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STATBOX Concept For Simulation Of Urban Phenomena

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Abstract

An urban environment is a dynamic system which is constantly changing in terms of space and time. There are two dimensions in any urban environment – the physical dimension and the functional dimension. All of the structures of an urban environment interact and people are the intermediaries in this process. The spatial structure of cities has been studied from various perspectives by architects, urban planners, environmental scientists, economists, geographers etc. Constant monitoring that is based on remote sensing, spatial statistics, simulation etc., is needed to make on going note of transformation in the various types of land use that exist, movement of people and business environment. Many authors stressed that using the GIS technology, the spatial features of geographic data can be introduced in the simulation and GIS, spatial analysis plays an important role in the development of geosimulation models. The integration of the virtual reality technology with a dynamic data model will gives a realistic representation and visualization of the real world. Such complex accessibility for the user with an excellent interaction and manipulation capabilities of the virtual environment will be used in different kind of projects connected with simulating urban phenomena or pedestrian/crowd movements. The presented system consists of the STATBOX units, comprising of video data storage. Data collected by STATBOX units is sent to the Main server, where the video data is processed to generate classified information. Based on the collected statistical data, as well as information on the location of the STATBOX units and GIS models of territory, the geosimulation model is automatically prepared. The model is adequate to the real world - no deep knowledge on the simulation techniques is needed to use the proposed system. A prototype of Riga central park performance model is used as an example of STATBOX data collection and simulation process. GIS system with integrated ortofoto map, digital route map, digital plan of landuse, are used as the basis for the model development. The result is a geosimulation model adequate to the pedestrian movement and ready for further experiments. The created system can be used by different users, like businessmen/ investors, researchers, state and municipal institutions. However, the main target group is the SMEs, as they are more flexible and ready to take decision to change location than large companies.

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1. Introduction

Focus of this paper is on the pedestrian behavior in spatial environments, data collection and simulation methods of pedestrian movement models.

As urban environment is a dynamic system the interaction among different kind of functions are extensive and changeable and people are the intermediaries in this process. The constant monitoring is needed to make ongoing note of transformation in the various types of the networks that exist among different spatial structures, links, flows, relations etc. The use of the latest technologies makes it possible to regularly monitor the development direction of the spatial structure. Automated procedures for data collection as remote sensing by spectrometer, aerial photography, video, etc. have provided new information sources at fine resolutions, both spatial and temporal [1].

The GIS is successfully used in researching urbanized areas, and it is of good assistance to urban planners so that they can deal with problems in a quick and precise way when evaluating the development of urbanization and the relevant processes [2] [3] [4] [5] [6] [7]. The implementation different kind of databases in GIS has meant that the process of spatial analysis and modeling of real-time processes and phenomena has become faster, more accessible, and more understandable for those who need to take decisions [8] [9] [10]. The GIS plays also an important role in the development of geosimulation models. New methodologies for manipulating and interpreting spatial data developed by geographic information science and implemented in the GIS have created an added-value for this data [11].

Geosimulation is a modeling approach which is concerned with the construction of high-resolution spatial models. These models are used in order to explore ideas and hypotheses about how spatial systems operate when developing simulation software and tools to support agent-based simulation, and applying simulation to solve real problems in geographic contexts [1].

The recent generation of models employs a multi-agent system (MAS) based approach in order to represent the movement of people in virtual geographic environments. Combining MAS and GIS for simulation purposes gives birth to a new simulation approach called MultiAgent GeoSimulation (MAGS) [11].

Models generally represent autonomous objects, and focus on their interactive behaviour in a system setting [12]. In addition to this, an artificial neural network (ANN) application also includs transport and pedestrian movement planning, as well as transport and land use interactions [13] [14], because the land use system supplies transport system with estimates of the location and volume of travel generation.

The past decade has seen a rising interest in, and strong development of, simulation applications of human behaviors. Simulating urban phenomena or pedestrian/crowd movements has attracted the attention of not only urban planners and government officials, but also of retailers, advertising agents, and people involved in urban management [15].

High-traffic areas such as entertainment parks, museums, sports facilities, etc., need to evaluate the impact of construction changes such as the placement of a new kiosk or advertising panel etc. [16]. Pedestrian movement models have been developed since the 1970s. There are a number of possible approaches to simulating and modeling pedestrian movement [17]. Most models focus on a specific aspect of pedestrian movement, which can often be distinguished on the basis of geographical scale — from the micro-scale movement of obstacle avoidance, through the meso-scale of individuals planning multi-stop shopping trips, up to the macro-scale of the overall flows of masses of people between places [18].

Helbing and Molnar's [19] work on small-scale pedestrian models, which simulate human behavior in crowds and small spaces is noteworthy. In simulation of pedestrian movement the agent based modeling use of Kerridge *et al*. [20] and Batty et al. [10], where agents can simulate the behaviors of individual persons. With macroscopic flow characteristic gathering automatically was developed the real automatic pedestrian counting device using video camera [21].

Some of researchers use cameras in side view and detect the rhythm of walking to discriminate pedestrian from other objects [22] [23]. Pedestrians moving alone can be tracked with very good accuracy [24] used one line detection as the photo-beam technology developed to count the number of pedestrians passing that line using the top view camera. Significant advancement of pedestrian motion analysis was recently developed with a side view camera [16] [25] and [26] employed event detection and activities classification on the video camera for monitoring activities of peoples and spatio-temporal XT slices to obtain trajectory patterns of a human walking [16].

Haritaoglu I. [27] detected single and multiple people through their silhouettes and monitoring their activities in an outdoor environment. The planning process of different kind of spatial structures is advisable to use simulations to compare actual data and the real situation with those that are obtained during the simulation – that makes it easier to forecast the future situation [28].

The proposed data collections and modeling with STATBOX simulation system is a cost-effective and efficient solution for monitoring of the movements.

2. Geosimulation

A relatively new alternative for the research of urban systems is geosimulation [1] that is based on the concept of Geographic Automata Systems (GAS), which tightly couples spatial data and process models within a single, integrated system. Geosimulation is concerned with automata-based methodologies for simulating discrete, dynamic, and action-oriented spatial systems, combining cellular automata and multi agent systems in a spatial context.
Agents in multi-agent system correspond to the following principles [13]:

- Autonomy. An agent possesses individual goals, resources and competences; as such it operates without direct human or other intervention, and has some degree of control over its actions and its internal state.
- Sociability. An agent can interact with other agents, and possibly humans, via some kind of agent communication language. Through this means, an agent is able to provide and ask for services.
- Reactivity. An agent perceives and acts, to some degree, on its close environment; it can respond in a timely fashion to changes that occur around it.
- Pro-activeness. An agent may be able to exhibit goal-directed behaviour by taking the initiative.

The geosimulation agents additionally should correspond to the following principle:

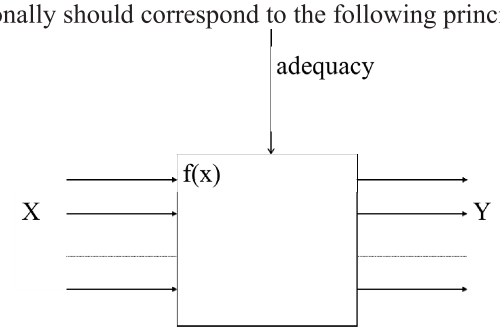

Fig. 1. Simulation concept

- Mobility. Agents can be static or may change their location in time

Geosimulation differs from the traditional urban modelling with the structure and composition of the simulation elements distinguishing four main features [1]:

1. Time representation – usually models of geosimulation systems are executed in real-time simulation mode, where the simulation time is divided into discrete change intervals.
2. Representation of scale - geosimulation systems can provide a very detailed spatial scale of simulation process.
3. Entity-based simulation possibilities - opportunities to provide simulation process at atomic level, where each simulation object has its specific attributes and specific behaviour.
4. Interaction - it is possible to extend the interaction between a localized form of the model entities, or in contrary – in a more general way.

Geosimulation model is based on a real existing adequate model, which is created and used for conducting experiments with it. In this context the STATBOX concept simulation model can be described as a black box with input X and output Y (see **¡Error! No se encuentra el origen de la referencia.**).

Creation of a geosimulation model implies finding such function f(x), which guaranties the same or close to the same result Y as in the real world. In this case the model should include such inputs X, which are significant to the result Y. In most cases the model f(x) is not linear, which means that it cannot be calculated using only mathematical methods. During the experiments it is possible to simulate what happens if the input X is changed; or if the model f(x) is changed, e.g. to see what happens if the left turn is prohibited on a street.
The simulation environment used is a multi-agent simulation system, which allows to describe each object as an agent. Typical structure of simulation procedure is as follows:

- Definition of the problem. In this case it means extracting the simulation system from the real world, analysis of elements and their correlation, collection of statistical data and definition of the simulation task.
- Creation of a conceptual model and a computer simulation model.
- Simulation model adequacy. It has to be kept in mind that the simulation goal is not only finding an f(x), which guarantees an adequate result in Y. In many cases it is possible to create a function y = f(x), but the main function f(x) which is right for the result y, is not adequate to real situation. Thus the statistical data is not only required for exits, but also for any objects inside f(x), which can significantly impact the final result.
- Experiments with simulation model and analysis of simulation results.

According [6], formally, a Geographic Automata System (GAS), G, may be defined as consisting of seven components:

$$\boldsymbol{G \sim (K, S, T_S, L, M, N, R_N)} \qquad (1)$$

where
K – set of types of automata featured in the GAS,
S – set of states
T_s: $(S_t, L_t, N_t) \rightarrow \mathbf{S}_{t+1}$ – set of state transition rules, used to determine how automata states should change over time.
L – the georeferencing conventions that dictate the location of automata in the system
M_L: $(S_t, L_t, N_t) \rightarrow \mathbf{L}_{t+1}$ – the movement rules for automata, governing changes in their location in time
N – represents the neighbours and their relations of the automata

R_N: $(S_t, L_t, N_t) \rightarrow \mathbf{N}_{t+1}$ – rules that govern changes of automata relations to the other automata in time.

But geosimulation is not only simulation methodology itself. It also includes a methodology for GIS model transformation into Geosimulation models. The transformation process is when all GIS layers also are automata and GIS only represents their location. In this case the simulation system adds additional parameters for each GIS layer agent, which are necessary for simulation. In this case according [30] terminology used in GAMA simulation system is Agentification of GIS data.

3. System description

The system consists of several STATBOX units and a Main server (see figure 2)**¡Error! No se encuentra el origen de la referencia.**. STATBOX controls the given territory by means of video surveillance. If a visual change appears, it is assumed by the system that there is an object whose movement has to be monitored. In this case sensor saves video data for future analysis (RAW DATA). All raw data from sensor after a certain time period is sent to the Main Server (MS), which
collects data from all sensors. After collecting raw data, Statistics Data Processor (MS internal service) processes all raw data and extracts all object movements. All moving objects are compared to each other by the neural network and then stored into the database.

Database enables generation of statistical reports (how many objects have been monitored by particular sensor in a given period of time). Based on the database and the GPS information from sensors and available map data, MS simulation process builds a simulation model for the analysed territory. In order to collect this data, the users should place the STATBOX receivers in the chosen place for a certain period of time, and after the necessary data is collected and processed; users get ready simulation model for further experiments.

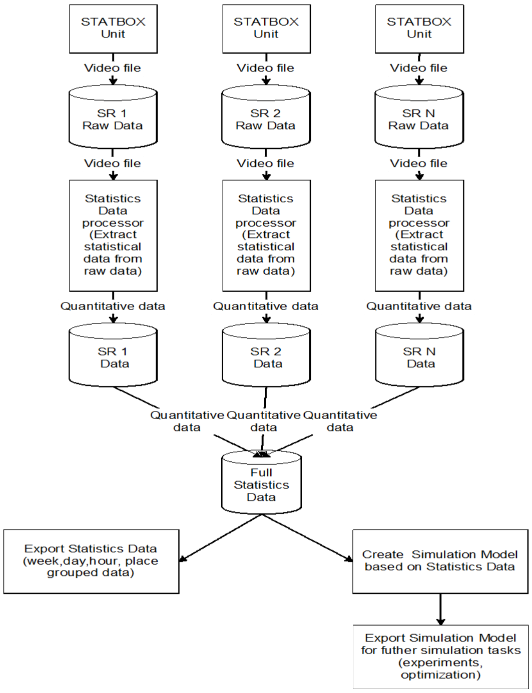

Fig. 2. STATBOX concept

4. Example

The basis selected for the STATBOX approbation and model creation is Vermanes park in Riga. This park is not only a recreation green zone, but also a transit way for many pedestrians. The park is compact, closed area with the total of 11 exits.
The research process is divided into three steps:

1. Collection of statistical data at the exits;
2. Approbation of the STATBOX concept;
3. Creation of an adequate geosimulation model, and determination of the behaviour model with and without object recognition.

For the approbation purposes in two places of the park (see the white points in the fig 5) at the same time video has been taken. Number of people crossing the park was average, compared to the rush hours, and the weather on that day was sunny. The video devices used were two similar mobile phones (Iphone 4s). Taking into account the shading effect, video was calibrated with same colour etalon. Length of video was approximately 2 x 15 minutes.

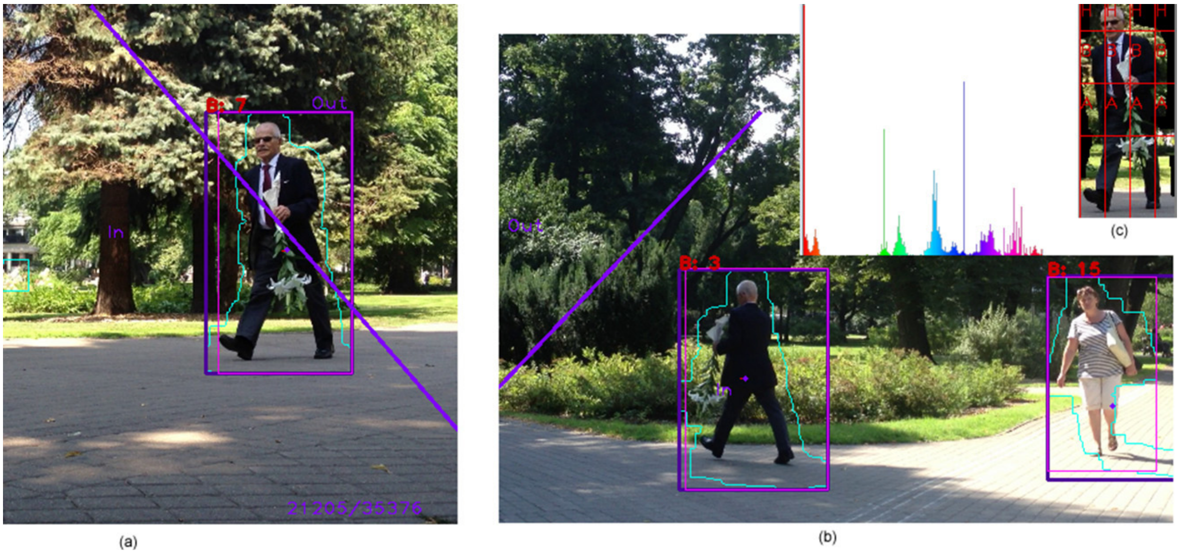

Fig. 3. video motion

In video analyse process At the beginning of the video analysis process, the dividing line is determined manually (see figure 3).
(a), (b) dividing line) to define the “in zone” and the “out zone”.

The further video analysis functionality includes recognition of objects in video file; extracting objects from video frame and creating metadata information necessary for object comparison with already saved objects from any of STATBOX units (see figure 3).

(a) un (b)). Metadata is created from a complex histogram. The histogram is created from several object parts (see figure 3)

(c)). Object comparison is based on a feed-forward neural network (see figure 4). In the current example, the first layer contains 192 neurons (inputs), the second (hidden) layer has 16 neurons, and output layer has 2 neurons. The recognised objects from all STATBOXes are compared to each other. For example, for object in

the figure 3 there are 207 pictures recognized from one video and 152 pictures recognised from the other video. In the comparison process there are positive results in 80.92% cases.
On the basis of software for visual recognition have taken C++ with OPENCV library.

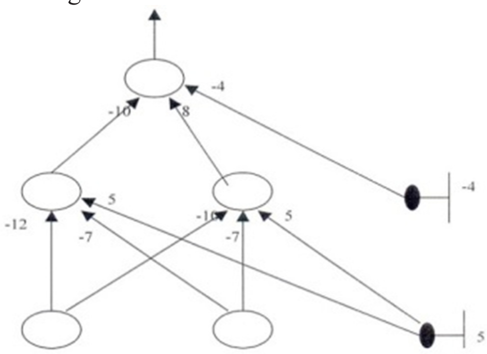

Fig.4. Feed forward Neural network

5. Geosimulation model

The park has 4 main exits and 7 less important exits. The transit flow connects the two diagonal exits, as well as the two side exits, where pedestrians cross the park without stops. The other park territory is green recreation zone, which is used by the other park visitors. During the first experiment a geosimulation model was created using number of pedestrians entering and leaving the park without their recognition (see fig 5,(a)). As visually seen, there are significant flows by diagonal and also between all main exits. Compared to the real situation, there is no flow between Merkela/Barona street and Merkela street; Merkela/Barona street and Barona/Elizabetes street; Barona/Elizabetes street and Elizabetes/Terbatas street.

During the second experiment, the collected data was used for recognition of pedestrians entering and leaving the park. In this case the visual model is adequate to the real situation (see fig 5,(b)).

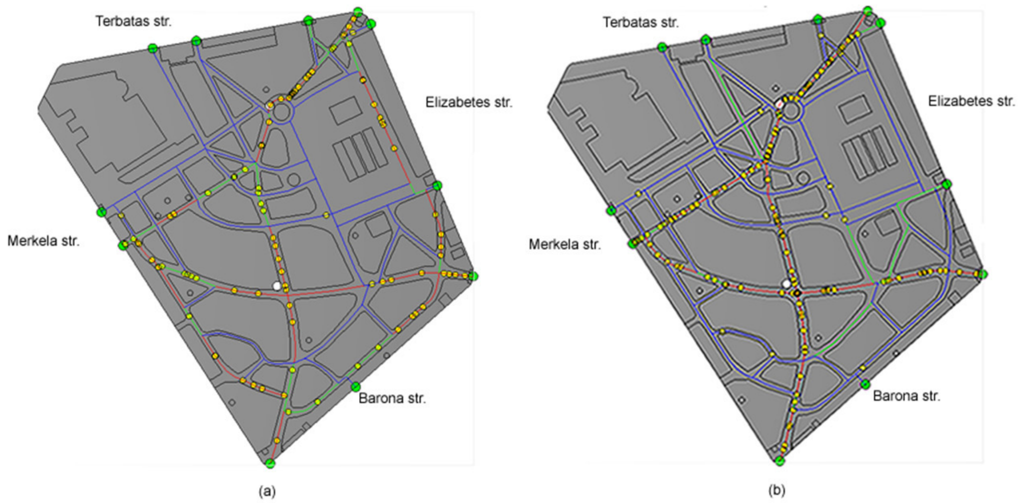

Fig. 5. Geosimulation model

On the basis of simulation language for automated simulation approach have taken GAMA simulation platform [30].

6. Conclusions

The presented research is devoted to the creation of geosimulation models based on the GIS models and acquired information on pedestrians entering and leaving the territory. This information includes not only the number of pedestrians, but also their conceptual visual recognition. The GIS model at the beginning is "agentised", which means that all GIS model objects are interpreted as agents in geosimulation model.

The creation of geosimulation model is a time-consuming and complicated exercise. Nevertheless, it is possible to automate many functions of model creation. Use of the statistical data and capacity data in GIS models and additional description of movement object nature allows for creation of an adequate model not only to statistical data, but also reflecting the real situation.

The further research should be directed toward increase of the visual recognition quality. If objects' histograms functions are similar, comparison process sometimes identifies wrong objects as similar ones. In this case there is a clear need for inclusion of additional meta information, e.g. identification of special markers, like bicycle, carry-on bags, textures. This can be done by use of better visual segmentation algorithms and use of additional technical solutions, e.g. video cameras together with infrared cameras. This work should result in a complex solution, which includes collection of statistical information and its preparation for future tasks in model creation. This complex system will allow solving many geolocalization tasks in the future.

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