Transportation in Smart Cities - Tracking and Improving Driving Comfort

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***Abstract*— The rapid process of urbanization of the population in the world, as well as increased application of mobile and ubiquitous computing in all spheres of human activity, caused the modernization of the conditions of transport and traffic. Smart devices with the ability to collect data from the context of vehicles and passengers provide the possibility of processing them in order to increase the quality of transport services. If this information is publicly available and used to form collective intelligence in order to improve the transport conditions for residents of the cities, then they contribute to the areas of smart traffic in the concept of smart cities. The paper describes a smart transport service, which provides the possibility of monitoring the vibrations in the vehicle, in order to improve the level of comfort when driving in urban transport. The client-server application collects information about vibrations, and the result of their processing is publicly available estimations of routes, according to the criterion of driving comfort.**

I. Introduction

The growth and development of the application of information and communication (IC) technologies, in addition to the numerous innovations that digitalization brought into everyday life, resulted in the creation of a new concept of smart cities. A smart city is an urban environment based on IC technologies used to improve the general living conditions of the population. As modern technological achievements such as the Internet, smart devices, etc. are accepted and used by the majority of the population, there is a possibility of collecting data about their environment (the context data), in order to implement new and improve existing services available to the citizens. These services may include the domains of health, economic, school, traffic, administrative, and other sectors of the city.

The central themes in smart cities are society, economics, governance, and the environment. The social aspect refers to the fact that the city exists for the benefit of its inhabitants, while the economic factor is reflected through continuous economic growth and development. The topic of governance relates to the political aspects of the city, while the theme of the environment indicates that the city should maintain its functionality for the needs of present and future generations, with the efficient use of resources. Smart cities have their own attributes, infrastructure, and components. The attributes include sustainability (issues of pollution, waste, climate change, etc.), quality of life (emotional and financial satisfaction of the population), urbanization (technology, infrastructure) and smartness (smart population, economy, mobility, etc.) [1].

The infrastructure of the smart city consists of a physical, technological, and service component. Physical infrastructure includes buildings, roads, railways, water supply system and so on. ICT infrastructure is the only intelligent component of a smart city that keeps all other components together. It is based on IoT (Internet of Things) and BigData [2], [3]. IoT consists of: things (a sensor, a device connected to a network with the ability to interact with a user or manage another device), a local area network, the Internet, and the cloud. BigData refers to large quantities of data read from the sensors, obtained by crowdsourcing, and the like. The realization of their storage and processing requires the use of more complex methods than traditional [4], [5]. The service infrastructure combines the previous two components [1].

Figure 1. The components of smart cities

Figure 1 shows the basic components on which the idea of smart cities is based: smart business, energy efficiency, smart health, smart household, smart agriculture, smart education, smart management, Big Data, Internet of Things, and smart traffic, which is especially prominent as it will be the subject of this work.

Intelligent Transport Systems relate to all types of traffic (road, water, air) and involve the existence of various types of navigation and communication devices for data exchange between vehicles or between vehicles and a fixed location. They provide information on the fastest, cheapest and safest routes.

The motivation for our work is to improve the quality of life of the citizens through the concept of smart cities and its services. Collecting vibration data while driving can be used to generate public data about road comfort maps. These maps can be useful when transporting patients, sensitive or dangerous materials. Our aim is to show how existing solutions [17] that collect context-aware data can be used to improve the components of smart cities, in this case, smart traffic.

The described system [17] has the ability to record the level of vibration in vehicles (which affects the comfort of passengers), and the storage, processing and display of data on potentially critical locations on the road. Data collection is done using a mobile application for the Android operating system, processing using the Web system, and as a result, the road comfort maps are obtained.

The paper is organized in the following way. The second chapter gives an overview of the papers that contributed to the realization of smart traffic services and who dealt with similar problems. Then, the architecture of the mobile application for measuring vehicle comfort is given, describing the technologies used to implement the application, and then displaying it. The final chapter gives a conclusion and directions for further research and improvement in this domain.

II. Related Work

Three traffic issues are current in the concept of smart cities: smart parking, smart transport, and smart vehicles. These are all problems that are solved by intelligent transport systems. Smart parking is one of the most difficult issues to solve, but the solution to this problem contributes to significant savings in time, space, and energy resources. Smart transport means solutions that improve travel efficiency by performing analysis and predicting the route in order to reduce the number of traffic accidents, increase passenger safety, achieve better productivity and a healthier environment. Smart vehicles have smart functionalities to enhance the safety and comfort of the passengers. They have the ability to connect to smart devices and can provide services like networking in a unique system to perform monitoring e.g. houses or driver's offices, the transport of goods at efficiently determined routes, etc. [6].

The development of the smart transport service was dealt with by authors [7]. This paper discussed the gathering collective intelligence to inform passengers about the number of vacancies and the exact time of arrival of public transport vehicles. This system works in real time, has been implemented in Mexico, and has given good results.

The solutions in the field of smart transport were also dealt with by the authors in the paper [4]. As a result of the analysis of the importance of data openness, crowdsourcing and sensors in the concept of smart cities, mPASS and WhenMyBus applications have been created. The first is intended for persons with special needs in order to find a safe route, while another application aims to help the passengers of public transport to monitor the movement of buses. The use of crowdsourcing for similar purposes is described in [8].

The use of IoT in intelligent transport systems has been described in [9]. The service described in this paper refers to the use of RFID controllers in vehicles in order to record traffic jams and to determine the frequency of traffic on the appropriate routes. The combination of the previous two services was described in [10].

The paper [11] shows the use of mobile devices and GPS to determine the distance of the train from the ramp, so it can be raised by clicking on the button that represents the ramp on the map in the mobile application. The application of context-aware systems in train traffic is also the subject of [12]. The comfort of passengers in trains is the subject of the paper [13].

The paper [14] describes the possibility of using mobile devices with sensors in order to determine the comfort in the vehicle, but the information is used locally, intended for the individual user of the application. The paper [15] deals with the analysis of comfort, but all changes in the vibration level are attributed to the unevenness of the road surface. Vibration analyzes for the purpose of determining comfort were also dealt with by authors [16], who used the embedded systems and LabView implementation software.

III. System for Recording and Processing Vibration Data

It is difficult to quantitatively represent the comfort, because it is influenced by factors that are subjective, when it comes to the transport of passengers. Inadequate conditions during transport may have an adverse physical and psychological impact on passengers and thus cause a bad mood, anxiety, back pain, joint pain, nausea, and so on. In the case of passengers who already have some health problems, the health condition can worsen due to uncomfortable transportation. This is especially important when transporting patients. However, some types of materials need to be transported with a higher level of comfort (fragility, hazardous / flammable substances).

The comfort of the passenger during driving is affected by seat vibration, arm vibration, foot vibration, noise, seat design, temperature, humidity, air pressure, seat-to-seat distance. One of the most important factors of comfort is the level of vibration the passenger feels when transporting. Vibro comfort is directly proportional to the acceleration that affects the body of the passenger while driving. The comfort of transport is influenced by three factors: the driver, the type and condition of the vehicle and the condition of the road.

Estimation of the comfort level in this paper is based on measurement of vibration comfort according to the ISO 2631 standard with additional calculations above the measured data. The effective acceleration value (aRMS) for the discrete system is calculated according to formula (1):

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

where a_{zi} is the i-th measured acceleration in the Z axis (vertical axis) and n is the number of samples. The obtained result shows the appropriate level of comfort, and the classification of these levels is given in Table 1.

TABLE I. THE COMFORT LEVELS ACCORDING TO ISO 2631 STANDARD, AND ACCORDING TO THE VIBRODROID APPLICATION

a_{RMS} [m/s^2]	Comfort level (ISO 2631)	Comfort level (our approach)
0-0.315	Not uncomfortable	Comfortable
0.315-0.63	A little uncomfortable	A little uncomfortable
0.5-1	Fairly uncomfortable	
0.8-1.6	Uncomfortable	Uncomfortable
1.6-2.5	Very uncomfortable	
> 2	Extremely uncomfortable	

In the Android application, RMS is calculated for all three axes, according to (1), and then for each sample of the three-axis accelerometer *i*-th modulo according to (2):

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

where a_{xi}, a_{yi}, a_{zi} are the accelerations along the X, Y and Z axes respectively in the *i*-th sample, and a_{iRMS} is the *i*-th modulo of acceleration of all three axes. Using these values in the standard time interval, aRMS is calculated according to (3):

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

where *n* is the number of samples.

In addition to the above calculations, the maximum value of the acceleration module calculated in accordance with (2) is calculated at each interval of time. For the detected maximum acceleration mode (aPeak), the detected acceleration values for all three axes are memorized, such as latitude, longitude and velocity. Also, at the set time interval, maximum acceleration values are calculated for all three axes (MAXX, MAXY, MAXZ).

Based on all of the above, after each interval of time for the crossed section of the road, the following information is stored:

- IDT: location marker ID
- RMS_X, RMS_Y, RMS_Z: X (Y, Z)-axis calculation according to (1)
- ARMS: acceleration magnitude according to (3)
- APEAK: acceleration magnitude maximum value in the values calculated by (2)
- APEAK_X, APEAK_Y, APEAK_Z: X (Y, 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, MAX_Y, MAX_Z: real value on X, (Y, Z)-axis where absolute maximum X (Y, Z)-axis value is detected
- COMFORT: (0=comfortable; 1=a little uncomfortable; 2=uncomfortable) according to Table I.

The measured data for each interval is remembered in the KML or CSV file, depending on the user's choice. By uploading data to the server, the comfort maps for the appropriate locations are updated [17], [18].

IV. VIBRODROID APPLICATION

To track comfort, an Android application has been developed. The paper [10] describes a method of development Android applications that operate in the background, with built-in sensors. Realized background application works with an accelerometer and GPS sensors using RxJava from the ReactiveX package [11]. RxJava's functionalities are based on Observable and Subscribe classes that are linked through the Subscription interface. Using RxJava allows creating independent threads and the scheduling of processes is done in the background.

After logging and calibrating the device, the appearance of the received window of the VibroDroid application is shown in Figure 2. Figures 3 and 4 show the recording of the comfortable and uncomfortable point on the road, respectively.

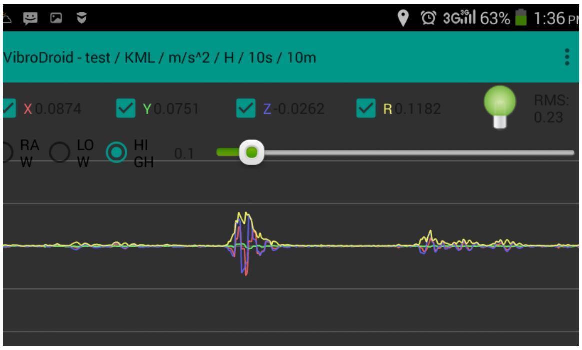

Figure 2. Measuring vibrations using the VibroDroid application

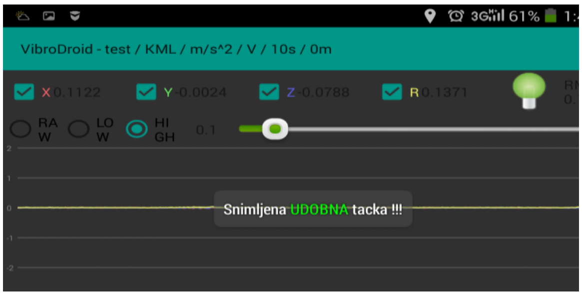

Figure 3. Recording comfortable points

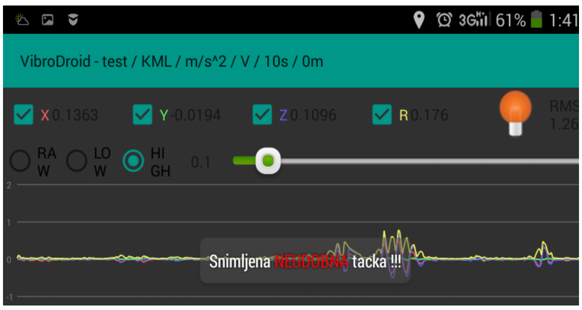

Figure 4. Recording uncomfortable points

The appearance of the created map based on the recorded data is shown in Figure 5.

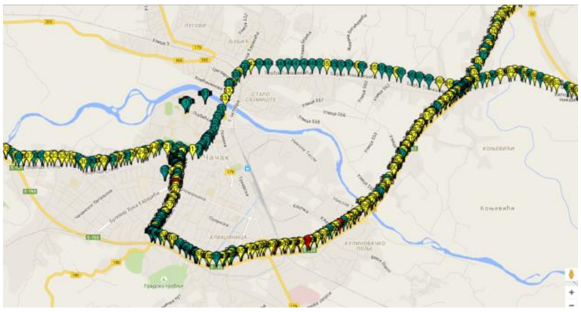

Figure 5. Appearance of a created comfort map

The picture shows one of the recorded road maps of the road, on the territory of the city of Čačak. Green color is characterized by comfortable driving intervals, yellow partially comfortable, while uncomfortable intervals recorded while driving are presented in red.

V. Conclusion and Future Work

The integration of modern technological achievements in various areas has led to the creation of the concept of smart cities, in which collective intelligence is used in order to improve the quality of life of the inhabitants. The result of the successful implementation of IC technologies in traffic is a smart city component, called smart transport, based on intelligent transport systems.

One such system is also a comfort measurement system developed as an Android application. Every smartphone user can install the application and measure the level of comfort while driving with a properly positioned phone. Because smart cities are based on IoT technology, the use of this application does not have to be limited to a smartphone, or any smart device, or an Android OS-based smart car component.

The presented system can be very useful in various categories of transport. The most important application can be for medical purposes, i.e. to monitor the comfort when transporting patients in emergency vehicles. This application represents the topic for further research in order to improve the conditions of patient transport, and therefore to influence the improvement of the service of another area of smart cities, which is smart healthcare.

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References

[1] S. P. Mohanty, U. Choppali, and E. Kougianos. "Everything you wanted to know about smart cities: The internet of things is the backbone.", *IEEE Consumer Electronics Magazine*, vol.5.3, pp.60-70, 2016.

[2] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities.", *IEEE Internet of Things journal*, vol.1(1), pp.22-32, 2014.

[3] C. Perera, A. Zaslavsky, P. Christen, and. D. Georgakopoulos, "Sensing as a service model for smart cities supported by internet of things." , vol.25(1), pp. 81-93, 2014.

[4] S. Mirri, C. Prandi, P. Salomoni, F. Callegati and A. Campi, "On combining crowdsourcing, sensing and open data for an accessible smart city.", *Next Generation Mobile Apps, Services and Technologies (NGMAST), 2014 Eighth International Conference on. IEEE*, pp.294-299, 2014.

[5] M. Batty, "Big data, smart cities and city planning", *Dialogues in Human Geography*, vol. 3(3), pp.274-279, 2013.

[6] Y. Jog, T.K. Singhal, F. Barot, M. Cardoza and D. Dave, "Need & Gap Analysis of Converting a City into Smart City", 2017.

[7] P. Wences, A. Martinez, H. Estrada and M. Gonzalez, "Decision-Making Intelligent System for Passenger of Urban Transports", *In International Conference on Ubiquitous Computing and Ambient Intelligence*, pp. 128-139, Springer, Cham, 2017.

[8] K. Farkas, G. Feher, A. Benczur and C. Sidlo, "Crowdsending based public transport information service in smart cities." *IEEE Communications Magazine*, vol.53(8), pp:158-165, 2015.

[9] A. Das, P. Dash and B. K Mishra, "An Innovation Model for Smart Traffic Management System Using Internet of Things (IoT)", *In Cognitive Computing for Big Data Systems Over IoT*, pp. 355-370, Springer, Cham, 2018.

[10] S. Apsara, G. A. Rashmi, K. V. Mohankumari, L. Anitha and B. Jyothi, "Smart Public Transport System Using Internet-Of-Things", *International Journal of Advance Research, Ideas and Innovations in Technology*, vol.3(2), pp.1163-1170, 2017.

[11] R. Velayutham, T. Sangeethavani, and K. Sundaralakshmi. "Controlling railway gates using smart phones by tracking trains with GPS.", *Circuit, Power and Computing Technologies (ICCPCT), 2017 International Conference on. IEEE*, pp.1-3, 2017.

[12] E. Aguirre, P. Lopez-Iturri, L. Azpilicueta, A. Redondo, J. Astrain, J. Villadangos and F. Falcone, "Design and implementation of context aware applications with wireless sensor network support in urban train transportation environments", *IEEE Sensors Journal*, vol.17(1), pp.169-178, 2017.

[13] T. K. George, H. M. Gadhia, R. Sukumar and J.J. Cabibihan, "Sensing discomfort of standing passengers in public rail transportation systems using a smart phone", *In Control and Automation (ICCA)*, pp. 1509-1513, 2013.

[14] H. Zhao, H. Zhou, C. Chen, and J. Chen, "Join driving: A smart phone-based driving behavior evaluation system", *In Global Communications Conference (GLOBECOM)*, pp. 48-53, 2013.

[15] A. S. El-Wakeel, J. Li, M. T. Rahman, A. Noureldin, and H. S. Hassanein, "Monitoring Road Surface Anomalies Towards Dynamic Road Mapping For Future Smart Cities", *GlobalSIP*, pp.828-832, 2017.

[16] J. C. Castellanos, and F. Fruett. "Embedded system to evaluate the passenger comfort in public transportation based on dynamical vehicle behavior with user's feedback." *Measurement*, vol.47, pp.442-451, 2014.

[17] Z. Jovanovic, R. Bacevic, R. Markovic, S. Randjic and D. Jankovic, "Information System for the Centralized Display of the Transport Comfort Information", *Facta Universitatis, Series: Electronics and Energetics*, vol. 30(4), pp:557-570, 2017.

[18] Ž. Jovanović, D. Janković and A. Peulić, "Mobilni sistem za određivanje nivoa udobnosti u vozilu", *INFOTEH-JAHORINA* Vol. 15, pp:442-446, 2016.