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Geoinformational components of mobile appliances for «Smart City" problem solution: current state and prospects

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Abstract. The results of the investigation of geoinformational technologies application and their component in "Smart City" projects for planning and effective operation control of the city engineering communications by urban infrastructure and geospatial data flow are analyzed. The usefulness of information-technology appliances creation for complex information support of the local engineering communication network function control using the possibilities of geoinformational components is explained.

Key words: "Smart City" project, geoinformational components, city engineering communications, mobile appliance, big data.

INTRODUCTION

"Smart City" is the concept providing information technologies application for creation of comfort living, transporting, effective working, educational, information retrieval, security upgrading and other conditions for people within urban systems (cities, agglomerations, societies, etc.). The motto of the modern information technologies application in urban systems is "Smart, accessible and safe city for everybody". The tasks of city engineering communications control, individual transporting route guidance, e-government, human flow organization and management, supervision over certain categories of citizens: people with mental diseases, children; remote viewing of domestic animals, organization of citizens safety in the shopping centers, near ATMs, in subway and many other tasks can be successfully solved by means of software, algorithmic and information-technology solutions.

THE OBJECTIVE AND TASKS OF THE RESEARCH

The objective of the research is to analyze information-technology appliances available on the market for the support of the processes connected with city infrastructure; to investigate the architecture of the mobile appliances customer part; to explain the importance of creation of effective information-technology solutions for analyzing the state of operation and control of the city engineering infrastructure networks.

The tasks of the research is to find and analyze the effective solutions for creation of software-algorithm mobile appliances for implementation of "Smart City"-class projects designed to provide effective control and analysis of activity and planning of thee city engineering network development using geoinformational components.

The practical usefulness of this paper is in the system presentation of advantages and disadvantages of mobile software appliances available on the market.

THE STATEMENT OF THE TASK.

Modern cities on European as well as on other continents are intensively implementing the "Smart City" information technologies in various fields and spheres. The concept of "Smart City" is interesting and innovative for Ukrainian cities. Before implementing the "Smart City" project in Ukraine it is necessary to analyze the existing in the world experience concerning such information-technology projects implementation and support.

In informational society the "Smart City" concept is becoming more and more important as the source of the citizens living standards improvement. Foreign scientific investigations and application of their results demonstrate that there is no universal solution for city transformation into "smart" one. The "Smart City" projects concept is to be connected to a certain city, prospective areas of intellectual initiative application and to understand that economic, demographic and geographic changes influence the general global trends of city development. The choice of the model of the "Smart City" development depends on local situational factor. Geographical position, population density and connected with it overloading problems are important factors for the determination of the ways for the "Smart City" project implementation. Population increase and urban centers growth cause the series of technical, social, economic and organizational problems which, as a rule, endanger economic and ecological state of the city development. The increase of the number of the city life spheres modified by the "Smart City" projects variety promote its resistance rise on different levels – technological, economic, social and ecological.

The "Smart City" concept implementation requires sufficient material and technical resources and in many cases even structural reorganization of existing systems. At the same time profits from energy savings, control processes optimization reimburse the expenses on their implementation.

One of the most important components of software-algorithm appliances for the "Smart City" is geospatial data.

THE PECULIARITIES OF TECHNOLOGICAL SOLUTIONS IMPLEMENTATION IN THE "SMART CITY' PROJECTS

Implementation and application of information society technologies including technological solutions in the "Smart City" projects specify overcoming several objective and subjective differences which occur:

1. on the stage of data collecting and processing in the processes of information consolidation obtained from the different-type sources and analyses of very large data files.
2. during confidential and personal information (legal aspect) use by accessing and connected with possible privacy breach performing video surveillance, movement monitoring, etc.
3. on the stage of implementation of technical solutions involving agreement with the city governmental and community services concerning the possibility of receiving data for the implemented software-algorithm appliance module functioning. Therefore a considerable amount of the "Smart City" projects are regarded as artificial ones which are difficult to extend within the region or country as a whole.
4. on the stage of product use by the end-user since the development of interfaces and procedures of decision making accounting individual peculiarities of various social, professional and age categories of city residents is very important [7].
5. on the stage of making decisions in the real-time scale which occur due to updating and changes in infrastructural city networks.

THE TRENDS OF THE IMPLEMENTATION OF INFORMATION-TECHNOLOGY SOLUTIONS FOR THE "SMART CITIES"

One of the most promising trends of the implementation of information-technology solutions for the "Smart City" projects are the processes of the city energy network control and application of effective policy of energy saving in urban systems. Information-technology solutions concerning data analysis processes regarding energy consumption in large city are offered in the papers by Kaylee Zhou, Chao Fu, Shanlin Yan [13]. The approach according to which the integration of geospatial data (energy-communication network, meteorological charts) with statistic data about energy consumption according to the city life rhythm using big data technologies is suggested.

Kerry Schiel, Olivier Baume, Geoffrey Caruso, Ulrich Leopold [14] have analyzed certain aspects of energy consumption in the city: this means the hazardous emissions, their reduction due to the implementation of effective energy saving measures. The authors created web-oriented platform for monitoring performance and hazardous emission analysis as well as energy demand in different city districts within 24 hours.

Another important trend of the development and effective use of the "Smart City" concept application is traffic flow logistics and management. To increase the supply chain efficiency and reduce losses from transport delays resulting in deterioration of goods, the model [15] which includes three main components of the "smart" transport management, i.e. "smart" goods, "smart" vehicles and "smart" infrastructure is offered. The given model is essential for implementation where GPS navigation and digital maps are used to optimize the route, transportation and to position the goods temporary storage.

The problem of traffic jams on the city highways is one of the critical ones in big cities. The "smart" solution of the problem of the city transport time-table [17] management is suggested and the system of traffic dynamic management on the basis of optimal distribution of transport infrastructure space aimed at traffic jams and accident situations decrease is developed. Simulator which allows to model the driver behavior at installation of new regulating road signs and their influence on traffic is created.

We should understand that popularity of appliances for the "Smart Cities" is growing rapidly and the number of their usage profiles is increasing. This fact stimulated to carry out analysis of the "smart" mobile appliances popularity among the businessmen [16]. Comparison of mobile business-appliances loaded and registered on Brussels residents smartphones was made according to the following criteria: Google Play or App Store receiving source; paid or free-of charge appliances, categories of the customers chosen appliances (financial operations, travelling, currency exchange, etc.).

Michele De Gennaro, Elena Paffumi, Harald Scholz, Giorgio Martini [18] have analyzed the experience of San Francisco (USA) and Seoul (South Korea) cities where the "Smart City" systems were effectively introduced. The authors came to the conclusion that effective and stable "Smart City" systems occur as the result of dynamic processes where the persons of the state-owned or private sectors should coordinate their activity and join their possibilities and resources. It is suggested to form the system of city smartness evaluation on the basis of eight factors which generally stimulate the "Smart City" concept implementation. The advantages which these smart cities got from complex control systems introduction were also analyzed.

The implementation of the "Smart City" principles and information-technology platforms is impossible without modern high-speed and effective networking use. Evgeny Khorov, Andrey Lyakhov, Alexander Krotov, Andrey Guschin [19] have analyzed possibilities and effects, cost and technological alternate solutions for the city area dense covering with wi-fi network technology for rapid introduction of self-regulating city systems and communication between various technological components in the “Smart City” (“smart house”, “smart communication networks”, “e-government” and others).

THE ARCHITECTURE OF THE “SMART CITY” APPLIANCES

One of the prime components of software-algorithm appliances for the “Smart city” is geoinformational platform. According to the geoinformation use character the “smart” information-technology solutions can be referred to passive or active ones. Passive appliances use goedata as the source of cartographic information or route visualization [9]. Active appliances for the “Smart City” are able to supplement or update cartographic information in the real-time mode. For example as far as new building is concerned it is ATM mounting, new shopping centre opening, etc. [10].

The information technologies of software-algorithm appliances oriented on the “Smart City” residents needs as a rule provides collection, updating and processing big data. In its turn this generates practical need of big data information technology use on the level of municipal decisions as well as personalized data processing [12-14].

Mobile information-technology appliances usage provides that the customers part will use minimal resources taking into account the limits of storage space of mobile computer devices. It provides the storage of the main information bases and their processing on the server part. The effective solutions in this case are usually based on cloud computing [11-12].

Data on appliances for the “Smart City” taking into account its architecture are given in Table 1.

Table 1. Architecture of software-algorithm appliances for the “Smart City”

References	User category	GIS	Big Data	Statistical maps	Dynamical maps	Active appliance	Mobile appliance	Cloud computing
[1]	a, b, c	+		+	+	+	+	
[2]	a, b, c	+		+	+			
[3]	c	+		+		+		
[4]	a, b, c	+		+		+		
[5]	a, b, c	+			+	+		
[6]	a, b, c	+		+	+	+		
[7]	a, b, c	+			+	+	+	
[8]	c	+		+			+	
[9]	a, b, c	+		+		+	+	
[10]	c	+		+		+		
[11]	a, b, c	+	+					+
[12]	c	+	+	+				+
[13]	c	+	+	+	+			
[14]	c	+		+	+	+		+
[15]	a, b		+					+
[16]	b	+		+		+	+	
[17]	b	+	+	+			+	+
[19]	a, b, c		+				+	

a– an average citizen; **b** – tourists; **c** – community services.

THE USERS

The users of software-algorithm appliances for the “Smart City” regarding their location can be relatively divided into three categories:

- the user is at home
- the user is at work
- the user is travelling around the town

Depending on its location the user can use various “smart” appliances.

In case when *“the user is at home”* the safety-related tasks and the tasks for adjustment of comfort conditions in the users flat are updated. The “smart house” concept is based on the modern informational technologies designed to improve sufficiently the house keeping processes. The main problems to be solved are organization of security from outside invasions, home microclimate setting (temperature conditions, plants watering, air moistening, etc.), remote supervision over the children, people with special needs and aged people, domestic animals, employees and other.

The situation *“the user is at work”* refers not only to the use of various appliances for industrial processes automation but also to the possibility to use solutions allowing to track location of communal and municipal workers (fire fighters, policemen, taxi drivers), to control social work progress and performance, etc.

The situation *“the user is travelling around the city”* is demanded not only by the city residents but also by the guests and tourists. The main problems to be solved here are information search, route mapping and updating in the real-time mode.

THE SPHERES OF INFORMATION-TECHNOLOGY SOLUTIONS USE FOR THE “SMART CITY” ARE:

1. management of crowded areas;
2. transfer of people flow;

3. regulation of public transport traffic density;
4. e-government;
5. processing of city residents personal data;
6. control of informational and communicational networks;
7. mapping and correction of transport routes in the real-time mode;
8. creation of 3-D models of buildings and city engineering communications;
9. procedure of city planning;
10. energy saving and energy supply management.

In order to solve the above listed problems it is necessary to use spatial data depicting:

a. transport routs, subway and public transport stations;
b. public spaces;
c. communal, public and governmental establishments (hospitals, banks, petrol stations, etc.);
d. spatial layout of streets, buildings, dwellings;
e. spatial layout of engineering and communicational networks;
f. spatial layout of trading and business institutions;
g. spatial layout of tourist and entertainment establishments;
h. meteorological charts with corresponding forecasts.

Table 2. Problems, solved by means of the “Smart City” oriented software-algorithm solutions

References	GIS platform	Problems	Used data about urban infrastructure
[1]	ArcGis	1, 2, 3	a, b, c
[2]	GoogleMaps	4,5	d
[3]	ArcGis	6,7	d, e
[4]	ArcGis	7	a, b, c
[5]	GoogleMaps	7	a, d, g
[6]	ArcGis	7	a, d, e
[7]	ArcGis	8	a, d
[8]	ArcGis	8, 9	d, e
[9]	GoogleMaps	7	a, b, c, d, e, f
[10]	-		-
[11]	ArcGis	7	a, b, c , d, f
[12]	-		-
[13]	Gis but not indicated	10	e, h

THE GEOINFORMATIONAL COMPONENTS IN THE “SMART CITY” SOFTWARE-ALGORITHM APPLIANCES

In most analyzed by us information-technology solutions in the context of the “Smart City” formation the geoinformational components, systems or complexes are used in one way or another.

Geoinformational components used on different technological stages of the “Smart City”-class system formation are described in 28 papers among 38 analyzed ones published in 2010-2016.

Among proprietary designs of the geocomponents of soft-ware-algorithm appliances for the “Smart City” we distinguish them as:

1. *Data sources.* The import of maps or map components depicting the layers of the subject sheets about objects (highway maps, city streets network, maps of logistic, energy and communal infrastructure, etc.) is carried out from geodata bases. Further geodata processing aimed on generation of solution options, alternatives or data search on user request is performed. The basic requirement to geodata sources is availability of the widest set of subject layers and various scaling of digital maps as well as data updating frequency [1,15,18,28]. The fundamental motto for geocomponents of the “Smart City” software-algorithm appliances sold as data sources is stated as *“There is no extra geodata. All information should be presented immediately and should be located in the single data store.”*

2. *Means of geodata storage and visualization.* In this case geocomponent is one of the basic appliances oriented on the ‘Smart City”. In many cases geocomponent is responsible for resulting map creation (prediction of urbanization processes, modeling of crisis phenomenon and emergency situations), depicting analysis results (rout mapping, modeling of alternative solutions, monitoring of process courses (traffic jams, crowds during public events, operation of public transport and subway system, etc.). To solve these problems the complete set of map with various scales is not required. Usually single-purpose maps presenting 1-3 types of the object [2,8,25] are used. The main requirement is availability in geocomponent of built-in map editing, updating and mounting means.

Digital maps used in information-technology solutions for the“Smart Cities” can be divided into *static* and *dynamic*. *Static* maps are considered to be unchangeable in the processes of technical appliances use, they are not updated or very rarely updated by geodata suppliers (several times a year). Highway, objects of logistic infrastructure and other maps also refer to this category. Such statistic maps are usually present in engineering-technological solutions for the “Smart Cities” together with dynamic maps [1-4, 6, 8-10, 12-16].

Dynamic maps require more complex application of the “Smart Cities” appliances specifying availability of editing means and creation of new maps. Dynamic maps are usually used in appliances realizing governing and monitoring tasks [1,2,6-7]. The maps often updated by designers or even edited and supplemented from specified appliances are considered to be dynamic ones.

The facts concerning geoinformational component of the appliance providing the search and analysis of the places for alternative energy sources system deployment are given in the paper "Smart Energy Systems for coherent 100% renewable energy and transport solutions" [21]. Conceptually the method is based on supplementing and combining classical electrical networks with recovery means of energy production (solar generators, windmills, etc.).

Various appliances with reality supplements become more and more popular. Geoinformational components tool set is actively used for this purpose. Reality spatial model "supplementing" the project basis is formed in this respect. The results of the development of geoinformational 3D system (Augmented Reality Geographical Information System (ARGIS) implemented in the form of the "Smart City" appliance used for city planning are given in the paper "A 3D GIS-based Interactive Registration Mechanism for Outdoor Augmented Reality System" [22].

Hubo Cai, Asadur Rahman, Xing Su, Hongtao Zhang [26] described original approach to the solution of the problem of city transport flow management. Due to geoinformational component the selection of the optimal location of traffic signs, barriers and fences for higher traffic safety is carried out. Road fork and complex highway networks in big cities require balancing according to the following principle: too much traffic regulation causes traffic jams, too little results in higher risk.

Urbanization processes prediction is one of the vital problems solved by geoinformational technologies application [27]. In general urbanization is a spatial process. It is favorable to use geoinformational tools for its description.

The appliance implemented on the basis of goeinformational components for city planning [28] using multilayered maps is also of great interest. Decision making in the outskirts of built-up areas is complex multicriteria problem in which the factors sufficiently depend on spatial object location.

ORGANIZATION OF UNDERGROUND INFRASTRUCTURE NETWORKS AND COMMUNICATIONS IN THE "SMART CITY"

In the developed information-technology solutions for the "Smart Cities" there is practically no means of analysis and management of the state of the city engineering networks and underground communications. Certain single-purpose maps of underground electric and gas networks, subway, etc. [14,20,28] are available.

Engineering networks and city underground communications are rather sophisticated systems and their state monitoring in big cities, development process optimization are very important information-technology problems which at present have no complex technological solution.

In order to improve and perfect the processes of city underground communication management it is reasonable to create information-technology solutions based on goeinformational components providing effective presentation of city engineering communication networks and fundamental analysis of their state and prediction the of the prospects of their development.

The high level of urbanization in modern society, megapolises foundation, the growth of city population cause the need to explore subsurface layers in the cities providing the improvement of the common city environment state as well as the development of underground communication systems. The exploration of the city subsurface layers is an important problem which solution provides extension of modern information technology use for effective formation of the city underground communication infrastructure.

Modern cities are complex systems characterized by the great number of interdependent informational, technological and economic processes. It requires finding the ways of implementation of the new approaches to city planning and residence to provide effective vitality and prosperity in megapolises. The development of communications as the most important components of any settlement supply plays the big role in these processes. Engineering networks including pipelines for drinking and industrial water supply under pressure, air, gas, oil, and other industrial products and materials, drainage, household and industrial sewerage (gravity sewers) and high voltage and weak-current cables, electric and communication transmission lines. Some city areas are distinguished by tight weaving of communication lines in such extend that cause difficulties in repair works performance and new communication laying out. Engineering networks are located mainly in the ground subsurface layers and it is possible to form their topographic form only due to special geodesic procedures. Effectiveness of engineering communication research in most cases depend on the method of geodesic inspection results analysis.

The method of subsurface sounding and profiling by means of broadband noncontact radrar is used for the problems of geological engineering, hydrogeology, high-rise construction, archeology, ecology, field engineering and search and rescue operations, etc. The subsurface sounding is the main component of the "Smart City"-classprojects as infrastructure modelling shoul be based on the use of already existing and new communication networks. There are a lot of methods of subsurface layers deep sounding such as: magnetic location, seismic sounding, magnetotelluric soundung, radio-frequency surveying, induced polarization, borehole surveying, gravimetric analysis, magnetometry, geothermal methods, remote sensing.

The method of magnetotelluric sounding is based on the non-contact mono-pulse stroboscopic investigations with ultra-wideband frequency range. This method of research allows us to find and determine the spatial boundaries of various heterogeneities deposits with different conductivity and dielectric penetration.

Підповерхневі шари історичної частини соціополісів, а це переважно центральної частини великих міст, потребують детального міждисциплінарного дослідження, що зумовлено низкою причин [37], серед яких:

Sub-surface layers of the historical part of the sociopolises, which are mainly in the central part of big cities, require detailed interdisciplinary investigation caused by a number of reasons [2], among them:

- the complexity of the survey processes by the method of deep electromagnetic sounding of the city certain areas, the results processing which requires complex approach;
- high probability to stumble the wartime weapon residues during earthwork performance;
- prohibition of the deep earthworks performance in the historical part of the city, etc.

In such situations it is reasonable to carry out deep sounding of the underground environment using the georadar and to process the obtained data with the help of specialized software..

Detection of underground networks is done by means of existing methods particularly those that provide accurate geodetection of the underground networks regardless of their material, their purpose or soil composition where they are laid .

Carried out by us research makes it possible to perform safe earthworks near underground networks or located pipelines avoiding accidents which consequences are disastrous and lead to sufficient financial losses or damages. The investigation of the underground communications is the component part of the “Smart City” and provides topographic terrain study. The results of the underground communications study are exposed on the separate topographic scheme which is inseparable part of the “Smart City” projects technical documentation.

In September 2016, we carried out primary research works concerning deep electromagnetic sounding of the territory of Ternopi lcity historical part. The tasks were as follows:

- determining and fixing of the levels of radiation sources (stationary and mobile) and of the electromagnetic field strength for existing communication systems in the area where the research were carried out within georadar operation frequency ranges of;
- obtaining the materials for the city complex communication infrastructure modeling;
- determining the appropriate depth of sounding (clarification of the dielectric penetration of the ground covering);
- obtaining the initial data for further systematic interdisciplinary processing.

Portable multipurpose georadar EasyRad GPR Pro with the following specifications [38] was used:

• The distance between receiving and transmitting dipole antennas is 101cm;

• Research frequency ranges - (20 -400) MHz;

• Power consumed by the device, 4.8 Watts

• Maximum voltage of the sounding impulse, 1000 V

• Frequency of sounding impulse passage, 70 ... 100 kHz

• Duration of the sounding impulse, 2-8 ns

• Maximum sounding depth (norm 100 MHz), 24 m

• Vertical resolution <10 cm

• Horizontal resolution <10 cm

• error of electric constants analysis and the rate of radio waves propagation in soil, 15-20%

• Error of soil moisture content analysis, 20-30%

• personal computer interface - USB, Wireless

• data rate, 115200 bits per second

• time of continuous operation of the batteries is not less than 8 hours

• operating temperature range (-10 ... + 50) ºC

Radarogram processing is done using the Prism2 software, which is based on the use of known image recognition methods.

Radargrams processing is done with the use of software Prism2 based on the usage of existing methods of image identification.

Table 3.– Scheme of “Engineering communication in the smart city” project data flow

Users data	**Functions performed by module / Users (business, citizens, power)**	**Problems solved by designer**	**The object of creation/ Transparence, monetization**
Data analysis	Analysis, visualization	Web-interface, users graphic interface, API	Monetization
Data exchange	City data storage	Functional compatibility	Rights for data, monetization, open data, privacy
Data storage	City data storage	Safety	Data structures
Gis data	City data storage	Services	Multilayer maps of city communications
Data transfer	Gateway	Safety	Protocol
Collecting data	Sensor	Safety	Interaction protocol
Data creation	Physical systems	Contracts	M2M
	Social systems	Safety	

CONCLUSIONS

The basic tendencies of the development and implementation of the "Smart city"concept in various spheres of city life are analysed in this paper. Classification of software-algorithmi appliences for the "Smart cities" according to architectural solutions and fields of use is developed.

The factors influencing the use of the geocomponent functional capabilities in software-algorithmic appliances, oriented to the information-technological support of the problems solving in "Smart cities" projects are analyzed.

The relevance implementation of geoinformation components in appliences with effective means of analysis and planning of the city engineering infrastructure development, communication networks and research facilities under surface layers is substantiated.

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