A system for Crowdsensing Vibration Comfort in Smart Traffic

Baljak, Luka; Filipović, Filip; Jezdović, Ivan; and Labus, Aleksandra

Abstract: ***The purpose of this research is developing a system for crowdsensing vibration comfort in smart traffic. The aim of the research is to develop a system which enables monitoring of vibration in city traffic using mobile devices. The developed system for measuring vibration includes a mobile application for collecting data, a set of web services and a non relational database. The system was tested with an experiment carried out in a city traffic. The results show that the developed system can be used for measuring vibration in traffic using crowdsensing and it allows the community to contribute to comfort improvement in city traffic.***

Index Terms: ***smart cities*, *crowdsensing*, *smart traffic***

1. Introduction

THE main problem of vibration in traffic is their negative impact on human health, because the human body is not created to perceive vibration [1]. Due to the influx of the rural population into the urban environment, an increasing number of people spend a lot of time in public transport on a daily basis [2].

By using Internet of things it is possible to precisely collect vibration data. One way to collect data about vibration in traffic is through crowdsensing technique, which means that a large group of individuals who own mobile devices collectively share data and extract information from them in order to achieve a specific common goal, which in this case is to achieve a higher level comforts of public transport [3].

The aim of this paper is to develop a system for measuring vibration comfort of public transport using the crowdsensing technique. The system is based on the use of a mobile application, which can be used by a larger number of people, which enables fast and efficient collection of data that can be used for more efficient decision making.

2. Related Work

2.1 Smart Cities

A smart city is an urban space that accelerates economic growth, offers high quality of life and facilitates citizen participation in health, education, utilities, business, transport and public security services [4]. In this work [5], a smart city is defined as a precisely defined geographical area in which ICT, logistics, and energy production are closely linked in order to create benefits for citizens in terms of well-being, improving the quality of the environment, and intelligent development. With the development of smartphones and advanced technologies (GPS, microphone, camera, etc.), citizens can collect data from urban areas. With these technologies, people can be part of smart cities and their services [6].

Areas of application of IoT solutions in smart cities can be categorized into several areas of application [7]: administration, participation program, and public security; buildings and houses; health protection; education, transport, and energy. Infrastructure of the Internet of intelligent devices and services in cities can contribute to the optimization of traffic, energy consumption, administrative and other processes [8]. From the aspect of communication, management and data processing, the multilayer architecture of the Internet of intelligent devices in smart cities consists of the following layers [9]:

- Measurement layer and sensors
- Network-Centric layer,
- Cloud-Centric layer,
- Data-Centric layer.

The lowest Internet infrastructure of intelligent devices is the sensor layer. It consists of intelligent (smart) devices that collect and process information from the environment. Such a device must have the following physical components [10]: power, memory, processor, and communication interface. The Network-Centric layer in the IoT infrastructure is responsible for providing a communication channel from sensors to the Internet, including the use of various technologies and network devices such as routers, base stations, and more. The Cloud-Centric layer is responsible for delivering available data and services to users. The role of cloud technology is to create an environment in which the management and use of sensors can be offered as a service to end users.

The application layer consists of applications that use data collected in the sensor layer to control various devices and smart buildings in the city.

Most of the existing solutions for smart cities are based on the integration of wireless communication technology, with the goal of creating a flexible and scalable infrastructure. A special segment in IoT infrastructure is a smart city solution that provides customers with the mobility and continuity of the network connection. The basic requirement is to enable use of different access technologies and to enable communication with smart devices and objects from different locations.

Technologies that enable development of a smart city include: internet intelligent devices, mobile technology, crowdsensing techniques, cloud computing, and big data.

2.2 Smart Traffic

The goal of smart traffic is to improve traffic infrastructure and traffic safety. It includes intelligent transport systems, automated traffic signaling and smart parking. Traffic control is of strategic importance in large cities [11]. Internet intelligent devices should provide interactive management of a central system for monitoring and regulating traffic. On the basis of the data obtained, traffic flows can be analyzed and improved in real time. The problem of traffic congestion is becoming serious due to increase in the number of inhabitants, the process of urbanization, and motorization. The use of ICT and intelligent transport systems (ITS) to monitor urban traffic can increase safety, make transport more efficient, reduce delays, and reduce environmental pollution.

2.3 Crowdsensing Techniques

Cities that have a predisposition to become intelligent can use IoT technologies and applications to collect and share real-time data [12]. Crowdsensing is a new paradigm that uses mobile devices to efficiently collect data, enabling the work of numerous large applications [13]. It is an ICT tool that focuses on different areas such as environment, citizen co-operation, urban traffic, health, and social networking [6]. The advantage of crowdsensing is use of sensory-based services [14], which is a cheaper way of applying smart cities in cities because they do not require expensive infrastructure [12].

Involvement of people is one of the most important features, and human mobility offers unprecedented opportunities for sensual coverage and data transmission [15]. There are two types of crowdsensing:

- Participatory sensing - requires participants to knowingly decide to meet application requirements by deciding when, where, how, and what observation to take.
- Opportunistic sensing - data from the environment is collected through applications without actively activating users (for example, continuous monitoring of Wi-Fi signals only requires that Wi-Fi be opened).

Some examples of using crowdsensing techniques include measuring pollution levels in the city, water levels, and monitoring of wildlife habitats. This way of collecting data enables mapping of various ecological phenomena by involving ordinary people. An example of a prototype for pollution monitoring is Common Sense [16]. Common Sense uses specialized handheld devices to measure air quality that communicate with mobile phones (using Bluetooth) to measure different air enthusiasts (e.g. CO_2, NO_x). These devices, when used on a large population, collectively measure air quality at a local or wider level. Similarly, microphones on mobile phones can be used to monitor the level of vibration in communities [17].

2.4 Theoretical Frame of Vibration Measurement

Vibration (vibratio - trembling, translated from Latin) represent periodic oscillations of the body around the equilibrium position. The equilibrium position is the position in which the body is not exposed to external forces [18].

Vibration is measured using an

accelerometer. It is a hardware component that is embedded in every smart phone. It reacts to the movement of the phone and updates each vibration for each axis. In case of hibernation of the phone, the X and Y axis vibration values will be approximately equal to zero, while the Z axis vibration will be equal to the gravity force on the phone. In order to avoid gravity from the observation itself, it is necessary to know in what position the phone is located during the measurement so that the value of the gravitational acceleration can be deducted from the values obtained from that axis. When the phone is on the move, the measured values represent a summarized motion of motion and gravity [19].

Accelerometer can be used to test soil vibration, to determine the vibration of workplaces or vehicles, and it finds great application in the mobile game industry. Manufacturers of same real games use movements that are controlled by the tilting of the phone, and the data on tilt and speed are precisely obtained from the accelerometer [19].

Determining the vibrations of the X, Y and Z axes is not enough to consider the effect on humans. Namely, it is necessary to perform a certain sizing on the basis of which it is possible to determine the influence. According to the ISO 2631-1 standard, it is first necessary to determine the mean square deviation [20]. After calculating the mean square deviation, it is necessary to determine the sum of the vectors of all measured vibrations at a specific location, which is designated as the total point vibration total value (PVTV) [20]. By summing up all total values of one-point vibration (PVTV), the total vibration total value (OVTV) is obtained [20]. Finally, in order to determine the comfort of the environment, the total vibration value (OVTV) obtained is compared to scale determining discomfort.

Discomfort is a subjective feeling that varies between individuals, but there is a certain consistency [21]. Human perception of vibration depends on its characteristics, such as strength, duration, orientation and characteristics of the people themselves, such as height, weight, gender, and age. A person in a sitting position (usually the target of a survey) senses vibration from 3 locations - seat, floor and backrest. Vibration at each location is viewed through three axes, X, Y and Z, as well as through rotation around them, as already explained. The rotational impact of the vibration in the backrest and the floor can be ignored. [20]

Human body has no single sensor or organ that senses vibration, but it has certain sensing systems that are sensitive to vibrations [22]:

1) Type - it is possible to detect the change in the position of the observed objects that occur as a result of shifting the head under the influence of vibration [22].
2) Vestibular apparatus - a static organ, which is placed in an internal ear which serves to maintain the balance and to provide information on the position of the body in the space [23]. If vibration cause head movements, this apparatus detects these changes and informs the brain about it [22].
3) Somatic nervous system - a part of the peripheral nervous system that is related to skeletal muscles under the voluntary control of body movements. It consists of afferent nerves that transmit impulses to the central nervous system [24],
4) Audit system - a sensory system that serves for the sense of hearing. It has the ability to detect the change in air pressure by more than 20Hz due to vibration [22].

When a man is exposed to vibration, his body negatively reacts to them [25]. Reactions can be controlled by muscles, but human body is not intended to deal with vibration, which can lead to health problems. Factors that can affect health deterioration due to exposure to vibration are cigarette smoking, obesity, duration of exposure, etc. [22].

One of the most common problems with vibration is lower back pain [26]. In the study [27], it was concluded, based on the large amount of observations, that vibration throughout the body has an impact on the occurrence of back pain. If, with the exposure to vibration, the lifting of the load is added, the effects are even greater. Although clinical back pain and lower back pain have never been correlated, there is statistically significant interdependence between these two phenomena.

In a study [28], conducted on a sample of 600 citizens exposed to body vibration, it was concluded that there is a significant correlation between vibration and lower back pain. The surveys used for data collection consisted of questions related to the private and business life of the respondents.

In addition to back pain, vibration has been studies as a cause of digestion, hearing, neck and shoulder pain, etc. [29]. Pain in the neck and shoulders was the subject of certain studies, but none succeed in finding the correct correlation. In the Ishitake study in 2002, vibration has been shown to affect the digestive tract, but not to the extent that it can endanger the health of a healthy person [20].

2.5 The Problem of Vibration in Traffic

In modern society, it is impossible to avoid encountering vibrations. Whether you are at work, or at home, or in the center of the city, you are exposed to the influence of vibrations. Whole body vibration by definition is transmitted through the accompanying surfaces and differs from the vibration transmitted from a certain part of the body, for example through hand. It occurs in a sitting, standing and lying position. In ISO 2631-1, most research is related to the seating position [20].

Passengers are irritated by vibration and consequently concentration may be reduced, depending on the psychological and physical condition of the person. For example, reading is difficult due to vibration [30]. A large number of people use public transport on a daily basis to carry out day-to-day activities. Although there is no official research that confirms that discomfort affects health, the assumption is that improving comfort has an impact on reducing health risks [20].

Traffic-induced vibration is one of the ways to cause damage to the environment. One of these ways is to create cracks in the facades of buildings, influence their depreciation, or have other impacts on households, etc. [31].

First of all, there are certain factors that influence the vibration itself [31]:

- quality and structure of sidewalk
- structure of vibration conductors to buildings
- structure and damage of roads
- speed and weight of the vehicle
- duration of exposure to vibration
- structure of the building (type, number of floors)
- distance from the road

It is very difficult to determine the effect of vibration on buildings experimentally, because there are many factors that affect the damage to the building. Precipitation, wind, man, aging, quality of the material, soil are just some of them. There are international and national standards that determine the allowed level of vibration in buildings, and one of the most famous is the ISO 4866 from the International Standardization Organization [31].

One way to collect data on vibration in traffic is through the crowdsensing technique, which implies that a large group of individuals owning mobile devices collectively share data and extract information from them in order to achieve a particular common goal, which in this case implies improving the vibration comfort of the environment [32]. According to classification of this technique referred to in [32], this form of crowdsensing is classified as an example of ecological crowdsensing in terms of the purpose of data collection.

3. Designing an IoT Based System for Measuring Vibration Comfort

3.1 Modeling the Architecture of the System for Measuring Vibration in Traffic

It is necessary to develop the infrastructure of the system for measuring vibrations in traffic using the Internet of intelligent devices. The proposed system includes the following components:

1. Mobile cellular architecture
    a. Power supply
    b. Communication modules
    c. Web services
    d. Accelerometer
    e. GPS
2. Mobile application architecture
    a. Local database
    b. Location services
    c. Accelerometer
3. Backend
    a. Database
    b. API for client applications
    c. Data processing and analysis services

The architecture of the system for measuring vibration in traffic using the Internet of intelligent devices is shown in Figure 2 and developed as a project of the Department of

Electronic Commerce at the Faculty of Organizational Sciences, University of Belgrade.

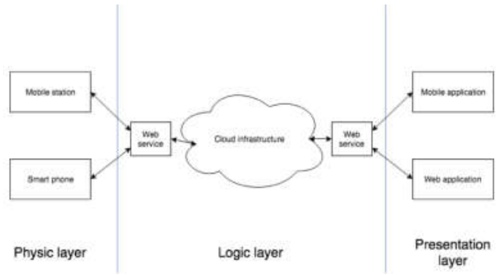

Figure 1 - Architecture of vibration measurement system in traffic in smart cities

In the physical layer, data from different sources is collected. The data is stored at the Cloud infrastructure through a web service. Communication is done through a web service. The presentation layer includes web and mobile applications. Data is displayed as tables, maps and charts.

Mobile stations with GPS and accelerometer are connected to the Raspberry Pi device. A web server written on the Raspberry Pi device allows wireless control of the system. The device can be installed in urban transport vehicles allowing data collection and transmission in real time.

Because of the large amount of data that needs to be stored, it is necessary to use an unrelated base. The mobile application of the mobile station communicates with the database through a web service. The web application uses data from the database for additional analysis and displays the results of vibration measurements to users.

3.2 Designing a Mobile Application

The mobile application enables manual and automatic vibration measurements that store time and location data for each measurement. Also, the application should provide the user with appropriate visualization of the measured results and, depending on the level of vibration, give the user an assessment of the level of vibration comfort. It is necessary to provide insight into the situation on certain lines of public transport, as well as on certain streets, residential and business buildings.

Android applications serve to communicate between systems and users. The software architecture of this part of the system is shown in Figure 2.

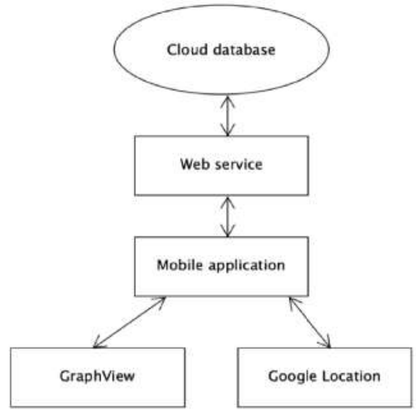

Figure 2 - Software architecture of the system

At the beginning of the process, recording of vibration data is performed. Upon completion of the recording, the data is stored in the local memory of the device and the process of analyzing the recorded data is automatically initiated. The analysis of the recorded data is done using the Fast Fourier Transformation used to record the recorded data in a separate representation of the separate frequencies. Upon completion of the analysis, the results, data, and metadata are sent via the API to the cloud.

From the user point of view the application has two ways to use it - manual and automatic, with more detailed specifications below.

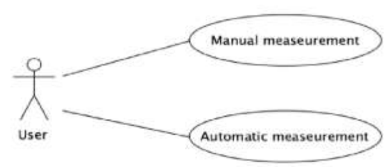

Figure 3 - Use Cases

3.3 Implementation of the Mobile Application

The application is developed in Android Studio in the Java programming language and is intended for mobile devices that have an Android operating system. For simplicity, the application is in English.

Projected use cases are implemented as follows:

1) Use Case: Manual measurement. The user can choose between 4 locations - at home, at work, on the bus and in the

car. After selecting his location, the user starts recording by pressing the Start button. Storing the location of the mobile phone is implemented using Google Location API, provided by Google for free. The API works by returning the last known device location to each location request, which is not available only when the location is disabled on the phone. The graph displays real-time vibration changes and is realized with the GraphView plug-in. Since there are 3 axes, the vibration for each of the axes is presented with a unique color. By pressing the Stop button, the recording stops and all collected data is sent to the database via the web service.

Figure 4 – Manual measurement

2) Use Case: Automatic measurement. The user initially selects the time interval between the two measurements and the duration of the measurement. Background measurements are made through the Background Service which is executed at a predetermined interval and lasts the selected time period. After each measurement, all data collected is sent to the database via a web service.

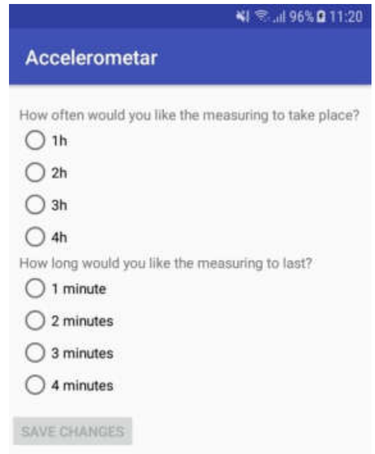

Figure 5 - Automatic measurement

Due to the incompatibility of the data for a relational database, a Mongo database was chosen, which was created on the site mlab, which provides service of storing Mongo databases on the cloud. The database is set up to have its own exposed public API (web service) through which it is possible to implement all CRUD operations from the application itself. As a rule, the documents in this database have their primary key - ID, which is used for accessing a document within the link to the API.

Each user in the database has own document in which all recorded vibration is stored. Due to the Mongo database structure, within the document of each user, there are five arrays, for the values measured in the bus, car, at home and at work, and one for the values measured automatically in the background, in which the measurement results are stored. Phone location is stored using two decimal values - latitude and longitude. Vibration is stored as oscillation values for X, Y and Z axes in a decimal format. The date and time are stored as a text value formatted as "dd.MM.yyyy. hh:mm:ss". Within the arrays, each element represents one measurement result, in which the recorded vibration, the date and time, location, and the width and length are stored.

In order to access data from an accelerometer embedded in a mobile device, it is necessary as the activity or service to implement the SensorEventListener interface and to select an accelerometer as a type of a sensor. After registering the sensors, activity/ service implements methods onAccuracy-Changed (Sensor sensor, int precision) and onSensorChanged (SensorEvent event). The second method is the most important one for this application because it contains implementation of the logic that is executed when a value of vibration on some axis changes, which happens very often. For this reason, storing the results of the measurement in the database is done every second, in order to avoid unnecessary overflow of data.

4. Evaluation

Testing of the system was performed from August 28th until September 3rd on the public transport line number 17 on the route between the stations of François DePere and the Marshal Tolbulhin Boulevard at the time interval from 12am to 22pm. The values obtained were measured in the seated position. Summarized results and derived parameters are given in the table 1.

Table 1: Summarized results

Type of bus	Value of vibration
Old	0.589
New	0.394
Total	0.417

Due to inability to find data on the age of the vehicle, or any categorization of vehicles in public transport, old vehicles are considered those which do not possess air conditioning, and new ones are the buses that have air conditioning. The total value of the vibration determines that the bus ride on the number 17 was overall a bit uncomfortable. From the obtained results, it can be concluded that the subjective perception of vehicle discomfort would be for new vehicles a little bit uncomfortable, while for old vehicles it could be said to be either a bit uncomfortable or completely uncomfortable, depending on the individual.

5. Conclusion

The use of an accelerometer, a hardware component embedded in many modern smartphones, for discovering impact of the environment on human health will surely experience a real bloom in the future.

There is no application that uses the measurements of vibration comfort of the environment mentioned in this paper. For example, after manually measuring vibration, it is possible to calculate the coefficient and to determine the level of comfort of the environment according to the scale. It is also possible to create reports based on automatic measurements and to welcome the user with them when they access the application the next time, or by notifying them that the report is ready. In addition, it is possible to allow user to supplement the list of locations to their will (adding cottages, trucks, sports centers, clubs or cafes in which a user spends his time) or in agreement with the public city transport the application can allow users to choose the exact line of public transport and garage number of a certain bus.

In order to increase the level of comfort of roads, buildings, and vehicles, it is possible to conclude an agreement with competent institutions that will present the measured vibration and will take appropriate measures of improvement in accordance with them. Based on the results of the measurements, it is possible to determine which streets are the biggest problems, which buildings need to be better isolated from the road, and which vehicles need to be repaired or removed from the traffic.

There are many opportunities for further exploitation of vibration for reducing health risks due to the increasing presence and ease of use of mobile devices. It is safe to expect that the mobile application industry will be one of the main exploiters of this functionality.

6. References

[1] Pope, M., Magnusson, A., Lundstrom, R., Hulshof, C., Verbeek, J. and Bovenzi, M. 2002, "Guidelines for whole-body vibration health surveillance", Journal of Sound and Vibration, vol. 253, no. 1, pp. 131-167.

[2] Kourtit, K., Nijkamp, P. and Arribas, D. (2012), Smart cities in perspective–a comparative European study by means of self-organizing maps. Innovation: The European journal of social science research, 25(2), pp.229-246.

[3] Ganti F., Ye F., Lei H.,2011, „Mobile crowdsensing: current state and future challenges“. IEEE Communications Magazine. 49(11), pp 32-39.

[4] L. Sanchez, I. Elicegui, J. Cuesta, and L. Munoz, "On the energy savings achieved through an internet of things enabled smart city trial," in *2014 IEEE International Conference on Communications (ICC)*, 2014, pp. 3836–3841.

[5] R. Dameri and R. P. Dameri, "Searching for Smart City definition: a comprehensive proposal Searching for Smart City definition: a comprehensive proposal TYPE (METHOD/APPROACH) Council for Innovative Research," *Peer Rev. Res. Publ. Syst. J. Int. J. Comput. Technol.*, vol. 11, no. 5, 2013.

[6] K. Farkas and I. Lendak, "Simulation environment for investigating crowd-sensing based urban parking," in *2015 International Conference on Models and*

Technologies for Intelligent Transportation Systems (MT-ITS), 2015, pp. 320–327.

[7] B. Radenkovic, M. Despotović-Zrakić, Z. Bogdanović, D. Barać, and A. Labus, *Internet inteligentnih uređaja*. Beograd: Fakultet organizacionih nauka, 2017.

[8] P. Wang, A. Ali, and W. Kelly, "Data security and threat modeling for smart city infrastructure," in *2015 International Conference on Cyber Security of Smart Cities, Industrial Control System and Communications (SSIC)*, 2015, pp. 1–6.

[9] J. Jin, J. Gubbi, S. Marusic, and M. Palaniswami, "An Information Framework for Creating a Smart City Through Internet of Things," *IEEE Internet Things J.*, vol. 1, no. 2, pp. 112–121, Apr. 2014.

[10] L. Sanchez *et al.*, "SmartSantander: IoT experimentation over a smart city testbed," *Comput. Networks*, vol. 61, pp. 217–238, Mar. 2014.

[11] B. Radenkovic, M. Despotović Zrakić, Z. Bogdanović, D. Barać, and A. Labus, *Elektronsko poslovanje*. Beograd: Fakultet organizacionih nauka, 2015.

[12] G. Cardone *et al.*, "Fostering participaction in smart cities: a geo-social crowdsensing platform," *IEEE Commun. Mag.*, vol. 51, no. 6, pp. 112–119, Jun. 2013.

[13] H. Ma, D. Zhao, and P. Yuan, "Opportunities in mobile crowd sensing," *IEEE Commun. Mag.*, vol. 52, no. 8, pp. 29–35, Aug. 2014.

[14] Á. Petkovics, V. Simon, I. Gódor, and B. Böröcz, "Crowdsensing Solutions in Smart Cities," in *Proceedings of the 13th International Conference on Advances in Mobile Computing and Multimedia - MoMM 2015*, 2015, pp. 33–37.

[15] N. D. Lane, S. B. Eisenman, M. Musolesi, E. Miluzzo, and A. T. Campbell, "Urban sensing systems," in *Proceedings of the 9th workshop on Mobile computing systems and applications - HotMobile '08*, 2008, p. 11.

[16] P. Dutta *et al.*, "Common Sense," in *Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems - SenSys '09*, 2009, p. 349.

[17] R. Ganti, F. Ye, and H. Lei, "Mobile crowdsensing: current state and future challenges," *IEEE Commun. Mag.*, vol. 49, no. 11, pp. 32–39, Nov. 2011.

[18] Jovančić P., „Skripta iz predmeta Tehnička dijagnostika, Univerzitet u Beogradu – Rudarsko-geološki faklutet".

[19] Sharma S., „What is the accelerometer used for in mobile devices", Source: www.credencys.com/blog/accelerometer/, [accessed 15.11.2018.]

[20] Marjanen Yka, „Validation and improvement of the ISO 2631-1 (1997) standard method for evaluating discomfort from whole-body vibration in a multi-axis environment",Source:https://dspace.lboro.ac.uk/2134/6250, [accessed 15.11.2018.]

[21] Griffin, M.J., Parsons, K.C. Whitham, E.M. 1982, "Vibration and Comfort - 4. Application and Experimental Results", Ergonomics, vol. 25, no. 8, pp. 721-739.

[22] Mansfield, N.J. 2005, Human response to vibration, CRC Press, London.

[23] Nedeljko Bajić, Phisical Dimensions of Aging, Motor Control, Coordination and Skill, LECTURE 6, Faculty of Education in SOmbor.

[24] Berberović LJ., Hadžisemilović R., Dizdarević I., 2986, Medicinska antrolpologija, Svejtlost, Sarajevo.

[25] Pope, M., Magnusson, A., Lundstrom, R., Hulshof, C., Verbeek, J. and Bovenzi, M. 2002, "Guidelines for whole-body vibration health surveillance", Journal of Sound and Vibration, vol. 253, no. 1, pp. 131-167.

[26] Palmer, K.T., Harris, E.C., Griffin, M.J., Bennett, J., Reading, I., Sampson, M., Coggon, D. 2008, "Case-control study of low-back pain referred for magnetic resonance imaging, with special focus on whole-body vibration", Scandinavian Journal of Work, Environment and Health, vol. 34, no. 5, pp. 364-373.

[27] Seidel, H. Heide, R. 1986, "Long-term effects of whole-body vibration: a critical survey of the literature", International Archives of Occupational and Environmental Health (Historical Archive), vol. 58, no. 1, pp. 1-26.

[28] Bovenzi, M., Rui, F., Negro, C., D'Agostin, F., Angotzi, G., Bianchi, S., Bramanti, L., Festa, G., Gatti, S., Pinto, I., Rondina, L., Stacchini, N. 2006, "An epidemiological study of low back pain in professional drivers", Journal of Sound and Vibration, vol. 298, no. 3, pp. 514-539.

[29] Griffin, M.J. 1990, Handbook of human vibration, Academic Press, London.

[30] Sundström, J. 2006, Difficulties to read and write under lateral vibration exposure, PhD. thesis, KTH, Sweden.

[31] Jakubczyk-Galczynska A., Jankowski R., 2014. „Traffic-induced vibrations. The impact on buildings and people", ISBN 978-609-457-640-9.

[32] Ganti F., Ye F., Lei H.,2011, „Mobile crowdsensing: current state and future challenges". IEEE Communications Magazine. 49(11), pp 32-39.

Luka Baljak is a student of master studies at Faculty of organizational sciences, University of Belgrade. Currently, he is an associate at the Department of e-business. His research interests are: e-business, Internet technologies and m-business.

Filip Filipović is a student of master studies at Faculty of organizational sciences, University of Belgrade. Currently, he is an associate at the Department of e-business. His research interests are: e-business, Internet of things and Internet technologies.

Ivan Jezdović is a PhD student at Faculty of organizational sciences, University of Belgrade. Currently, he is an associate at the Department of e-business. His research interests include: e-business, Internet of things and web development.

Aleksandra Labus is an associate professor at Faculty of organizational sciences, University of Belgrade. She is a treasuress of IEEE Computer chapter C-16. Her research interests include: e-business, Internet of things and m-business.