Urban Gamification as a Source of Information for Spatial Data Analysis and Predictive Participatory Modelling of a City's Development

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Abstract: The basic problem in predictive participatory urban planning is activating residents of a city, e.g. through the application of the technique of individual and/or team gamification. The authors of the article developed (and tested in Płock) a methodology and prototype of an urban game called "Urban Shaper". This permitted obtaining a vast collection of opinions of participants on the directions of potential development of the city. The opinions, however, are expressed in an indirect manner. Therefore, their analysis and modelling of participatory urban development requires the application of extended algorithms of spatial statistics. The collected source data are successively processed by means of spatial data mining techniques, permitting activation of condensed spatial knowledge based on "raw" source data with high volume (big data).

1 INTRODUCTION

In modern times, access to data (including spatial data) has become relatively easy. "Raw" data, however, require transformation into useful information, and then into applicable knowledge and skills of decision making based on the obtained analysis results. Activation of knowledge based on available information (also spatial information) is therefore of key importance in the epoch in which factories have ceased to be the places generating economic value, and media and teleinformation networks have become such places.The approach proposed by the authors combines the possibilities of GIS packages and statistical software. It permits the performance of very complex analyses. One of the methods of such an analysis is the application of so-called data mining and data enrichment for the detection of patterns, rules, and structures "hidden" in the data base. Source data, e.g. location of objects in the geographic space and attributes describing them are almost commonly available. The determination of temporal-spatial correlations, key factors determining changes, or the spatial scale of their effect, however, require the transformation of "raw" data into information.

The authors used spatial data mining techniques to analyze the data collected for the city of Płock (with 100 thousand residents), in order to identify significant phenomena and problems occurring in the city.

2 INFRASTRUCTURE AND SOCIAL PROBLEMS OF PŁOCK

Płock is a city located in the Mazowieckie Voivodship, approximately 115 km west of Warsaw, the capital of Poland. The city has a population of approximately 125 thousand over an area of 88 km^2. In administrative terns, Płock is divided into 23 districts, including 21 residential districts, and two uninhabited industrial districts.

In the scope of revitalisation activities, the city authorities identified crisis areas with concentration of negative social phenomena, as well as economic, spatial-functional, technical, or environmental issues. The areas are also distinguished by an insufficient level of social participation and participation of residents in the public and cultural life of the city. In 2014, the Municipal Office of Płock conducted a

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Figure 1: Study area divided into 5 parts with 38 points of interest.

survey providing answers of 1904 respondents. In each of the designated areas, the following groups of problems were defined: technical problems, social problems related to the quality of life of residents, and problems concerning lack of certain forms of activity near the place of residence. Residents also identified areas requiring revitalisation. The results of the survey permitted preliminary verification of the main problems occurring in the selected part of Płock. For example, residents of the city centre (Old Town district) point out lack of places permitting various types of activity near their place of residence. The analysed area lacks places for spending free time (e.g. local club, internet café, library, fitness club, community centre) or events integrating the local community. Based on this information, the authors of the article selected an area located in the city centre for the analysis. The area was divided into five sub-areas differing in terms of main problems and barriers for local development. A total of 38 objects of public utility, parks, tenement houses, etc. evoking strong emotions in the residents of Płock were also identified in the area (Fig.1). The size of the pie chart represents the varied level of activity of the game participants in reference to particular objects in five selected areas of the city.

The following priority problems were identified for the designated areas:
Area 1 - "Tumska" – problem of the renovated Tumska Street (promenade) which contrary to the assumptions did not become attractive for the residents and new tenants;
Area 2 - "Obrońców Warszawy" (Warsaw Defenders' Square) – low standard of public space;
Area 3 - "Park na Górkach" – degraded green areas in the city centre;
Area 4 - "Nabrzeże" - problem of connectivity of the city with the river, low standard of public space;
Area 5 - "Starówka" (Old Town) - low standard of building development, depopulation of the area.

The identification of the primary problems of the city requires appropriate analysis of collected data. In order to transform passive and atomized individuals into open (geo)information society developing a vision of development of the city in the process of social participation, it is crucial to reach the emotions of the citizens, and to release their social energy. The opinions of the residents are valuable for further actions. One of the most effective (and most enjoyable) way to achieve such an effect is so-called gamification, i.e. encouraging the participants to take part in the mass "game" involving mobile applications, advanced technologies applying e.g. computer game engines, and elements of augmented reality.

In order to convince the city residents to express their opinions on potential directions of development of the city and its revitalisation, the authors developed a methodology and prototype of an urban game called "Urban Shaper". Tests of the game conducted on a

group of approximately 250 residents of Płock permitted obtaining a set of spatially distributed source data. The opinions of the residents, however, are expressed in an indirect way. Therefore, their analysis and modelling of the participatory process of the city's development requires the application of extended algorithms of spatial statistics.

2.1 Gamification in Collecting Spatial Information

For the purpose of increasing the involvement of recipients in the designed platform for collection of information regarding urban space, our team referred to solutions based on gamification defined as "the use of the mechanics and aesthetics of games and game thinking to increase the involvement of people, motivate action, and promote learning and problem solving training" (Kapp, 2012). Gamification is a relatively new trend emerging from deliberations of several researchers dealing with the effect of games on the life and behaviour of people, as well as from practical experiences of companies using gaming mechanisms to determine the behaviours of their employees (Clark, 2009; McGonigal, 2011; Zichermann, 2013; Robson et al., 2015). The key features of the approach include (Kapp, 2012):

- Development of a system with features of a game, aimed at involving participants in an activity based on a system of rules, goals, interactions, feedbacks, and measureable score system;
- Use of particular mechanisms typical of games such as points, levels, score, or time limits for the performance of particular tasks;
- Development of a coherent plot and aesthetics characteristic of a game;
- Generating a playful approach to the activity in participants, leading to an increase in internal motivation for action;
- Focusing on the subject of the game, and increase in emotional involvement for better memorisation of new content, and faster learning in such an environment;
- Development of a clear motivational system for participants;

Both the source data collected in the process of gamification and the resulting information are of georeferential character – they refer to a particular place in space, and are differentiated in such space. Therefore, their analysis requires the application of spatial data mining techniques, and the visualisation of results – a map (Goodchild, 2007; Gąsiorowski, Hajkowska, Olszewski, 2015). The application of modern advanced information-communication technologies permits fast obtaining of information resources of big data type. Their exploration, however, requires the use of a map (Fiedukowicz, 2013). Owing to the applied approach, large sets of spatial data are subject to interpretation, generalisation, and aggregation, leading to the development of a map as a medium of transfer of legible spatial information.

Research in the field of gamification, and knowledge acquisition from spatial data bases (Piatetsky-Shapiro, Frawley, 1991) are parts of the broadly defined concept of a smart city (Opromolla, 2015; Uskov, Sekar, 2015; Cecchini, 2015).

2.2 Game "Urban Shaper"

Game "Urban Shaper" is a network application developed in PHP language, adjusted to be used during workshops and discussions with residents. Data collected during the game are saved in the form of XLS spreadsheets, and exported during post-processing to a data mining system permitting their more thorough analysis.

The game has an implemented functionality of supporting real maps with marked points (buildings, areas) which the described problems and activities conducted by the participants concern.

Each team of 20-25 persons is divided into five groups of 4-5 persons. Each group receives information concerning their district/area of the city, demonstrating the state of buildings and places covered by the activities of the team, as well as problems occurring in such places. Each place and problem is described by means of five parameters: public services, recreation, commercial services, technical state, and tourist values.

Based on the awarded virtual "budget", the participants perform activities involving the elimination of particular problems (e.g. repair of broken lighting, repair of road surface, replacing heating systems in municipal buildings), or introduction of positive changes by adding new functions to particular areas (e.g. assembly of a playground, opening a community centre for residents).

The game can also be used as a tool for collecting geoinformation data during workshops as a part of the social consultations process.

The categories of information collected during the game include:

- buildings and areas attracting the attention of the participants to the highest degree;
- the most frequently selected revitalisation activities;
- problems most frequently pointed out by the participants as requiring close attention;

- differentiation of the strategy of spatial management depending on the area of the city;
- key functions ascribed by residents to particular areas;

The game offers a possibility of choice of a score system in a round in which the tool itself implements specified persuasion goals which can include:

- presentation of the most cost-effective revitalisation strategies;
- incentive for the development of strategies responding to specific objective problems of a given area (e.g. low availability of public services or recreational areas);
- generating interest in a specific area of the city or a specific category of activities, usually omitted by residents in proposals of corrective actions;

The selection of areas, problems, and information on potential revitalisation activities can be done in several ways.

Firstly, the information can be provided by the institutions of the city ordering conducting the workshops based on data available to public offices – e.g. information on the technical state of buildings, amounts of rent, purpose of particular areas, and information on social problems in particular parts of the city (e.g. from an institution of social welfare or the Police).

Another way of collection of the information (such a system was applied during the implementation of the pilot project in Płock) is the use of the existing results of surveys concerning opinions of residents regarding the revitalisation of the city, or conducting a mini survey on the subject. Such a survey can be of qualitative character, and has to be conducted based on a representative sample of residents – its exclusive objective is to obtain possibly the broadest range of proposals of places and problems that should be included in the game, without the necessity of estimation of their quantitative importance.

The approach of the Authors is not the only such solution in the world (more examples are described on websites: www.urbaninteraction.net/city-gaming/, www.blog.eai.eu/serious-games-in-sustainable-urban-development-part-1/). However the majority of existing games do not work on current spatial data, and they are not used as a tool of public consultation and social participation.

3 RESULTS OF THE PILOT GAME IN PŁOCK

The developed urban game methodology was tested on 15 April 2016 in Płock during the pilot game jointly implemented by team "Coniuncta" and the Municipal Office of Płock under the auspices of the International Training Centre for Authorities/Local Entities (CIFAL - Centre International de Formation des Autorites/Acteurs Locaux) of the United Nations Institute for Training and Research (UNITAR). The study involved the participation of more than 160 high school students aged 16-18.

Data collected during the pilot game were additionally enriched by attribute-spatial information obtained from the topographic data base and municipal registers, e.g. several thousand sale-purchase transactions permitted the development of a map of differentiation of real estate prices in Płock. The use of topographic data permitted the determination of distances from particular schools to 38 objects constituting elements of the urban game, because the level of interest of the participants in the technical state of such objects was very diverse. On the map (Fig. 1), the size of the pie chart represented the varied level of activity of the game participants in reference to particular objects in five selected areas of the city. The determination of the Pearson's correlation between real estate prices in a given area of the city and the level of interest of participants (Fig. 2) shows quite strong positive correlation between the factors for the Old Town area. In the southern districts: "Obrońców Warszawy" and "Park na Górkach", a negative correlation occurs.

Based on spatial predicators determined based on topographic correlations in the data analyses, such as distance from the school of a given student to points L1-L38, as well as the methodology of forming association rules, the authors proposed the following research hypothesis: "*The objects of interest of young residents of Płock are public purpose objects located within a distance of not more than 600 m from their school (up to 600 m)*". This permits the development of the following fuzzy rule: "*young citizens of the city are interested in public spaces located in the vicinity of the place of their education*".

Similar patterns of data mining were prepared for a holistic analysis of data collected in the course of the game, and general geographic and thematic data collected in the city registers with the application of decision making trees and other methods of machine learning (Fayyad, 1996; Cabena, 1998; Han, Kamber, 2000; Hand, 2001; Miller, Han, 2001; Witten, Frank, 2005; Nisbet, 2009; Fiedukowicz, Gąsiorowski, Olszewski, 2015). After performing the experiment in the majority of schools in the city, the collected data will be thoroughly analysed with the application of such techniques.

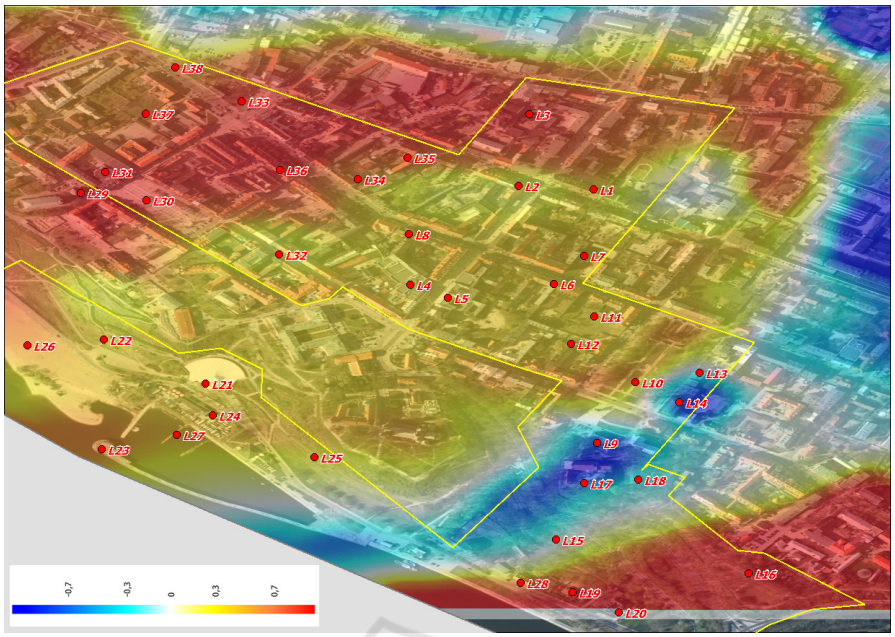

Figure 2: Pearson's correlation between real estate prices and the level of interest of participants.

Example data for area 1 "Tumska Street" concerning effects of decisions made by the participants are presented in the table 1. Point values expressed as the mean and standard deviation permit the determination of the priorities of revitalisation activities, as well as differentiation of decision making strategies adopted by the participants. The observed focus is on recreation and tourist functions of the analysed area, whereas for tourist values, the standard deviation is considerably higher, suggesting lower coherence of decisions in the scope. Low mean and low differentiation of decisions concerns technical state. This suggests that it is not treated as an important issue in the analysed sample of participants of the pilot game in the case of area "Tumska Street" (it can be e.g. a derivative of the actual best technical state of buildings in the area, also evident in the parameters of the location in the game).

Table 1: Decision results for area 1 "Tumska Street".

Area of effect	Progress mean	Progress standard deviation
public services	6.14	1.95
recreation	10.00	1.29
commercial services	5.29	1.80
technical state	5.57	0.98
tourist values	9.29	1.80

4 SUMMARY AND FUTURE PLANS

The results of the pilot game "Urban Shaper" conducted in Płock suggest a number of advantages of this form of activity from the point of view of obtaining information from city residents. The most important advantages observed in the course of the pilot game include:

- the possibility of obtaining opinions from a large group of residents at the same time in the course of a relatively short workshop;
- in addition to obtaining information, the game also offers educational values – it familiarises the participating residents with the basic terms in the scope of spatial planning. It can also constitute a starting point for a substantive discussion on problems faced by particular areas of the city, and optimum revitalisation strategies;

The choice of any setting of the game parameters permits using the game for both obtaining information (in this case the game does not award score to any specific revitalisation strategy), and for educational-persuasion purposes (Bogost, 2010) (in this variant, the game may assume specific preferences for particular models of revitalisation activities, e.g. energy-efficient, cost-efficient, or in accordance with the city's strategy).

The performed research employed exceptionally simple spatially located data available on the Google Maps website in the form of a "classic" map and ortoimage from satellite photographs. The intention of the authors is the expansion of the concept of the research in project FabSpace 2.0 "*The Fablab for geodata-driven innovation – by leveraging Space data in particular, in Universities 2.0"* currently implemented in the scope of programme Horizon 2020, by the application of more sophisticated sources of spatial information, e.g. satellite images SPOT 5 (spatial resolution of photographs 2.5 m-5 m) and SPOT 6-7 (pixel 1.5 m-3 m). The aforementioned systems register the panchromatic scope and near infrared. This permits the development of a composition in natural colours, and e.g. so-called standard composition. On the map, vegetation is represented by red colour, and is very legible. Satellite background defined in such a way can be used in a variant of the game dedicated to the issues of environmental protection, analysis of development of green areas, etc.

The presented issues are at the very preliminary stage of research. The authors plan to conduct the game at a massive scale in order to collect big data for many cities. The proposed (and many others) analytical schemes will be applied and improved.

The currently developed version of the game dedicated for mobile devices will be tested in several selected European cities. This will permit the analysis of spatial big data considering the cultural, economic, and social differences between residents of cities in different countries of the European Union.

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