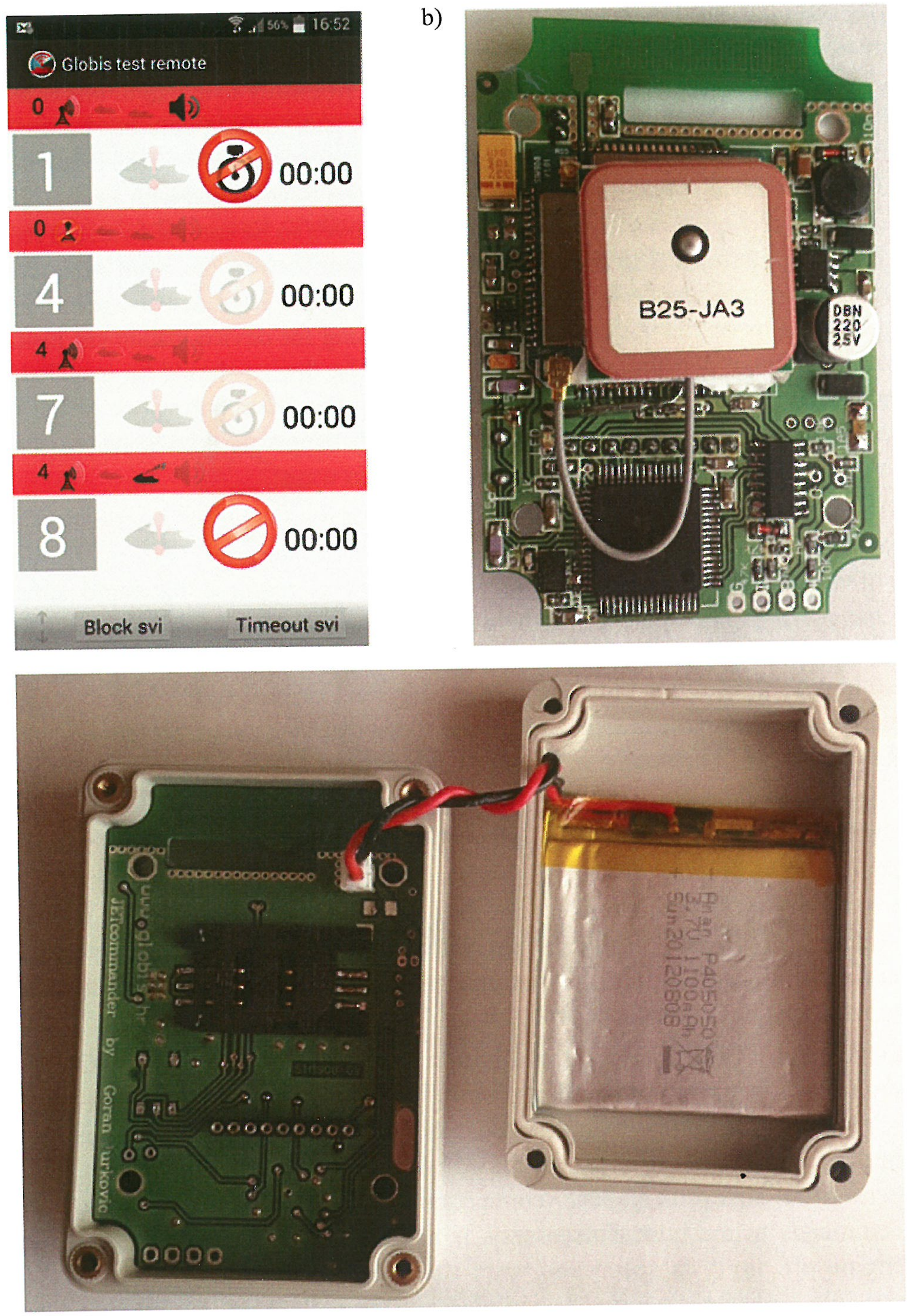


Figure 4 a) Android Application for employer's control over the speed boats; b) GNSS capable device assembled printed circuit board; c) GNSS capable device in waterproof enclosure.

storage on the coast. In the first mode the GPS location of the speed boat is used for detecting movement in situations while the speed boat is left in the sea overnight, but this method consumes more battery. The second mode is used when the speed boat is left on the cost. More advanced movement detection is done by using the built in 3-axis Digital Accelerometer that monitors any movement or shaking of the speed boat.

4 COLLISION DETECTION AND PREVENTION

To increase sea safety, speed boat collision detection and prevention was implemented also. Collision detection is performed using a virtual circle approach. In this case the virtual circle denotes an area around the speed boat that can be reached in a certain amount of time. The virtual circle around the speed boat has a variable radius calculated using the current boat speed (Figure 5). Safe distance between two objects must be more than twice the size of the object's possible travel distance obtained using its current speed.

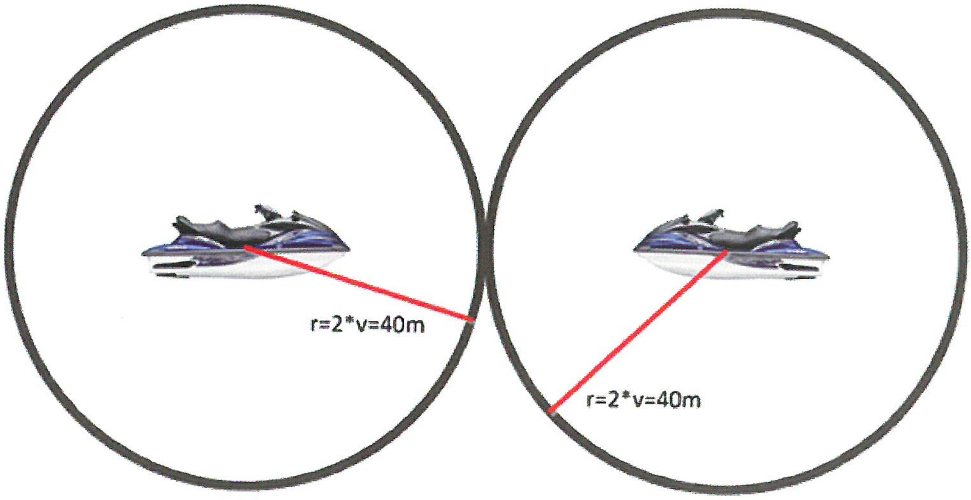


Figure 5 Simple collision detection method based on a virtual circle around the speed boat.

4.1 High speed boats and their dynamics

JetSki boats are popular because of its high speed and good driving dynamics. All other sea vessels have a slower driving dynamic like the ability of high acceleration and fast changing of trajectories. A standard JetSki can reach its maximum speed of over 20 meters per second (around 70 kilometres per hour) in a few seconds. The top speed of some models of speed boats can be up to 40 meters per second (around 140 kilometres per hour). Traveling course can be changed in less than a second, without losing any speed when changing its traveling course by a very big angle. These driving dynamics facts make the collision detection and prevention a challenging task. For example, recorded speed boat top speed and trajectory are presented in Figure 6.

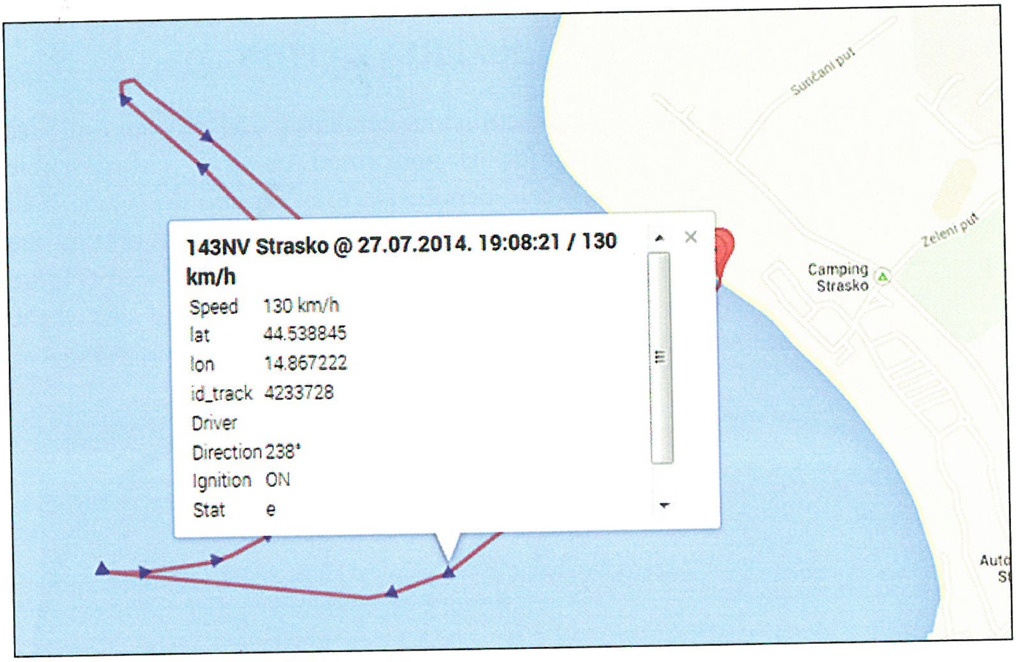


Figure 6 Top speed achieved and logged on a real location

Source: Made by authors based on [8]

4.2 Data Interchange

As this is a centralised system where all the collision calculations are done at the central socket server, safety radius of the collision free area has to be large enough because of the data interchange delay. The embedded system's algorithm is written to collect the GPS data, and sends it to the main Linux server over a GPRS connection and the Internet once every second. After socket server daemon receives current GPS data (location, speed and course), it compares this location with all the speed boats in the database that are near to the current boat's location within a thousand meters and makes the calculations. If a particular speed boat is entering the virtual circle of another boat, server responds to the embedded system inside the boat to reduce the boat speed.

The standard GPRS connection class 10 uses 60Kbps for download and 40Kbps for upload, but it switches automatically to 80/20 mode in a case of transmission of larger files. Local connection between the microcontroller and GPRS module is a constant 64KBps connection for upload and download. Data that are sent over GPRS are small data packages and the limits in the transmission speed aren't the issue. Increased number of mobile phones connected to GSM towers in one area congests the network and decreases GPRS throughput and data propagation. This could be a possible issue and further increase delays in received and sent data. Small delay is crucial for online collision calculations.

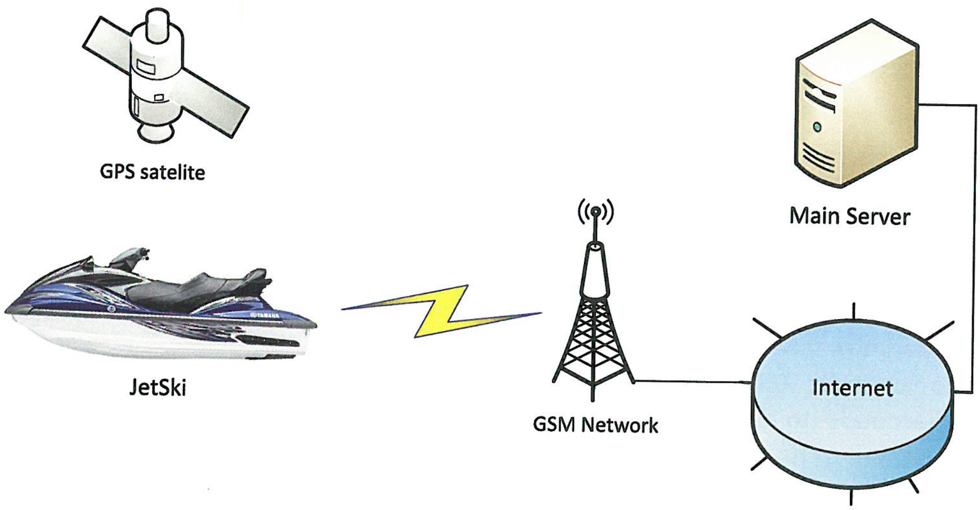
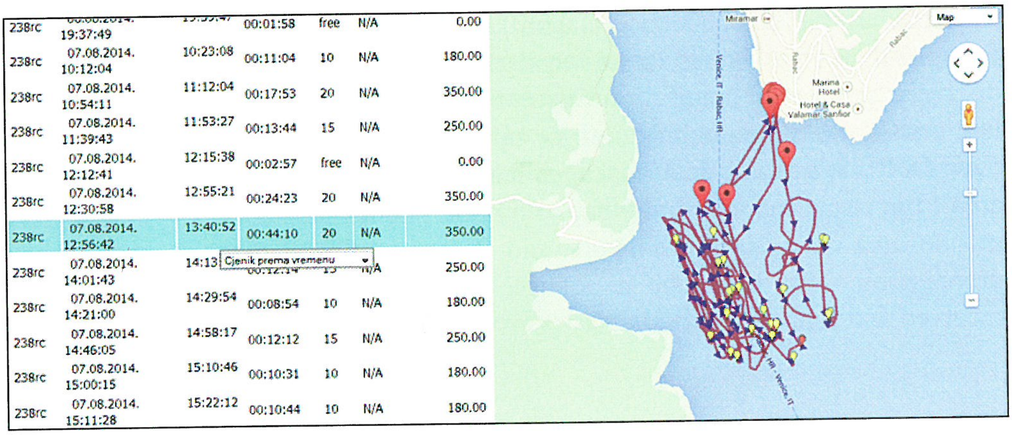


Figure 7 Block diagram of the proposed tracking system architecture

5 EXPERIMENTAL RESULTS

5.1 Vessel Tracking

By logging all geo-position data in server's database, reports could be generated afterwards for speed boat tracking and rental income analysis. Rate of data sending and recording was based on the speed boat's course change limited to a certain number of points in a minute. This approach generated enough data for basic tracking and generation of various reports. For collision detection, the data collection rate was higher (to one sample per second). Because of GPRS data traffic cost, collision detection was only enabled on a few boats for a small period of time in order to test the collision detection.



238rc	[illegible] 19:37:49	[illegible]	00:01:58	free	N/A	0.00
238rc	07.08.2014. 10:12:04	10:23:08	00:11:04	10	N/A	180.00
238rc	07.08.2014. 10:54:11	11:12:04	00:17:53	20	N/A	350.00
238rc	07.08.2014. 11:39:43	11:53:27	00:13:44	15	N/A	250.00
238rc	07.08.2014. 12:12:41	12:15:38	00:02:57	free	N/A	0.00
238rc	07.08.2014. 12:30:58	12:55:21	00:24:23	20	N/A	350.00
238rc	07.08.2014. 12:56:42	13:40:52	00:44:10	20	N/A	350.00
238rc	07.08.2014. 14:01:43	14:13 Cjenik prema vremenu	00:12:14	15	N/A	250.00
238rc	07.08.2014. 14:21:00	14:29:54	00:08:54	10	N/A	180.00
238rc	07.08.2014. 14:46:05	14:58:17	00:12:12	15	N/A	250.00
238rc	07.08.2014. 15:00:15	15:10:46	00:10:31	10	N/A	180.00
238rc	07.08.2014. 15:11:28	15:22:12	00:10:44	10	N/A	180.00

Figure 8 Generated income report with one driver's session trajectory generated from logged data on one real location.

Source: Made by authors based on [8]

5.2 Safety Area Estimation

In the touristic season, number of mobile phones on the beach increases significantly causing GPRS traffic and network congestion. Data propagation time through the GPRS and Internet connection increases from a few milliseconds to 2 seconds. So, unexpected delays in data acquiring and responding to it with an appropriate command are created. GPS data sample was acquired every second, but with a few seconds of communication network propagation. With such a delay collision prevention could not be established.

In real world field testing with two boats rushing to each other on almost top speed, the engine was stopped one second too late. The moment of engine shut down was the moment when the boats virtual circles began to overlap. Communication delay is a crucial factor here. So this centralised collision detection and prevention could be usable only with a two or three time larger radius of the virtual circle around the boat. In that case the boat is unusable, as the speed boat driving area is not big enough and it's impossible to drive two boats at that distance with one home location on the beach. Collision detection must be implemented as a decentralised system, with direct communication in-between boats over a radio signal network independent from the GSM network and a GPRS connection.

6 CONCLUSION AND FUTURE WORK

For a usable collision detection and prevention, speed boats must be equipped with some kind of boat to boat radio communication. It can be over a small distance and it can be with a smaller data transmission rate. The handshake and recognition procedure of the other parties in the communication must be fast. With such a type of communication every boat would reveal its current position, speed and course to other parties over a radio-communication network in a smaller circle like three hundred meters. Every boat's embedded system would receive and save data from nearby boats and calculate the collision possibility using all this data. In this way it would be a decentralized system for collision detection and prevention. Since, every boat would reveal its position to nearby boats; every boat would have data for its own local collision detection.

The calculations related to collision detection have to be done locally on an embedded system inside the boat. Only so the calculations can be done fast enough. Further advancement in collision detection and prevention would be in more advanced calculations that would take into consideration the current boat's course and speed. With a motion model it would be possible to predict the boat's future position, and to calculate the possibility of collision using the predicted data. More advanced collision detection and calculation can include the situation if the boat is moved from centre of the circle in the opposite way of the moving direction (Figure 9).

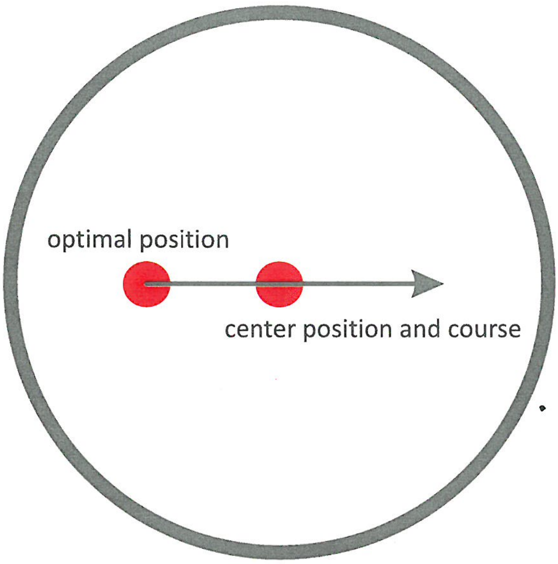


Figure 9 Moving vessel from centre position of virtual circle used for calculating collision.

Speed boats are very agile and dynamic. They change its course of movement with small speed drops and accelerate from low speed to top speed in just a few seconds. When the speed boat is changing its direction, the speed drop is proportional to the direction changed. For this reason is the boat moved from the centre of virtual circle to obtain more reliable collision detection. More complex collision detection calculations would enable boats to drive in parallel in the same direction, or to drive in opposite directions without an intervention of the collision prevention system to slow the boats down. So this type of collision detection is a good starting point for future work and analyses.

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REFERENCES

[1] Baris Simsek, Fatma Pakdil, Berna Dengiz, Murat Caner Testik, Driver performance appraisal using GPS terminal measurements: A conceptual framework, Transportation Research Part C, 26, pp. 49-60, 2013.

[2] Imad Jawhar, Nader Mohamed, Liren Zhang, Inter-Vehicular Communication Systems, Protocols and Middleware, 2010 Fifth IEEE International Conference on Networking, Architecture, and Storage, 2010, pp. 282-287, 2010., DOI 10.1109/NAS.2010.49

[3] Atmel mega AVR Microcontrollers http://www.atmel.com/products/microcontrollers/avr/megaavr.aspx Accessed: 13.05.2014.

[4] Analog Devices 3-axis Digital Accelerometer. Available at: http://www.analog.com/en/products/mems/mems-accelerometers/adxl343.html Accessed: 13.05.2014.

[5] SIMCom Wireless Solutions Co., Ltd SIM908 http://wm.sim.com/producten.aspx?id=1024 Accessed: 13.05.2014.

[6] Goran Jurković, Dynamic Software Update in Embedded Systems, Master Thesis, Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb, 2011.

[7] Goran Jurković, Vlado Sruk, Remote Firmware Update for Constrained Embedded Systems, MIPRO – path to knowledge and innovations – Rijeka: Croatian Society for Information and Communication Technology, Electronics and Microelectronics – MIPRO, 2014. pp. 1253-1257 (ISBN: 978-953-233-078-6)

[8] GLOBIS Global Commander. Available at: http://www.globis.hr/gcom/ Accessed: 13.05.2014.