Smart Transportation in the Service of Improving Healthcare in Smart Cities

Željko Jovanović, Aldina Avdić, Dragan Janković, *Member, IEEE* and Dejan Vujičić

***Abstract*— The daily increase in the percentage of urban population in the world, as well as the increasing use of information technology has led to the creation of a new concept - the concept of smart cities. The basic idea of smart cities is to improve the quality of life of population in various fields, such as economy, administration, health, traffic, education, etc. This paper shows the synergy between the components of smart cities, smart transport, and smart healthcare. Service proposals which are presented are one of the results of this synergy and their implementation in the form of an information system can provide better quality, safer, and more efficient transport to the patient.**

***Index Terms*—smart city, s-Transport, s-Health, smart transportation of patients.**

I. Introduction

In the era of analyzing data of computer systems users, nothing is being assumed anymore, but all possible steps are taken to get the most precise information about the user and his environment. Anyhow, seemingly insignificant data can contribute to some new knowledge and facilitate interaction with the user. If we collect information about a group of users, processing this information can make life easier for all members of that group.

The use of information and communication technologies (ICT) in cities in various forms for different urban activities has led to increased efficiency of these activities. A smart city is a place where traditional services become more flexible and more efficient using information, digital, and telecommunication technologies. In a smart city, digital technologies provide better public services for residents and better use of resources.

One definition of smart city says that it is the city that connects the physical infrastructure, IT infrastructure, social infrastructure, and infrastructure to encourage the collective intelligence of the city.

There are many components on which smart cities are based. These are smart transport, smart healthcare, energy efficiency, smart technology and infrastructure, smart education, smart management, and smart people [1].

Smart health is one component within smart cities, and in fact includes electronic health and its aspects to improve the quality of life of the population in smart cities [2].

The application of mobile and ubiquitous computing has brought increasing attention to collecting data from the user's environment. These data constitute a context, and applications using this data are called context-aware applications [3]. The use of smart mobile devices for the purpose of improving the health status of the user has led to the formation of a new area in the field of electronic health, which is mobile healthcare (m-Health).

The natural synergy of mobile and electronic healthcare with the concept of smart cities has created a new term - smart health (smart health, s-Health) [2]. The definition of s-Health is similar to the definition of m-Health, with the emphasis that it is used within smart cities. In addition, s-Health and m-Health are different in the source information they use, and in the flow of this information. For m-Health, source information comes from users/patients, while s-Health, in addition to this information, also uses collective data obtained from the infrastructure of the smart city. Regarding the difference in the data, it refers to the fact that after processing, the m-Health systems return the data back to the user, and s-Health systems return data to the user, but also affect the collective data of the smart city.

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.

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 includes solutions that improve travel efficiency by performing analysis and predicting the route in order to reduce the number of traffic accidents, increase passenger safety, provide better productivity and a healthier environment. Smart vehicles have smart functionalities to enhance the safety and comfort of passengers. They have the ability to connect to smart devices and can provide services like networking in a unique system to perform monitorings e.g. houses or driver's offices, the transport of goods at efficiently determined routes, etc. [4, 5].

The aim of this paper is to show that the components of smart cities do not need to be independently monitored, but efforts should be made to make improvements within one component in order to affect positively other components of smart cities.

The paper is organized in the following way. In the next chapter we give an overview of the papers that dealt with

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this problem of patient transport. Then a proposal of possible services and a way for their realization was given. This is followed by a demonstration of the implementation of the proposed services. Finally, the directions for further research are given.

II. Related work

As the subject of our research is the link between smart healthcare and smart traffic, this chapter provides an overview of papers dealing with patient transportation issues. Some of them dealt with the management of ambulance cars in crisis situations, suggesting the use of various algorithms and technologies. Thus, the authors of the paper given in [6] deal with the problem of choosing the optimal choice of vehicles for patients, taking into account different parameters, with an emphasis on finding the balance between effective choice and patient satisfaction. Requirements can be dynamically changed, and this problem is solved by using a two-phase heuristic procedure and the tabu search algorithm.

In the given paper, as well as in papers [7-9] transport of the patients in an emergency is disscused, and the so-called EMS - emergency medical systems. The [10] also proposes an algorithm whose goal is to efficiently manage the transport of patients, taking into account the length of the transport, the length of the route, the reduction of costs if there are more requests, etc. In [11] the emphasis is on improving the quality of patient transport services when it comes to emergency situations, but in this case the patient's comfort has not been taken into account. The paper [12] also deals with the transport of patients with special needs due to disease susceptibility.

Vehicle comfort has not been considered in the systems described in the papers above, and we believe that only by adding this parameter and the services we are proposing, they would be more complete and comprehensive, and the quality of patient transport would be significantly improved.

III. Smart Transportation Healthcare Services

Inside the areas of intelligent transport systems, systems that provide effective routes can positively affect patient care. Namely, if we have a patient with injuries that require special care and sensitivity during transportation, such systems can recommend us the route to the destination to choose, taking into account the comfort in the vehicle while driving on this route.

To get information about driving comfort on a route, we need to measure the vibrations of the vehicle while driving, and we can do this using a smart device with an accelerometer, as described in [13, 14]. Collected information is sent to the server, where it is processed, and at that time the level of comfort for the appropriate location is recorded (comfortable, medium comfortable, uncomfortable).

There are several scenarios of how these data can be used to improve transport conditions of patients.

The first scenario is based on the data of the level of vibration at a given location. That level is remembered, and the route at which the measurement is performed can be evaluated based on the comfort. This was the subject of our previous research and this scenario is described in detail in previous papers [15-17].

Another scenario includes, in addition to the above data, recording the data of the vehicle in which the measurement is performed. In this way, it is possible to compare the recorded comfort routes when using various emergency vehicles. If the recorded data in one of the vehicles are significantly different from the others, the cause of discomfort may be the vehicle itself, not the route. In this case, the system would suggest the most comfortable vehicle, and signal that there are vehicles that may need repair.

The third scenario is the recording of driver data, because in the same way, as in the above case, it can be the cause of vibration (due to the rough driving mode), not the vehicle or the route. On this occasion, the system recommends the most responsible driver available, based on its assessment by the vibration measurement system.

The next chapter gives an overview of the realization of these services in the form of a web portal that has been implemented as an upgrade to the existing capabilities of the client server platform for storing and processing data on the status of particular routes in terms of driving vibrations.

IV. Smart Patient Transportation Service

For the purpose of processing the collected information about vibrations while driving, which are used to create publicly accessible comfort maps, a client server application has been developed. The client part is a mobile Android application that is used to record and send information about recorded comfortable, less comfortable or uncomfortable points while driving. The server part processes this data, and as an output generates comfort maps for the locations on which the measurements were made. The realization of this part was done using Java Web technologies and the Google Maps API for displaying GIS data.

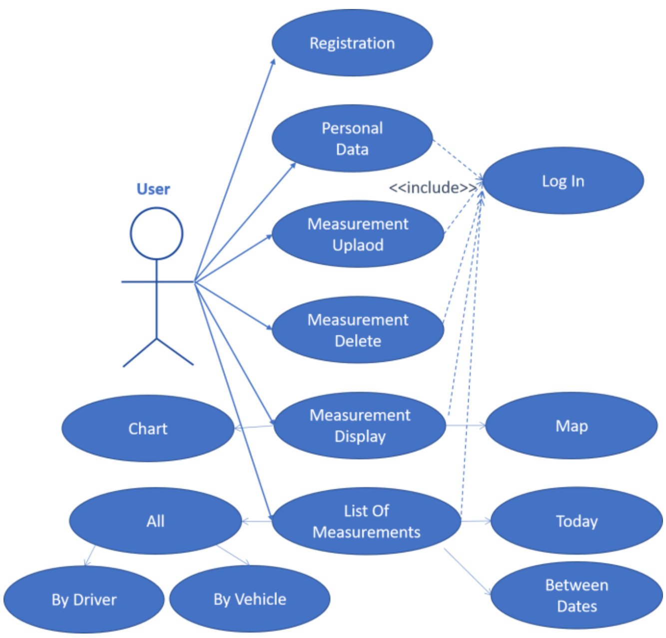

Fig. 1. Use-case diagram of the system for smart transport of patients

In order to view the recorded data, a portal has been developed that provides the following possibilities:

- login to the portal
- browsing by files, i.e. measurements
- displaying a created map or chart
- delete a measurement
- display detailed information by clicking on the point where the measurement was performed, etc.

The display of all system options is given by the use-case diagram in Figure 1.

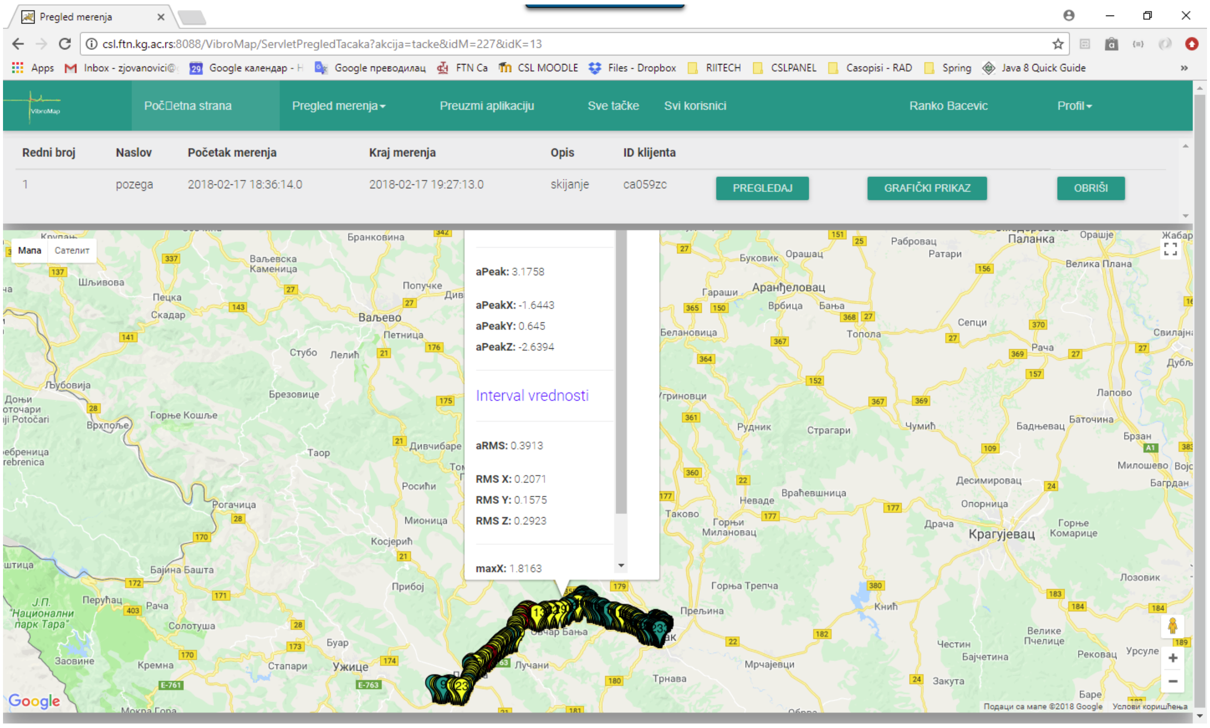

Fig. 2. Displaying the map and recorded vibration data at the selected point

Figure 2 shows the comfort map formed based on the selected measurement, and details when selecting one of the memorized points. The degree of comfort is shown in colors, with the red color marking the uncomfortable route intervals, green marking the comfortable and yellow the medium comfort.

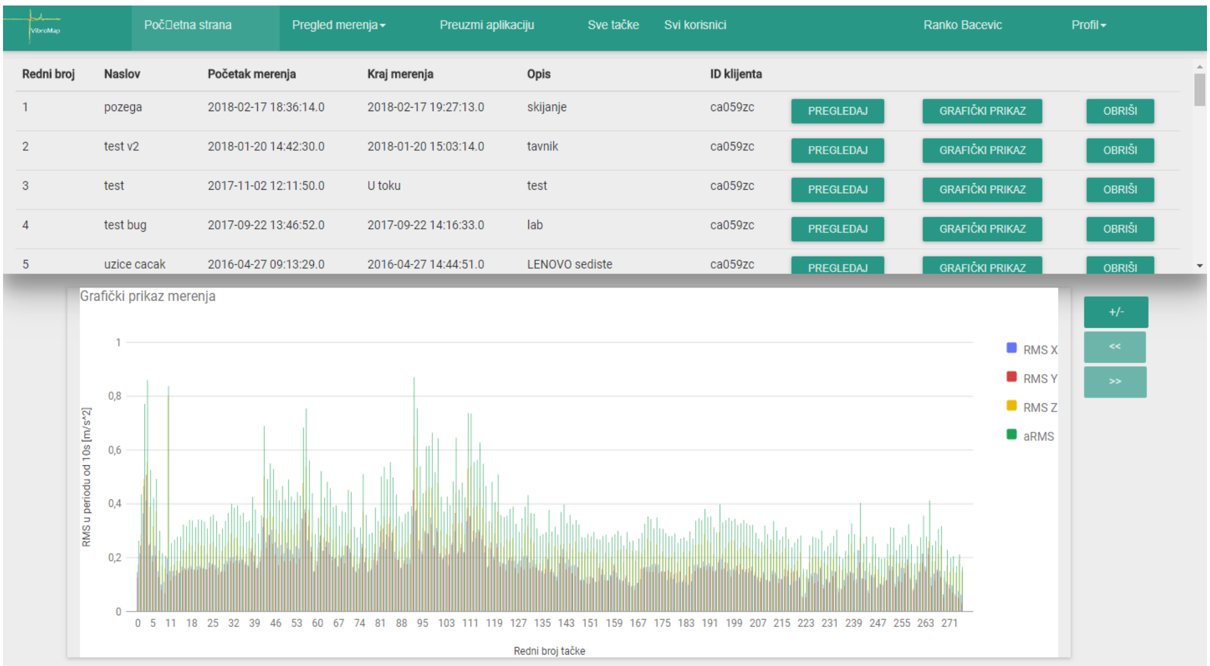

Fig. 3. Graphic display of recorded vibration data at the selected point

Figure 3 gives a graphical representation of the measurement and oscillations along the route. By combining more measurements, based on common features, publicly accessible maps are created, which can be used by all residents of smart cities for their own needs.

However, information on these routes can be enhanced by remembering data about drivers and vehicles within the internal medical information system. They can use publicly available information, and affect them by their measurements, but at the same time, with additional aspects.

Thus, the maps for the appropriate route can be created and compared, in case when different vehicles were used, or when different drivers were operating the same vehicle. In this way, the system records estimates of both drivers and vehicles, which can be taken into account during the assessment of the most effective choice for patient transport.

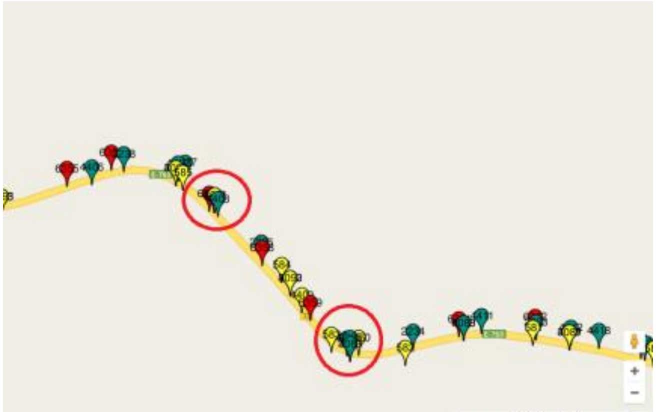

Fig. 4. The result of creating maps based on multiple recordings.

Figure 4 shows a map created by comparing several different measurements on the same route by different drivers. From the picture it can be concluded that the maps are not identical and that there are inconsistencies in comfort, although this is the same route and the same vehicle.

V. CONCLUSION

The result of successful implementation of ICT in traffic is a component of smart cities called smart transport, based on intelligent transport systems. One such system is also the system for measuring the comfort in vehicles shown in this paper. Comfort is calculated by measuring vibration, and measurements are recorded and processed using a client-server system.

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. Consequently, the services of another area of smart cities are improving, i.e. smart health. Three scenarios in which the proposed system can be used for this purpose and their implementations are described in this paper.

The subject of further research will be the adaptation of the real-time system, so that it can be a part of the EMS system, as well as the improvement and optimization of the marker clustering algorithms, in order to obtain even more precise information about vibrations while driving.

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