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INFORMATION SYSTEM FOR THE CENTRALIZED DISPLAY OF THE TRANSPORT COMFORT INFORMATION*

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Abstract. *This paper introduces the information system for presenting road comfort map. The map is generated based on the conducted transportations. As a basis for the information system and the source of the comfort information, developed Android application is used. It calculates comfort parameters using three-axis accelerometer values. The calculated data are recorded into the files in the proper format. Recorded files are uploaded on the information system to be viewed and analyzed. As a final result of all recorded transportations, it is possible to generate a map of roads comfort. The paper presents the current functionality of the system and the current roads comfort map of covered roads in Serbia. Based on the collected data about 50% of transportation intervals were comfortable, 44% was moderately uncomfortable, and 6% was uncomfortable.*

Key words: *Android, Transport comfort, GIS, Comfort map*

1. INTRODUCTION

The term transport comfort cannot be strictly defined, but it is of great importance in the assessment of transport quality. The problem is the subjective comfort feeling which is different for every person. Comfort depends on many factors like acceleration (vibration), noise, temperature, compartment space, etc. If only mechanical effects are of interest, then generally the acceleration and vibration that passengers feel during the ride have the greatest impact on passenger comfort. Vibrations are caused by three factors: vehicle condition, driver skills (driving style), and road condition. As for vehicle condition factors, suspension system and tires are most important vehicles parts that affects on vibration. Nowadays, some vehicles suspension systems have active suspension control for better

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comfort and vehicle stability. Driver skills and driving style are also important. At the same road and with the same vehicle, two different drivers could provide different comfort for their passengers. Sharp turning, sudden braking, and accelerating are usually marked as uncomfortable actions. Road conditions are probably the most important for the passenger's comfort and safety. They can be categorized as static and dynamic factors. Static factors are commonly associated with a location, like road bumps and potholes. Dynamics factors appear suddenly, like rain, snow, or landslides. Also, the impact of other traffic participants is significant dynamic factor.

On the basis of the above facts it is evident that many factors affect the comfort. It is very important to achieve as comfortable transportation as possible. Uncomfortable transportation affects the mental and physical conditions of even healthy passengers. The impact on passengers with the health problems is even greater since uncomfortable driving could impair their medical condition.

Due to the discomfort location, as one of the most important information for assessing the comfort of transport, the usage of Geographic Information Systems (GIS) is of great importance. Nowadays, there are several commonly used GIS systems, e.g. OpenLayers, ArcGIS, OpenStreetMaps, Geomedia, and GoogleMaps. Usability and the possibility of integration into other application increase their popularity. The aforementioned GIS systems are under constant development and new functionalities are implemented almost every day. Its interactivity with the users in real time provides an increasing amount of information. The dynamics of development and user interaction information can be seen in the example of latest GoogleMaps GIS novelty. The route from point A to the point B is colored according to the traffic jams detected on presented location. Information for appropriate road color marking is gathered from numerous users of Google Maps navigation.

As a basis for generating road maps of comfort, which are presented in this paper, features of GoogleMaps GIS are used. The aim of the information system presented in this paper is to generate road comfort maps according to the information gathered from the users of the client Android application. Client Android application calculate comfort parameters based on the accelerometer and GPS data.

The paper is organized as follows. Related work is presented. Android application functionalities and implemented calculations for transport comfort are demonstrated. After that, functionalities and usage of the developed Web-based information system are demonstrated. At the end, overall information gathered by developed information system is presented.

2. RELATED WORK

In 1972, the International Organization for Standardization (ISO) issued a standard: "A Guide to the Evaluation of Human Exposure to Whole-Body Vibration" [2] which is still in general use. It is used for the evaluation of working conditions and exposure to the vibrations. The effect of vibration on health, at work, sitting, and other life situations is described in the paper [3]. Higher vibration exposure has negative health effects. For vehicles, transport comfort is most affected by tires, suspension, shock absorbers, seats, etc. The suspension system impact on the passenger's comfort on various types of roads is presented in papers [4-6]. It is presented that suspension system has great positive effects on comfort but can't eliminate it. Besides vibrations, the noise produced by tires may also affect passenger's acoustic comfort as presented in [7].

Gathering information from nodes to centralized unit is the trend nowadays. Wireless sensor networks allow data collection and centralized processing, like in paper [8]. Sometimes it is called swarm intelligence [9].

The role of smartphones is increasing in this area of research. The reason lies in the fact that smartphones equipped with sensors such as accelerometer, gyroscope, and GPS are increasing their processing capabilities for better performances. Some phones have processing power almost as classic computers. The paper [10] presented a system based on mobile phones to detect potholes on the roads. The phones were placed in taxi vehicles and recorded the locations of detected discomfort. For detection, only vertical (Z-axis) was used. In the paper [11] smartphones are used to monitor conditions during transport. Potholes, bumps, and siren sounds are detected.

Comfort calculations are usually based on the accelerometer signals processing. Accelerometer detects dynamic movements and is also affected by the static gravity influence. For appropriate dynamic calculations, it is necessary to eliminate the static gravity influence from accelerometer signal values. This is usually done by some signal filter implementation. The authors of [12, 14] developed the automotive real-time observers and attitude estimation system, based on an extended Kalman filter (EKF). The authors of [15] used high-pass filter for the road potholes detection.

Vibration duration exposure and interaxial influence need to be addressed. In [16] authors didn't observe any statistically significant differences in discomfort between the 10, 15 or 20-second vibration exposure. In [17] authors showed that single axis vertical vibrations were typically associated with the less discomfort than multi-axis vibrations. Also, different sensitivity for different axes is detected, for similar ranges of vibration. According to these, the data from all axes need to be collected for appropriate comfort level classification. Although the vertical axis is the most influential, the others cannot be ignored.

Artificial intelligence usage is increasing in this field of research. In [18] neural network was used in order to analyze the quality of public transport. In [19] Bayesian network was used for recognizing the mode of transport. For artificial intelligence implementation it is necessary to collect a lot of data for its training.

Work presented in this paper is based on the Android applications, which development and use are presented in the paper [20]. Measurement of comfort is realized by using values obtained from the triaxial accelerometer that helps determining the level of passenger comfort. In addition to the accelerometer, GPS is used for discomfort location detection. Accelerometer signals are passed through High pass filter for the static gravity influence elimination. It is set up to cut off 10% of low frequency signals. Decision time intervals is set to 10s, and all three axes are used for comfort level classification. Developed information system will be used to collect large number of information that could be used for artificial intelligence implementation in the future work.

3. INFORMATION SYSTEM ARCHITECTURE

Developed information system is realized in form of a client-server system. Client part is realized as an Android application which measures comfort parameters during transportation. Server part is realized in form of Java web application with Google Maps support for data presentation. Block diagram of the developed client-server information system usage is presented in Fig. 1.



Fig. 1 Blog diagram of the developed information system usage

As presented, information gathered from all client users are stored into one database (in server part of client-server system), which allows transportation and road comfort analysis. With longer information system usage collected information will be of more significance and more detailed analyses could be performed. Since smartphones are widely used nowadays, there is a large number of potential users for the developed information system.

4. ANDROID APPLICATION – CLIENT APPLICATION

Android application is based on three-axis accelerometer data calculations in the standard ten seconds time interval. The development of the main application functionalities was presented in [20] using RxJava [21] for accelerometer calculations, GPS monitoring, and main application thread. To classify transport comfort, it was necessary to determine the comfort levels.

4.1. Comfort levels

ISO standard [2] is in general use for the comfort level determination. It assumes that acceleration magnitude, frequency spectrum, and duration represent the principal exposure variables, which account for the potentially harmful effects. At the national level (Serbia), there is standard ICS 13.160 (SRPS ISO 2631-1:2014 Mechanical vibration and shock: Evaluation of human exposure to whole-body vibration, Part 1: General requirements) which is translated version of ISO standard [2]. In [2-3], authors have shown that the sensitivity of the human body at different frequencies depends on the intensity of acceleration. The

effective value of the acceleration (a_{RMS}) for a discrete system is calculated according to the equation (1):

$$a_{zRMS} = \sqrt{\frac{1}{n}(a_{z1}^2 + a_{z2}^2 + \dots + a_{zn}^2)} \quad (1)$$

where a_{zi} is the i^{th} Z-axis acceleration (vertical axis) and $n=200$ is a number of samples. For real Android application usage accelerometer sampling is performed 20 times per second and decision interval is set to 10s. According to [2] comfort levels are defined and presented in Table 1. Only vertical axes are used for comfort level classification.

Table 1 Comfort levels according to ISO standard 2631-1 [2]

$a_{RMS} [m/s^2]$	Comfort level
0-0.315	not uncomfortable
0.315-0.63	a little uncomfortable
0.5-1	fairly uncomfortable
0.8-1.6	uncomfortable
1.6-2.5	very uncomfortable
> 2	extremely uncomfortable

In developed Android application, all axes aRMS values are used for the comfort level classification. Three comfort levels are chosen and defined in a way presented in Table 2.

Table 2 Used comfort levels in the developed Android application

$a_{RMS} [m/s^2]$	Comfort level
0-0.315	comfortable
0.315-1	little uncomfortable
> 1	uncomfortable

By comparing Table 1 and Table 2 it can be seen that first comfort level (comfortable) from Table 2 is the same as the first comfort level (not uncomfortable) from Table 1. Little and fairly uncomfortable levels from Table 1 are merged to one level (little uncomfortable) in Table 2. Also, very and extremely uncomfortable levels from Table 1 are merged to one level (uncomfortable) in Table 2.

4.2. All implemented calculations

The Android application is designed to calculate parameters in standard time intervals. Accumulated vibrations are calculated according to equation (1). This calculation is performed for all three axes (RMS_X, RMS_Y, and RMS_Z). Besides these values, for every acceleration sample, the application calculates the magnitude of all three-axis accelerations (2).

$$a_{iRMS} = \sqrt{a_{xi}^2 + a_{yi}^2 + a_{zi}^2} \quad (2)$$

where a_{xi} , a_{yi} , a_{zi} are X-, Y-, and Z-axis acceleration in the i -th sample, and a_{iRMS} is the magnitude of all three-axis accelerations. According to these, a_{RMS} for the decision time interval is calculated according to equation (3).

$$a_{RMS} = \sqrt{\frac{1}{n} * (a_{1RMS}^2 + a_{2RMS}^2 + \dots + a_{nRMS}^2)} \quad (3)$$

where a_{iRMS} is the i^{th} magnitude of all three-axis accelerations, and n is the number of samples.

For the most uncomfortable sample, maximum magnitude values (APEAK) and their three-axis values (APEAK_X, APEAK_Y, and APEAK_Z) are calculated. For detected APEAK the GPS data (latitude, longitude, speed, and time) are stored. Beside these, all three-axis maximum accelerations (MAX_X, MAX_Y, and MAX_Z) are calculated. As a result of the decision time interval calculations, the following values are saved:

- IDT: location marker ID
- RMS_X: X-axis calculation according to equation (1)
- RMS_Y: Y-axis calculation according to equation (1)
- RMS_Z: Z-axis calculation according to equation (1)
- ARMS: acceleration magnitude according to equation (3)
- APEAK: acceleration magnitude maximum value in the values calculated by equation (2)
- APEAK_X: X-axis acceleration value in APEAK
- APEAK_Y: Y-axis acceleration value in APEAK
- APEAK_Z: Z-axis acceleration value in APEAK
- LATITUDE: GPS data for APEAK
- LONGITUDE: GPS data for APEAK
- TIME: GPS data for APEAK
- SPEED: GPS data for APEAK
- MAX_X: X-axis real value where absolute maximum X-axis value is detected
- MAX_Y: Y-axis real value where absolute maximum Y-axis value is detected
- MAX_Z: Z-axis real value where absolute maximum Z-axis value is detected
- COMFORT: (0=comfortable; 1=a little uncomfortable; 2=uncomfortable)

4.3. File formats

Developed Android application on a used mobile device saves the final result in files. Measurement data are located in the file name separated by the symbols "--" (two hyphens). These are: the time when the measurement is taken, title and description of the measurement, a unique user ID, and measurement ID. Below is the example of the file name format.

```
// format
date--title--description--userID—measurementID.txt

// example
2016-04-02-09-02-52--transport—mladenovac to belgrade--13--183.txt
```

The data that need to be stored in the database are also separated with "--" symbols. Each file row data presents calculated data for one decision interval. File row data order needs to be the same as the column order in a database for a successful insert. As a row

delimiter, symbol ";" is used. Below is the example of file row data format and a sample data row.

```
// format
measurementID -- userID --rmsX--rmsY---rmsZ--aRms--aPeakX--aPeakY--
aPeakZ--aPeak--latitude--longitude--time--speed--maxX--maxY--maxZ--
description;

// example
183--13--0.0627--0.033--0.0917--0.1159--0.4161---0.0571--0.0059--0.42--
44.4534864--20.6799459--2016-04-02-09-03-01--0--0.4161---0.2515--0.295--
merenje;
```

5. WEB APPLICATION FOR CENTRALIZED DATA PROCESSING – SERVER APPLICATION

The server part of the developed client-server information system (VibroMap) is realized as Java Web application. It is developed as multilayer application in the Model View Controller (MVC) architecture. For data presentation, the *View* part of the MVC, Java Server Pages (JSP) is used. The *Controller* part is developed using *Servlets*, while the *Model* is based on Java beans and the Data Access Object (DAO) classes for communication with the MySQL database.

Developed information system allows to its users to preview and analyze saved transportations (created by the developed client Android application) in a GIS form.

The server part of a client-server information system has two types of users, registered users and administrators. VibroMap registered user functionalities are presented by the use-case diagram shown in Fig. 2.

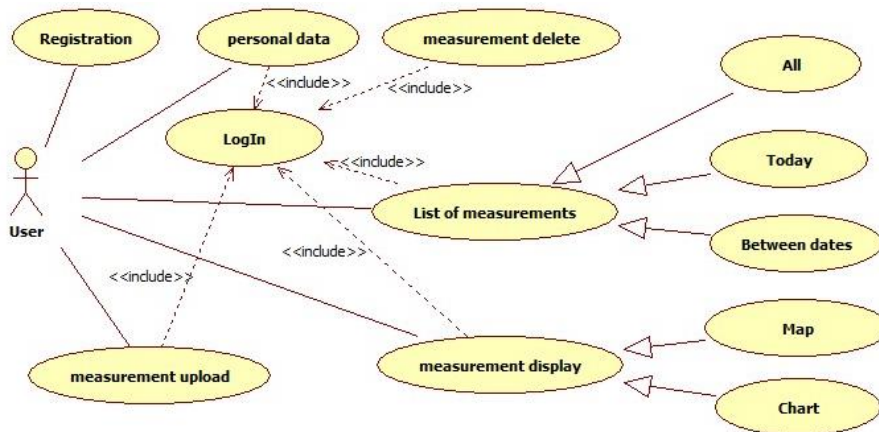


Fig. 2 The VibroMap use-case diagram

After the registration and successful login, the registered user can upload the created measurements, preview them in GIS or chart form, and also delete them. List of measurement

can be presented by date (today or dates in between). Main functionality is the *measurement upload*. The *Measurement upload* algorithm is presented in Fig. 3.

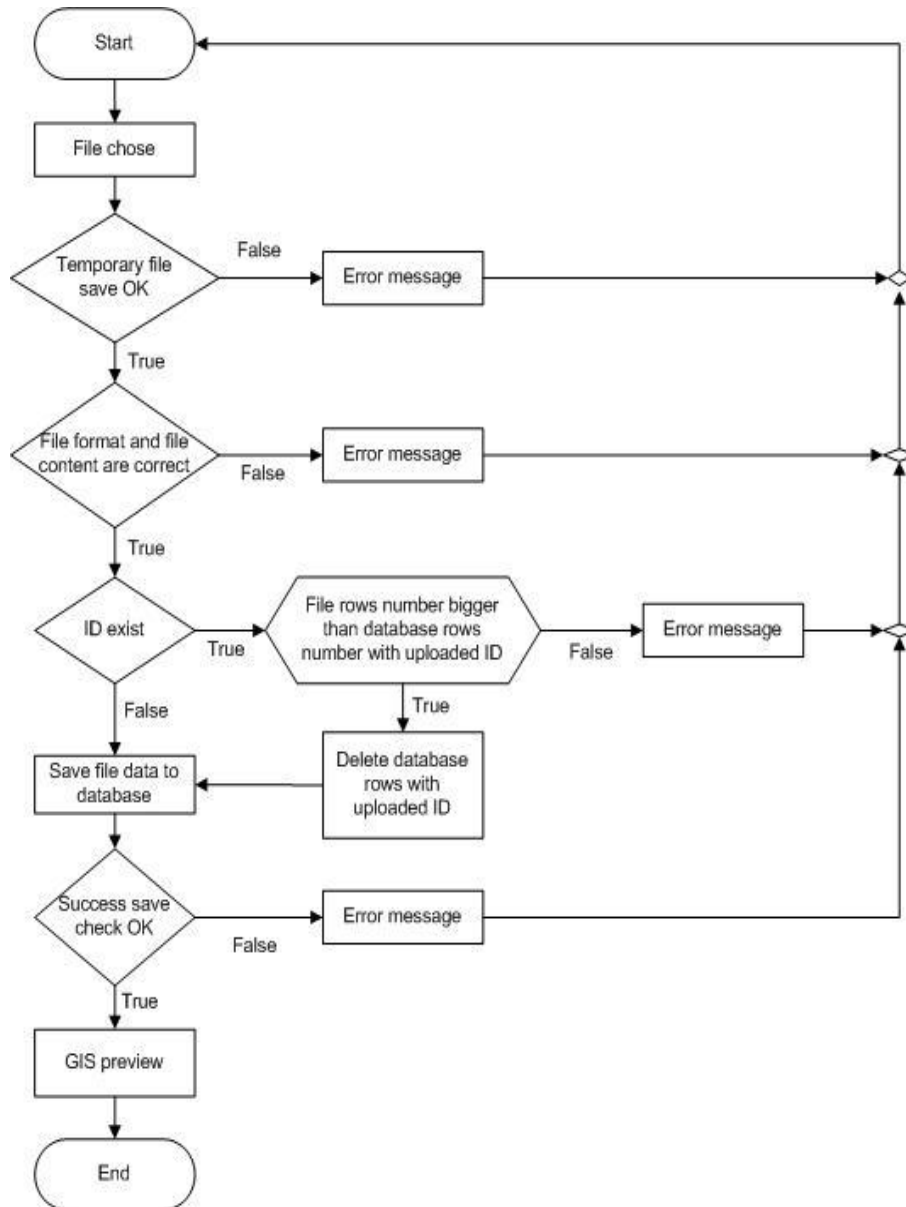


Fig. 3 The measurement upload algorithm

Successfully created files with developed Android application can be uploaded to the VibroMap by the registered users by choosing the *measurement upload* functionality. The

Choose file window will appear and the created file needs to be selected. Selected file is sent to the controller part of VibroMap to the Servlet called *ServletUploadFile*. It creates a temporary file with uploaded file and checks its name format and content format. After a successful check, an existence of the saved file's measurementID in the database is performed. If the ID doesn't exist, the file data are stored in the database. If the ID exists, then the rows numbers in the file and the database (rows with uploaded measurementIDs) are compared. If the file rows number is higher than the database rows number, then the database rows are deleted. This functionality is implemented for the future work in real time Android application data upload because the internet connectivity loss could lead to incomplete data recording to the database. After successful upload the data are presented in GIS format using Google Maps. Every file row is presented with an appropriate marker on the map. In a case of error in any of the presented validations, an appropriate error message is displayed and data upload is canceled. Copying the data from the file into the database is performed by the SQL query in the following format.

```
LOAD DATA LOCAL INFILE file_location INTO TABLE table_name FIELDS
TERMINATED BY '--' LINES TERMINATED BY ';' (column names,...);
```

File data are first stored in the temporary table. Then, depending on the marker type, data are copied to appropriate table (marker or analysis). After a successful copy, the uploaded file and the temporary data are deleted.

Beside registered users' type, VibroMap has administrator user type. It can preview data of all registered users and generate overall road comfort map which is the most important functionality presented in this paper. This functionality is realized using GoogleMaps GIS. The Google provided GoogleMaps API in June 2005 which allowed its integration into third party applications. The integration is performed by client-side scripting using JavaScript and AJAX. As default map center, latitude and longitude of the city of Čačak, Serbia, are chosen, with zoom value of 8. This location is chosen since most of the measurements are conducted in its surrounding. To take advantage of GIS, data with location parameters like latitude and longitude need to be passed to the map. These data are usually stored in a server side application database. GoogleMaps API is realized using client side language (JavaScript). The server side Java programming language functionalities are included to perform database queries. By combining server-side Java programming language and client-side JavaScript programming language, the appropriate data arrays for GIS presentation are created. Every array member is presented by one marker on the map. As additional functionality, the actions could be added to the markers by defining the appropriate marker listener using *google.maps.event.addListener* function. This enables info window preview for the marker click action. All calculated data for the clicked location are presented.

5. PRESENTATION OF THE USAGE SCENARIO OF THE DEVELOPED INFORMATION SYSTEM

With every uploaded measurement to the Web application, new data about transportation comfort are stored in the database. Road comfort map becomes more complete and more comprehensive. The presented system is in usage since December 2015. First upload was on December 7, with measurement created on relation Čačak-Užice. Until competition of this paper, 38 successful file uploads were performed. Fig. 4 presents all collected data (zoomed-out).

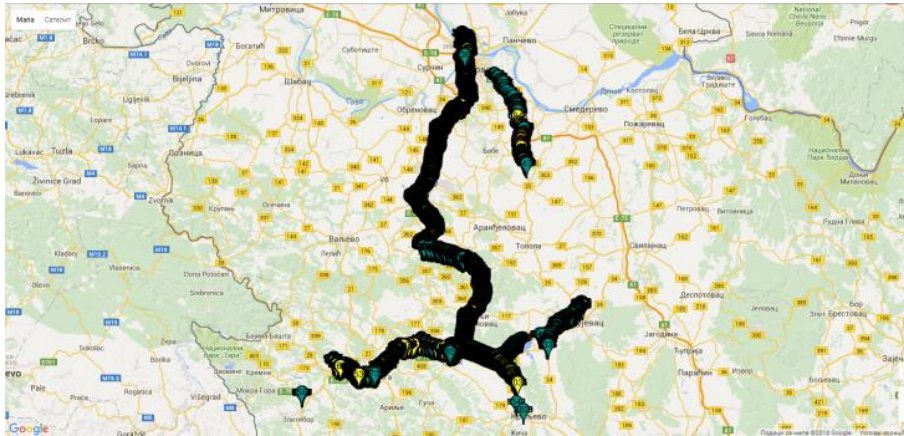


Fig. 4 The complete road comfort map (zoomed-out)

The presented information system is mostly developed on Faculty of technical sciences in Čačak. Therefore, most of the measurements were conducted from the city of Čačak, Serbia, to the other cities. At this stage, comfort map could be analyzed on several destinations: Čačak-Užice, Čačak-Beograd, Čačak-Kraljevo, Čačak-Kragujevac, and the part of Mladenovac-Beograd destination. On the zoomed-out map it is not easy to detect the comfort value (marker color) for certain location. Since the map is interactive, it could be zoomed into the desired location for a detailed preview. The road comfort map of Čačak main roads is presented in Fig. 5.

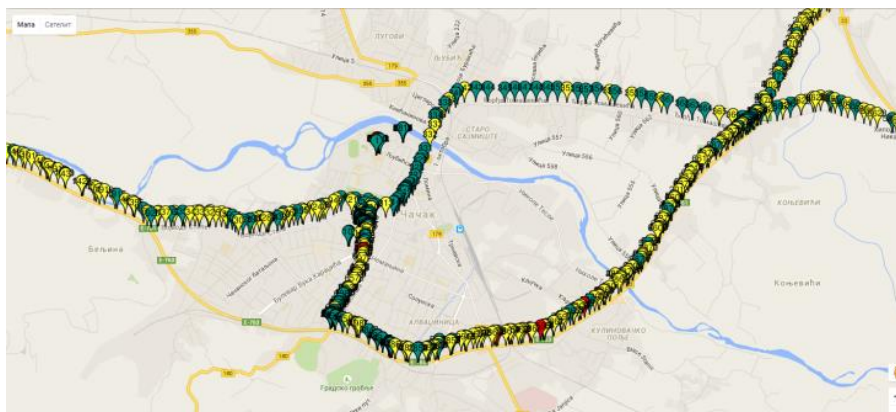


Fig. 5 The road comfort map, city of Čačak, Serbia

Since the developed Android application is most widely used for intercity relations, only the main roads are marked. The marker color presents first level of information for measured comfort level:

- green - comfortable interval,
- yellow - semi-uncomfortable interval,
- red – uncomfortable interval.

Every presented marker contains information for ten seconds driving interval around its location. Marker location is a location with highest detected discomfort value (max Apeak) in ten seconds comfort decision interval. Detailed information (second level of information) are presented by click on the desired marker in the info window form. This is shown in Fig. 6.

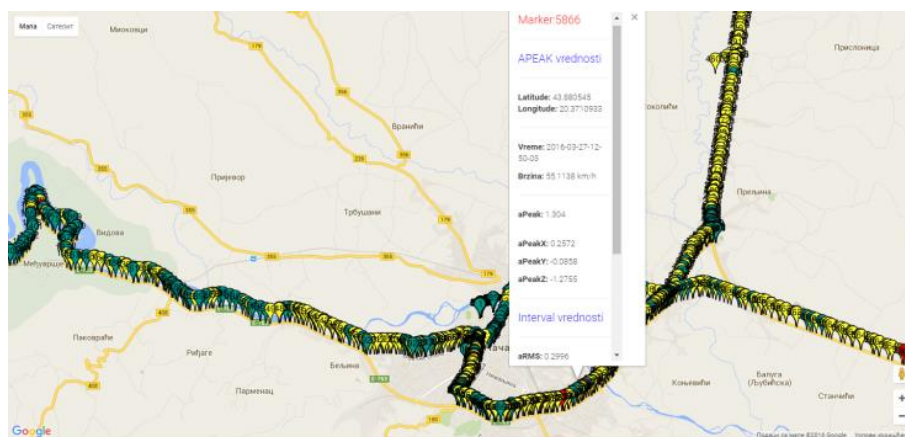


Fig. 6 The preview of all calculated data for the desired location, presented by clicking on the desired marker in the info window form

As presented in Fig. 6, besides GPS data (latitude, longitude, time, and speed) all calculated parameters over accelerometer signals are displayed. Thanks to these, it is possible to provide additional analyses about comfort, or the discomfort cause.

By increasing the number of the uploaded measurements, the map becomes more complete and provides more information. It is important to mention that some relations are measured only once while some have several conducted measurements. The Fig. 7 presents the part of the relation Čačak-Beograd which is measured three times.

By analyzing the Fig. 7, it can be seen that some locations from different measurements are marked with the different color markers, and some with the same color markers. In the case of the same color markers, every measurement detected the same comfort level. In the case of different color markers, detected comfort level from different measurements differed. There are several causes for this situation.

The first cause is the elapsed time between measurements. It is possible that a location that was comfortable in the meantime had a problem (the appearance of potholes, bumps, landslides ...) and that in the next measurement became uncomfortable. Also, it is possible that the uncomfortable location is repaired in the meantime by the road maintenance department and therefore become comfortable.

The second cause lies in the variety of vehicles that are used for the measurement. To be precise, on the same road different vehicles have different comfort levels for their

passengers according to the vehicles class and condition. In any case, the presented comfort is detected inside the vehicle.

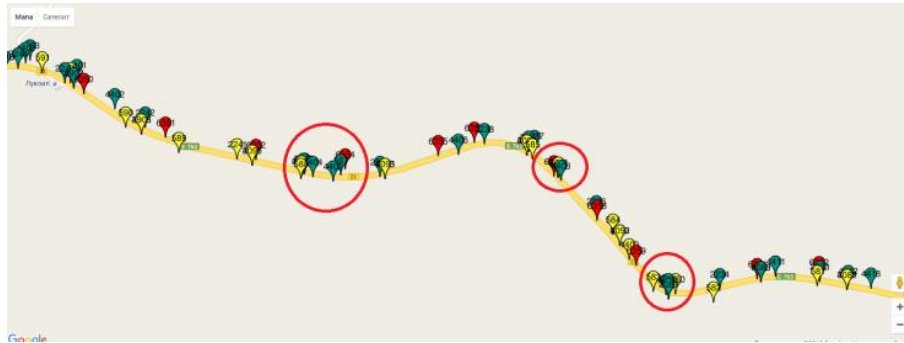


Fig. 7 The preview of the relation with multiple conducted measurements

The third cause is driver and its driving skills. Driver with more experience adjust its driving based on the road conditions. This could result with the comfortable driving even though road conditions are not satisfying. Also, the opposite scenario is possible, when the less experience driver makes sharp turning or hard braking for not being able to adapt to the road conditions.

The fourth cause lies in the influence of the other traffic participants. Their activities like overtaking or braking could result with lower comfort level.

Based on all measurements performed so far it is possible to analyze the transportation comfort statistics. The statistics for all 38 performed measurements are shown in Table 3.

Table 3 The statistic of performed measurements

Title	Value (%)
Number of measurements	38
Total number of markers	6923
Comfortable markers	3500 (50,56)
Semi uncomfortable markers	3012 (43,50)
Uncomfortable markers	411 (5,94)

Since developed Android application is used only in intercity transportations, presented statistics demonstrate transportation comfort for the part of Serbia primary roads. According to the results, around 6% of driving intervals was very uncomfortable, while almost 44% have some discomfort cause in it. Overall only 50% of intervals was comfortable.

6. CONCLUSION

In this paper, a Web-based information system for generating transport comfort maps is presented. Measurement of transportation comfort is conducted using Android application presented in [20]. Presented information system provides the centralized data

functionalities and GIS preview in the form of interactive GoogleMaps. The advantages of presented information system are the Web-based approach, whereby the data are available to all users of the system worldwide. Information that the system can provide can be of great importance when choosing the route for the next transportations. If some of the already recorded paths are going to be used, reviewing the routes previous transportations before setting off on the trip can provide information about expected road conditions. The implementation of GoogleMaps API enables an efficient and interactive display of the measured data. The benefits of the developed information system are increasing with every newly conducted measurement.

As a future work some improvements are planned. The first one is a grouping of close markers into a cluster of markers and providing one overall piece of information based on all gathered markers data. This would provide road comfort information based on all conducted transportations in the presented location. The second one is the communication between client Android application and the server part of the information system. Detected comfort values using Android application could be transferred to the developed information system in real time. This would allow an insight into the current status of each vehicle with an active Android app in real time. The third one is implementation of artificial intelligence in comfort level recognition where the collected data would be used for its training.

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