Mobile Location-Based Social Distancing Recommender System with Context Evaluation: a Project Approach

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Abstract

This paper describes main modern tendencies for projects in the design and development of urban route planning recommender systems. In this research the difficulties and unsolved problems were analyzed for development and use of location-based mobile recommender systems for social distancing. This paper focuses on project of development of mobile location-based recommender system with context evaluation. The main features of decision-making on passing and changing the route are analyzed. Technologies for determining the danger of crowding and managing human flows have been studied. The study considers the possibility of creating software to manage the flow of people within the city to ensure social distancing. A prototype of a mobile application has been created, which will be used to teach the multi-agent system the peculiarities of the space-time behavior of pedestrians during quarantine.

Keywords 1

Mobile location-based recommender systems, urban route planning, social distancing, crowd prevention management

1. Introduction

The key element for social distancing is the management of human crowd [1]. Everyone has a smart gadget of one type or another and information technology for managing big data, including personal data of smartphone users, opens up new opportunities to prevent crowds.

Route planning in the context of urban infrastructure and with the provision of social distancing is a guarantee of safe, efficient and "smart" navigation of people within large settlements. Classically, the task of paving a route is usually solved for cases of tourist travel, long-distance travel with a large number of points to visit, or travel to unfamiliar places.

Crowd management, organization of human flows during mass events, during rush hours at traffic interchanges, in crowded places was still considered a task relevant to megacities, festive and festival events, places of religious pilgrimage, etc [2].

This was not a problem for non-urban areas, the daily life of provincial cities, and even low-density countries. The 2020 pandemic has changed the situation radically.

2. The human crowd prevention management

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The current level of development of mobile devices allows them to implement different types of sensors (eg, GPS, accelerometer, camera, digital compass, magnetometer, barometer, gyroscope) [3]. Thus, "smart" devices (such as smartphones, Google glasses, Apple Watch and Mi Band) can be used to collect a variety of spatial information about the user, as well as from the environment. Mobile devices can now be used to determine noise levels, speeds, temperatures, and more. Meanwhile, these devices can upload sensor-sensitive data to the data collector's server over wireless access networks, such as cellular or Wi-Fi, at a convenient time and location.

Thus, it becomes technologically possible to develop mobile crowd sensing (MCS) [4]. MCS is a paradigm that encompasses a large number of people with sensor and computing devices, in which people can collect probing data and receive certain information. Depending on the level of user involvement, MCS can be classified into two categories: opportunistic sounding and participatory sounding. The first is a passive process where probing data is collected automatically without the user's knowledge of the gadget. The latter is an active process when users need to directly initiate probing actions, such as the choice of sensory tasks and the solution of inquiring efforts [5].

Due to the advantages of sensing functions in smartphones and user mobility, MCS provides unique functions for processing big data arrays [4]:

- *Scalability:* High scalability is one of the key features of MCS. In a fixed network of sensors, increasing the sensing area will lead to the deployment of sensors in an extended area, which is time consuming and expensive. With MCS technology, it is easy to achieve the collection of probing information over a large area, motivating more mobile users in the extended area to participate in probing tasks. Thus, MCS is an effective paradigm with high scalability and is very suitable for collecting sounding data over a large area, such as the territory of settlements. Meanwhile, high scalability also makes MCS more reliable compared to a traditional touch network for creating software to manage the flow of people within the city to ensure social distancing.
- *Flexibility:* Another unique feature of MCS is its great flexibility. In a fixed sensor network, changing the sensing area will require changing the settings and relocating the sensors. However, in the MCS system, the system must recruit some mobile users in the target area for probing, which is easy to achieve due to the large number of mobile users among citizens and the fact, that smartphone is always with the user. Therefore, MCS is a flexible paradigm for collecting sounding data.
- *Self-Determination of User Behavior*: Self-determination of gadget user behavior is a major feature of participatory probing, which is a major category of MCS. When probing participation, mobile users can make their own decisions instead of being guided by a central controller. Mobile device users are heterogeneous. They may be in different places with different interests and opportunities. Their mobile devices can have different functions, memory capacity, power, etc [6]. Thus, each mobile user can decide whether to participate in MCS or not, and take on different tasks based on their own situations. Meanwhile, the usefulness of each mobile user may be influenced by the decisions of other mobile users, which make each mobile user's self-determination more difficult.
- *Different data quality:* due to the heterogeneity of mobile users, different functionality of their smart devices, different data quality is obtained - another feature of MCS. In fixed sensor networks, sensors are usually pre-deployed based on a single model or format. Therefore, the number of sensors and the type of data they can produce are known a priori. This makes it easier to control the quality of the data. However, with MCS, data quality may change over time due to mobile user mobility, mobile user preferences, and different probing contexts. To maintain the confidentiality of participants, some programs remove identification information from the sensor data. In this way, anonymous users can send low-quality or even fake data to the platform. In addition, data provided by different participants may be redundant, duplicate or inconsistent. Therefore, how to collect high quality data is a critical issue in MCS due to the variety of data quality.
- *Weak power limitation*: In fixed sensor networks, power limitation is a major problem due to the inconvenience of replacing the power supply of the sensor. Many studies have focused on how to extend the life of a network. However, with MCS, the sensors are built

into users' mobile devices. Users can be aware of the remaining charge at any time and conveniently charge their devices when the battery is below a certain level. Therefore, power limitation is not a major issue for MCS [4].

3. A project of Mobile Crowd Sensing software for Multi-criteria route planning with risk evaluation recommender system

In order to reduce the severity of the problem and establish procedures for effective communication with the masses, to avoid manipulation of the public consciousness, there is a need to implement a project that involves the creation of Mobile Crowd Sensing software [7] for Multi-criteria route planning with risk evaluation recommender system [8].

Implementation of an IT project to create mobile location-based social distancing recommender system with context evaluation involves the passage of several classical stages.

Stage 1 Stage before project preparation. At this stage it is substantiated that in the implementation of external public mass communications, caused by the desire to implement such communications, there is a desire to expand the scope of operation and development of information exchange, and later the objects of material production. In the implementation of social communications, it is important not only what is used, but who participates in the interaction, how information and connections are used, to whom the information is addressed and where the communication links are directed. The effectiveness of information exchange and the whole process of communication with the masses largely depends on the recognizability of the subjects of communication of the subject of discussion (information exchange) and the communicative competence of those who try to control the consciousness of the masses.

The effectiveness of information exchange, which causes certain actions, depends on the level of communicative competence. Moreover, the key mechanism of influencing the masses of people is manifested at all levels of socio-cultural organization of society, which generates the social significance of the project. This approach contributed to the formulation of the goals and objectives of the project, the development of the project concept.

Stage 2. Communicative. This stage is to analyze the main components of the problem based on a wide range of sources and search for possible solutions; study of the project environment, selection of the optimal variant of the project task; tools for the project task.

Stage 3. Technological Execution of tasks by each project participant in accordance with the developed plan and division of responsibilities. Scheduling the project to determine the start and end dates of all project operations.

Stage 4. Final Presentation of the results of the project, presentation of the main functional characteristics of the information system.

One of the requirements of social distancing is to keep the distance between people in society and to avoid crowds of large numbers of people. That is, ideally, it is necessary to organize the movement of people so that their routes intersect as little as possible both in time and space [9]. It is desirable that people not only were not in one place at the same time (space), but also did not visit the same place in large number (time). To ensure these conditions when laying the route for the user of the recommended application, you must do the following [10]:

- Obtain data on the stay and movement trajectories of other city residents
- Analyze the density of people on different routes, streets
- Identify places of potential crowd formation
- Identify potential people who may encounter on the route and identify the risks of such a collision [11]
- Laying the trajectory in such a way as to obtain the least number of intersections with other people[12].

Analysis of the applications of tourist routes shows that the task of route optimization is usually to make it the shortest and cover the most popular destinations [13]. Unlike maritime navigation research [14], where safety criteria are preferred and traffic congestion is avoided. That is why the combination of models to take into account the risk of too close intersection with other road users with the functionality of spatially oriented tourist recommendation systems [15] will allow to change the algorithm of routing for the user so that the priority is not saving time and finding the most popular route [16].

The risk of forming a crowd of people according to the trajectories of the closest participants can be described as follows:

$$CR_i = \begin{bmatrix} H_{i,place} & H_{i,context} \end{bmatrix} \cdot \begin{bmatrix} Q_{i,places} \\ Q_{i,context} \end{bmatrix} \cdot w_{i,weathercond} \tag{1}$$

where CR_i is the crowd creation risk for area i, the subscript i is the area identification number, $H_{i,place}$ is the hazard index of the area popularity history (depends on how many people visit area in short time) , $H_{i,context}$ is the hazard index of context factors influence, $Q_{i,places}$ is a coefficient of quarantine restrictions influence, $Q_{i,context}$ is a coefficient of quarantine necessity (got from level of morbidity in the region) and $w_{i,weathercond}$ describes the influence of the weather conditions.

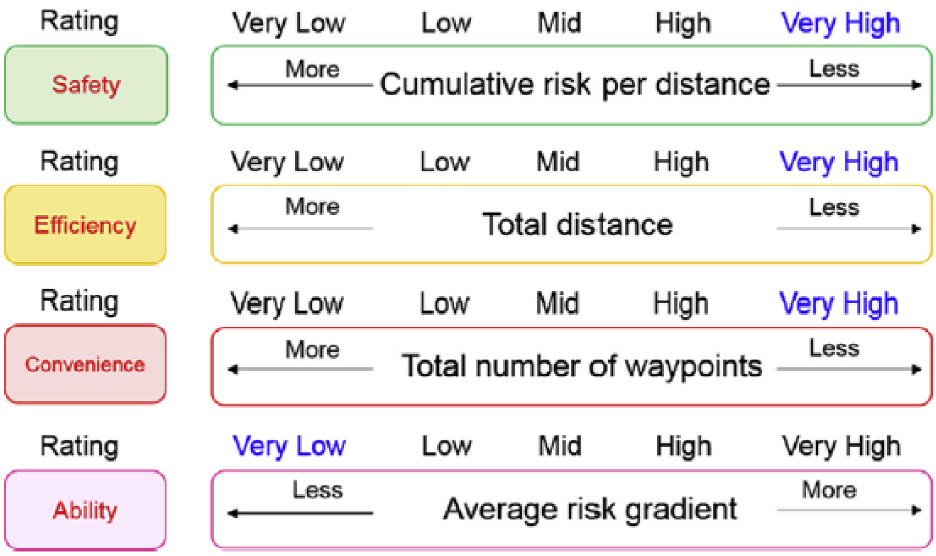

Figure 1: Risk evaluation analysis for avoiding human interaction on the urban area route.

To adequately assess the risk of crowding in a group of people walking through the city streets [17], when choosing a safe route, the following types of risk should be identified:

- The level of safety on different sections of the route and, in particular, pay attention to the peak risk indicator for the route [18].
- Optimize the total length of the route. The walking route cannot be too long. However, the shortest route can be more risky to cross with other people and form crowds [19]. In addition, during quarantine restrictions, people can use hiking for shopping or business as a kind of fitness exercise or a walk in the fresh air.
- Convenience of route adjustment while moving. A route in which it is difficult or impossible to make changes quickly (choose a detour, turn in another direction) is assessed as more risky. To obtain a rating in this case, the total number of route points at which it is possible to transform it is important. Such points are, for example, intersections and open areas, where a person can freely change direction and avoid contact with other people [20].

- The ability of the user to overcome the route: is assessed as the average risk gradient, which takes into account the impact on the assessment of the route of weather conditions, the physical condition of the pedestrian, time of day, etc.

4. Using smartphone big data and functionality in the project

For developing efficient tool for social distancing urban route planning various types of contextual information becomes important [21] and plays an increasing role in the calculation of complete, qualitative and correct recommendations from the user point of view .

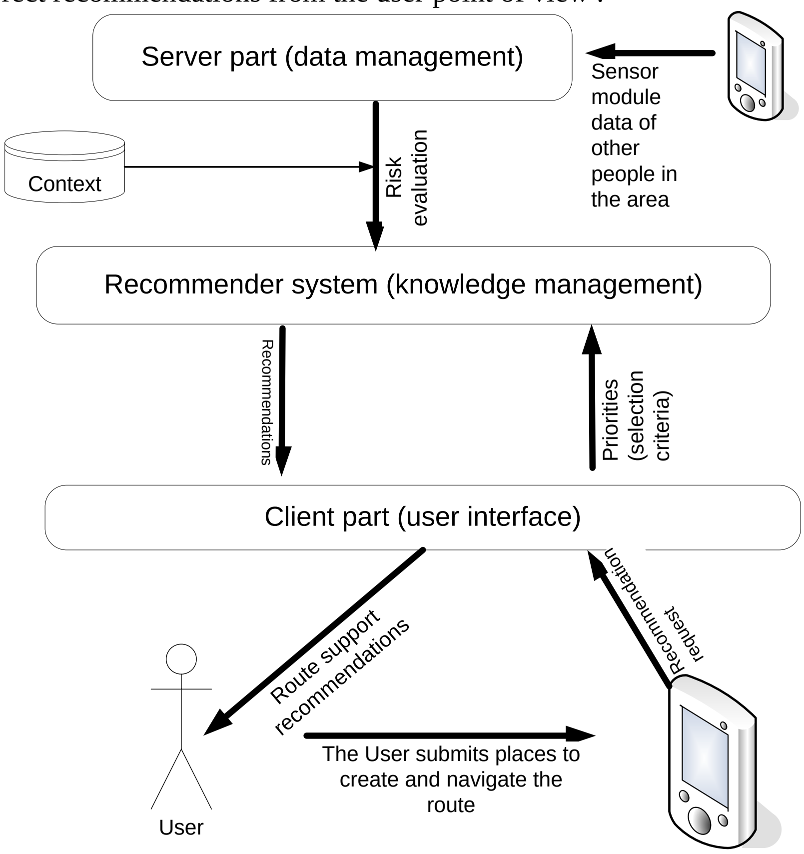

Figure 2: Using context analysis for social distancing location-based recommender system

The main challenges of the research include the development of a data collection mechanism for the training sample, to ensure the same quality and eliminate data redundancy, to take into account the requirements for confidentiality and security of personal data when using mobile applications, etc.

- *Development of a data collection mechanism for the training sample*: The purpose of the study is to collect sufficiently high-quality data from probing the routes of pedestrians on the streets of the city. However, conducting sensory tasks involves either implicit efforts (eg, monetary costs) or explicit efforts (eg, provides some feedback or evaluation) [22]. Meanwhile, mobile devices equipped with sensors are owned and controlled by individual users. Therefore, they may be reluctant to provide their sounding capabilities if they are unable to obtain adequate compensation for consumption caused by the performance of sounding tasks. To achieve the goal of collecting sufficient data on the navigation of people in the city, an effective incentive mechanism is important for the success of MCS. Incentives are usually divided into three categories: interest and entertainment, socio-ethical, financial rewards.
- *Optimizing activities for mobile users*: Given the sufficient number of MCS participants, their activities, such as the selection of sounding tasks and reporting of sounding data, are also important for both users and the system. Given the heterogeneity of mobile users, on

the one hand, heterogeneous mobile users compete with each other; on the other hand, they can work together to reduce costs or perform some complex tasks. How to model and analyze the competition and cooperation of mobile users is one of the main challenges for achieving group or individual optimization of mobile users.

In addition, data redundancy and data diversity should be taken into account when optimizing the spatial, temporal and spatio- temporal behavior of mobile users. For example, users of nearby mobile devices may send similar data to the noise level collection, resulting in data redundancy. In addition, devices in the same location may have different sensing capabilities due to a different brand of mobile communication or a different configuration [23]. Even such devices can receive different probing data when they are in different conditions (for example, a device in a pocket or out of pocket). Therefore, from a system point of view, how to optimize the behavior of mobile users is also an important question (Fig. 3).

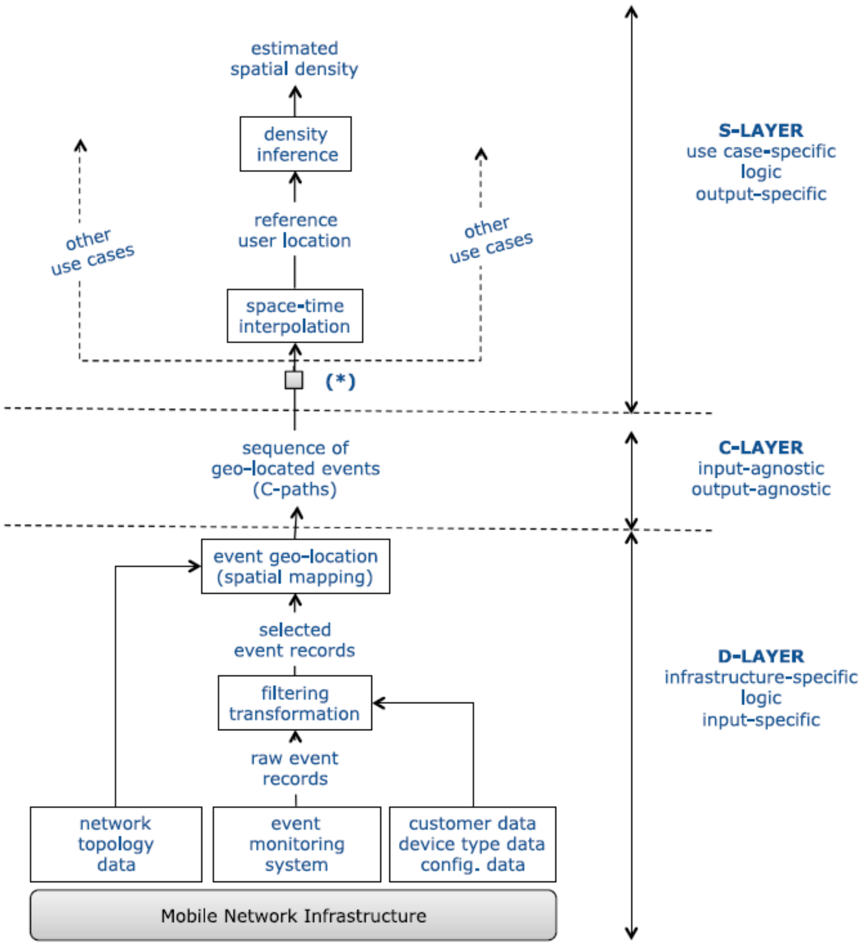

Figure 3: The process of human density (crowd) estimation procedure via mobile location-based social distancing recommender system [23]

- *Privacy and Security*: In mobile applications, privacy or security concerns may discourage users from sharing data from the sensors. For example, disclosing the identity of users or certain confidential attributes, such as location (such as home address or workplace), daily routes, and personal activities or conditions. On the other hand, some tasks cannot be performed without sensitive sensor data. For example, in a noise measurement program, you need to read the GPS sensor and the microphone sensor at the same time. Thus, exploring approaches that can both ensure the number of participants and maintain the confidentiality of participants is a necessary and challenging task. A popular technique is anonymization [24], which removes identification information from sensor data before disclosing it to a third party. However, the disadvantage is that an anonymous user can provide the system with incorrect or even false data - and this is currently one of the biggest problems in collecting sensor data from mobile devices (Fig. 4).

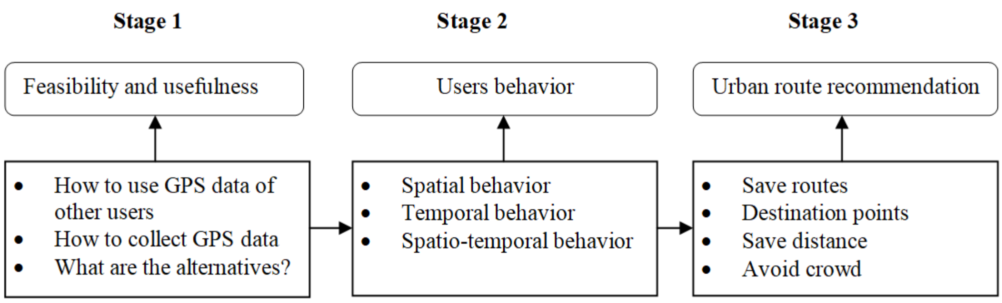

Figure 4: The process of collected from sensor data analysis and application in location-based recommender systems for social distancing urban route planning

Factors that play a role in the choice of individual's route around the city area may be devided into four categories: the available routes (including due to health conditions of the user, time of the day, weather conditions etc. [25]); the character (physical condition, age, mood and other personalized characteristics) of the traveller; the trip that is to be made (purpose of the trip, duration, importance for the user, etc.); other circumstances (context factors). The individual traveller chooses his path on the basis of route characteristics; these items form his choice factors. The other three groups of characteristics are of influence only on the relative importance and perception attached to those route characteristics [26–32]. These characteristics derive from directly measurable route attributes. The process of building a safe walking route with support for social distancing is shown in Figure 5.

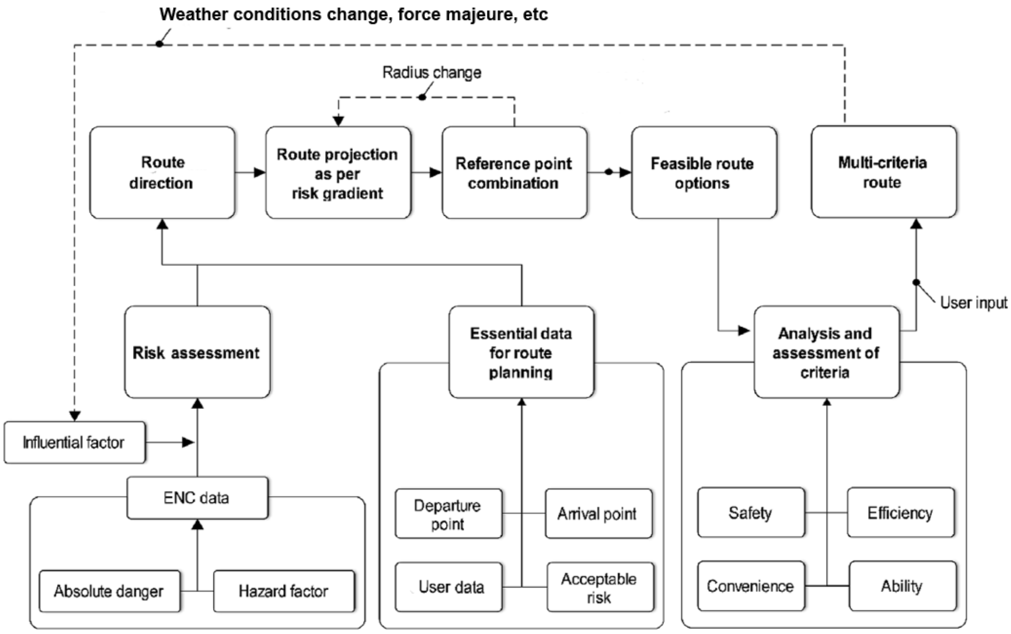

Figure 5: Flowchart of the multi-criteria context evaluation for social distancing urban route planning process.

The process is based on visualizing risk contours on a map as a framework for route planning, and essential data are input according to the circumstances. The procedure is followed by defining the navigational direction[33–36], projecting the persons route according to the gradient, analyzing a combination of reference points, deriving feasible route options, analyzing and assessing the risk criteria and social distancing options, and finally suggesting a safe route.

5. Construction of the training sample

The decision-making process for laying and promptly changing the route should be provided by a multi-agent system. To successfully configure it, you must first collect as large an array of data as possible that describes the temporal, spatial, and spatiotemporal behavior of different categories of pedestrians. In addition, the actual territory matters. Characteristics of streets, relief, features of city infrastructure. Therefore, the streets of the city for which the software is created must be used to collect data. In our case, it is the city of Chernivtsi (Ukraine). Given the research challenges described in Section 4, the simplest way to collect big data describing pedestrian behavior was chosen: a mobile application was created, the users of which joined the research group using digital authorization. They know that data from their mobile sensors will be collected in the cloud storage of the group administrator.

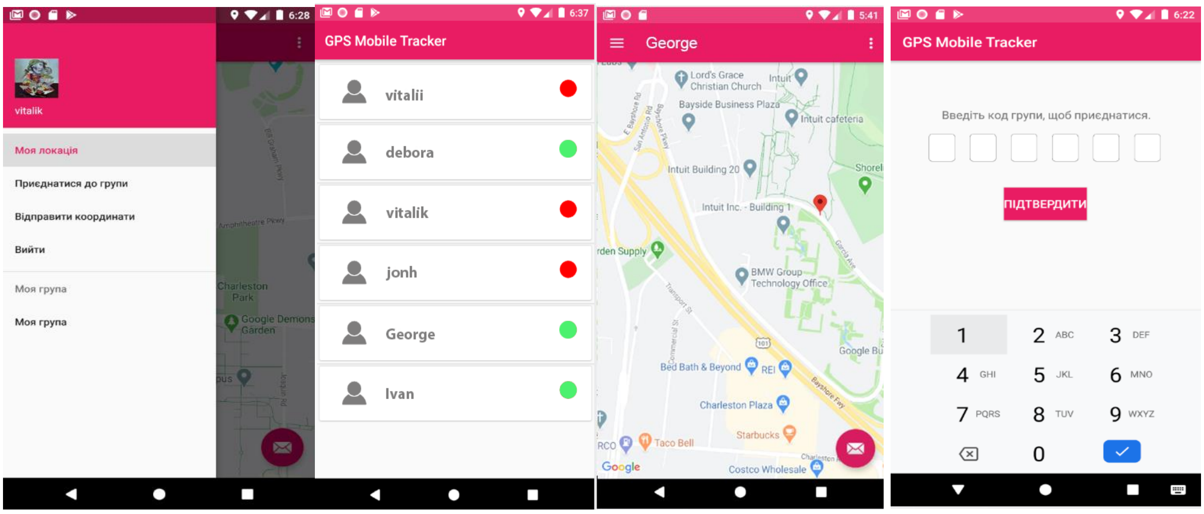

Figure 6: The process of collecting big data describing the typical behavior of a pedestrian in Chernivtsi.

The data collected in this way will be further used to train a multi-agent system. This will build a knowledge base, descriptive rules, to control the walking route of the smartphone user in order to organize social distancing. It is assumed to use the model shown in Figure 7.

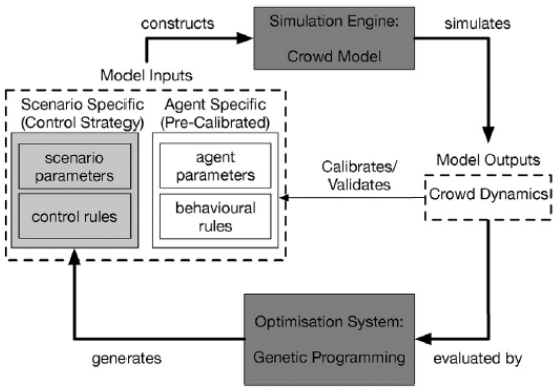

Figure 7: The proposed model for safe route planning, using agent-based decision making [3]

In an agent-based crowd model, crowd control solu-tions/strategies can be implemented as a set of scenario-specificparameters and rules to affect agents' movement. Due to thelarge number of parameter/rule combinations, it is necessary to automate the process of searching for the optimal combination togenerate the desired effect on crowd dynamics.

6. Conclusions

The study provides an analysis of the ways and resources for creating context-oriented mobile location-based recommender systems for social distancing route planning in urban area. The approach to building location-based recommender systems is proposed. It allows considering the context data in calculation of the risks for crowd appearance process. That provides better quality of recommendations and gives the opportunity to create recommendations for safe trip in the city in real-time. The prototype of the system is designed to provide a quality interactive trip support for the user during his moving. Preventing unexpected and unplanned crowds is currently a pressing issue for the health of urban residents. The use of data on the movement of city residents, taken from their smartphones and gadgets, as well as data from cellular stations will be useful to optimize the walking route with the provision of social distance. The previously listed data sets belong to the category of big data. Therefore, it is information technology for big data analysis and smartphone functionality should be the basis for the development of information support projects for social distancing. The main features of decision-making on passing and changing the route are analyzed. Technologies for determining the danger of crowding and managing human flows have been studied. The study considers the possibility of creating software to manage the flow of people within the city to ensure social distancing. A prototype of a mobile application has been created, which will be used to teach the multi-agent system the peculiarities of the space-time behavior of pedestrians during quarantine.

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