"Accessibility Map" and "Social Navigator" Services for Persons with Disabilities

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***Abstract*—The paper describes development process of information environment for persons with disabilities. Introduction describes the aim and objectives of development, the results of evaluation of typical demands and user scenarios for persons with disabilities. The first section of the main part describes common applications architecture and utilized technologies. Both services use the same data model, which includes description of route parts and roads, as well as information about accessibility of objects stored in the database of "Accessibility Passports" service developed previously. The next section contains description of the development process. The user scenarios, service functions, the use of Geo2Tag platform and Open Street Map with its libraries are presented. In "Social navigator" service the routes are described as a graph with weighted edges, where the weight is the rate of accessibility of the path parts. The mathematical method for estimation of accessibility according to various types of ability restrictions was developed and implemented in the service. The method is based on graph theory and provides an approach to formal ranging of the routes according to the accessibility level of persons with limited mobility.**

I. INTRODUCTION

This work is a part of long-term project [1] related to development of information environment for persons with disabilities. The aim of the project is to improve quality of life of persons with disabilities by addressing issues related to social exclusion, accessibility and mobility of disabled people by means of advanced ICT.

Presently the infrastructure of some cities in Russia is not friendly for persons with disabilities. Selection of a route to some socially significant facilities is challenging for a person with disabilities as information on accessibility of those facilities is not available. This lack of information makes visit to the social facility somewhat risky, and it means that the person can't fully participate in the life of the community.

In order to increase the accessibility of facilities for persons with disabilities a development of information infrastructure was proposed. The work described in the paper was targeted to develop the following system of services and supporting modules:

- "Accessibility Passports": web-service for preliminary collection of accessibility data of socially significant objects;
- "Accessibility Map": mobile service for cartographic visualization of information about social facilities categorized by accessibility levels and types of disability;
- "Social Navigator": mobile route planning service adapted for abilities of persons with various restrictions.

Standard navigation solutions for mobile devices are not friendly enough for persons with disabilities because they provide uniform solution without taking into account disability restrictions. "Social navigator" is able to make journey planning considering individual restrictions of a person. In addition to the journey planning, the service will provide functionality for collecting user feedback regarding conditions of a route. Such information can be summarized and provided to relevant authorities to help improving the infrastructure for persons with disabilities in the most demanded areas.

Section II describes interaction between the services, data storages and users. It includes information model, high-level system architecture and used data objects. Section III describes "Accessibility map" mobile service. Section IV describes "Social navigator" mobile service, its architecture and functions, route accessibility estimation algorithm, user ratings and obstacle promotion approaches.

II. GENERAL SYSTEM OVERVIEW

A. *System architecture*

The high-level architecture of the system is presented in Fig. 1. The description of each element is given below.

The "Accessibility Passports" service [1,2] manages and provides information about social facilities (hospitals, social centers, etc.) under the unified criteria and binds it to geographical coordinates. For regular users the service is available in read-only mode, but government authorities and administrators may add and update information via web-interface. A special software agent converts the data to geo-tags for the Geo2Tag LBS platform [3,4]. Geo2Tag permits access to data about social facilities in given coordinate areas for route planning, search queries, and displaying by means of cartographic services.

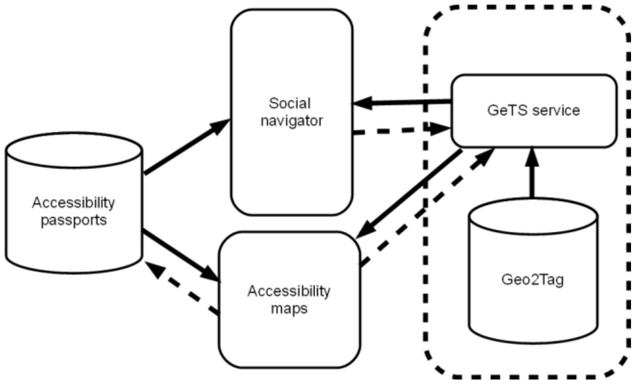

Fig. 1. System architecture

The "Social navigator" and "Accessibility map" services utilize data from "Accessibility Passports" transformed to geo-tags.

Geo2Tag-based LBS service consists of Geo2Tag LBS platform [3] and GeTS service [5]. Geo2Tag is used as storage for various objects and GeTS service provides functionality and application programming interface [6]. Geo2Tag platform was effective employed in development of applications related to healthcare and medical support [7, 8, 9]. Typically location-based service provides two types of information: read-only public data and private data. Public data aggregates verified and trusted information. The private space is used for storing found obstacles, which are not yet verified. The information from location-based service can be reused in other Geo2Tag-based services and applications.

Mobile application presents accessibility information for target places and provides navigation functionality. If a user finds a new obstacle along the route, then the information about the obstacle can be stored in his/her private space.

The web interface provides administration console for social services, government and administrators. Also web interface provides access to functions of the "Accessibility map" service.

B. The information model of the services

One of the key issues of the services is to collect information provided by different types of users: persons with disabilities, experts and employees of local social authorities, members of community-based organizations, ICT experts, volunteers etc. The common informational model of the services is shown in Fig.2.

The information can be presented in the following ways:

- *Information of social objects accessibility* is collected by local authorities with "Accessibility Passports" service. Also accessibility information about common objects (malls, shops, restaurants, cafeterias, cinemas, entertainment centers etc.) can be gathered by the service users.
- *Current road conditions information* is collected by volunteers and members of community-based organizations. The data should be moderated by an automated system based on rating models.
- The services data can be completed by *estimations and comments provided by users*. Such information increases reliability and relevance of the data. The user has an opportunity to confirm/deny/append content related to the visited place or used route.

The government authorities present the most reliable and official information on location and accessibility of social objects. This information is stored in "Accessibility Passports" database and can be used in route planning application without any moderation. The information gathered by organizations situated on social facilities and community-based organizations should be verified before presentation on the map or usage for route creation. The mathematical rating models should be employed to increase the reliability of user-provided information.

"Social Navigator" service should process and utilize all types of information from different sources.

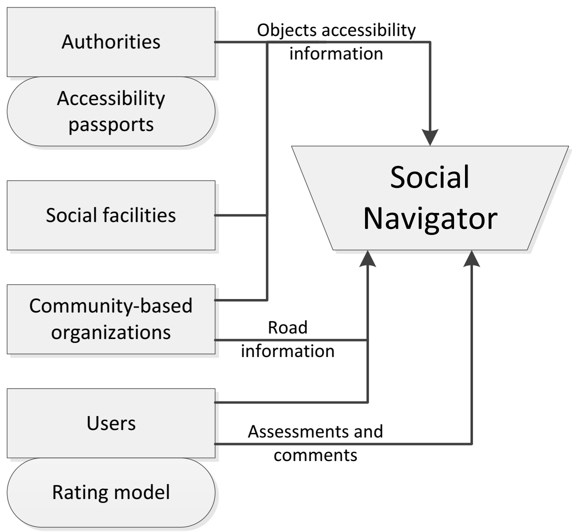

Fig. 2. The information model of the services

C. Data objects

An important part of the "Social Navigator" service is organization of data storage. The common data objects are shown in Fig. 3.

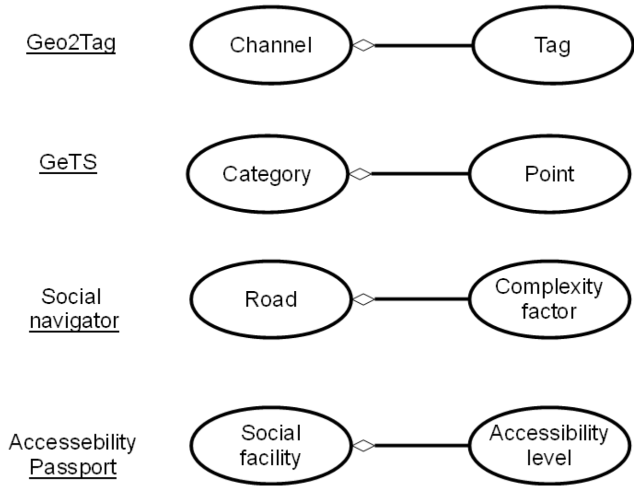

Fig. 3. Data objects

For navigation algorithm it is required to know start and end points, road graph and complexity factor for each road section. Start and end points and the list of disability types are specified by user. Road graph is taken from OpenStreetMap service [10]. The complexity factor is calculated using obstacle properties. The nearest obstacles are stored in Geo2Tag service and available via GeTS service (see Fig.3).

The main problem of storing obstacles in Geo2Tag is that Geo2Tag is a unified platform, which contains 2 entities: Channels and Tags. The Channel is a serial list of Tags. Each Channel is specified by its name and description. Each Tag is specified by its name, coordinates and URL. Therefore, an obstacle must be specified in Channel and Tag fields.

The GeTS service provides the following format of data. Each Channel name contains data format prefix (e.g. points, tracks, polygons) and Channel description contains packed description and data type (e.g. audio tracks, images, attractions). For obstacles it is required to use points format and provide data types for all disabilities. Also obstacles should be divided into permanent and seasonal. Each Tag name field contains packed short name and difficulty level.

The navigation algorithm uses only points in Channels corresponding to person disabilities. The private space is organized using the same structure. Client application can add disability information to the corresponding point in the user's space Channel.

If start or end points are social facilities, the algorithm uses accessibility level for this point. If a social facility has low accessibility level, any road from this point or to this point has high complexity.

III. Information service "Accessibility map"

A. Description of the service

"Accessibility map" service provides well-structured information on accessibility level of socially significant facilities, including the following items:

- name of the object/organization;
- description of organization activity;
- description of routes to an object;
- accessibility information related to the types of disability;
- estimation and comments provided by users who have visited the facility.

All organizations are grouped by activity (see Fig. 4). The categories are healthcare, education, social care, sport, culture etc. This list can be extended. Two means of visualization are available in the service: a categorized list of objects (Fig. 5), and a map with geo-tags (Fig. 6). Accessibility level of an object in the list is marked by color. Also search and filtering features have been implemented.

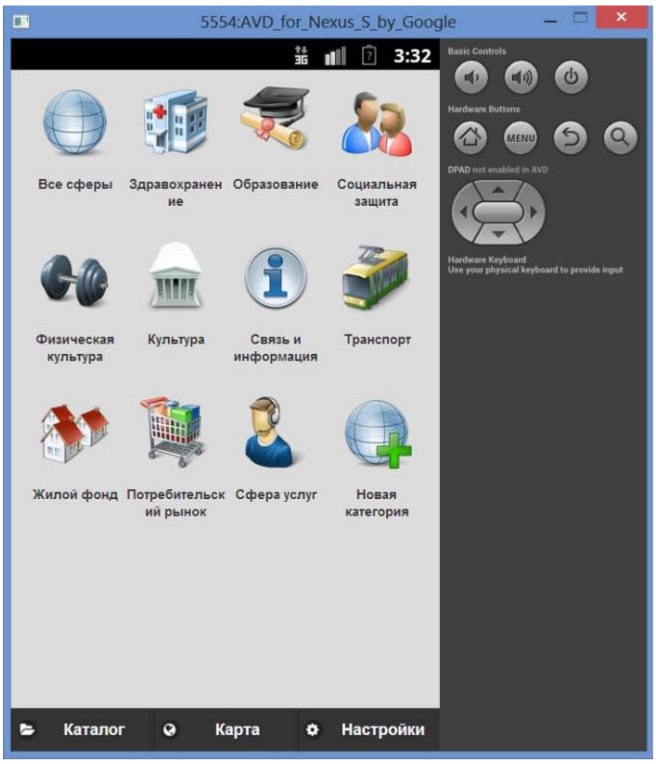

Fig. 4. "Accessibility map": main screen

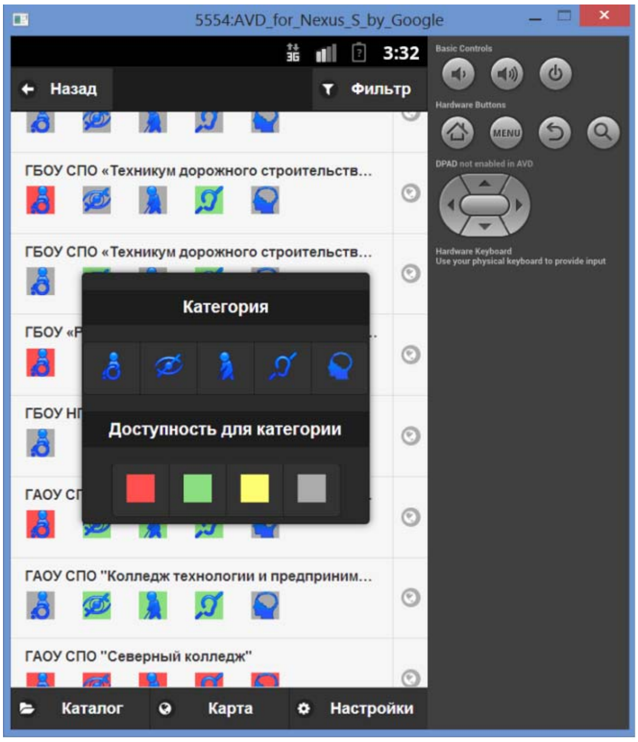

Fig. 5. “Accessibility map”: accessibility level configuration

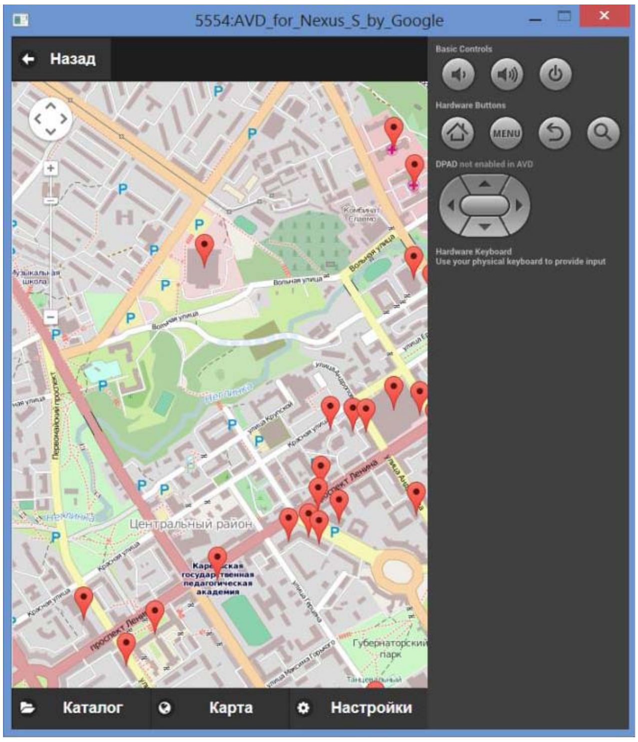

Fig. 6. “Accessibility map”: objects on the map

The objects can be filtered by the following criteria:

- organization's activity: healthcare, catering, sport, education, etc.;
- categories of persons with disabilities: “moving on a wheelchair”, “hearing-impaired”, “visually impaired”, etc.;
- levels of accessibility: “fully accessible”, “conditionally accessible” and “inaccessible”.

The searching of objects is performed by name and/or some key words.

The user can sort the list of objects by distance from current location.

B. Service implementation

The architecture of the service is presented in Fig. 7. It is based on the use of MVC (Model-View-Controller) approach [11]. The Geo2Tag storage contains geo-tags for the objects. Each geo-tag includes geographical coordinates and information related to the object. The database MySQL is also utilized to store information on registered users and content from users, which is needed for rating model implementation.

The program logic is implemented in WebAPI module. It is a web-service, which receives http-queries in defined format and returns the result in JSON format. WebAPI module provides required list of objects, makes user authorization and so on.

Mobile GUI and Web GUI modules share the same logic, but the Mobile GUI is used for small mobile phones, and Web GUI – for standard PCs and tablets.

Mobile GUI module is implemented using HTML5, JavaScript and CSS3 technologies [12]. Also JQuery, JQuery Mobile and AngularJS open source frameworks are used, as well as mobile application development framework PhoneGap.

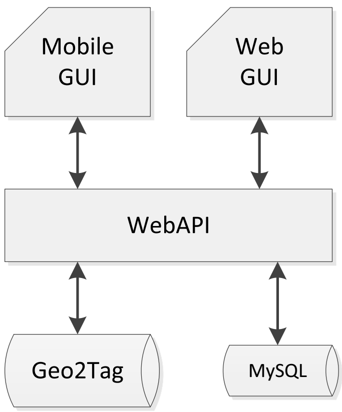

Fig. 7. “Accessibility map” architecture

Web GUI module was implemented using web application development framework ASP.NET MVC4. In practice, Web GUI controllers only provide access to WebAPI functions of “Accessibility map” service [11].

IV. “SOCIAL NAVIGATOR” SERVICE

A. Description of the service

Unlike standard navigation solutions for mobile devices, which are not friendly for persons with disabilities, “Social navigator” service enables journey planning taking into account individual restrictions of the user. The service also provides functionality for collecting user feedback regarding conditions of selected route. The information can also be forwarded to relevant authorities to help fixing problems as soon as possible, or at least to inform other users. Using traces of real trips, the service will enable a better planning of next journeys, e.g. by using the actual travel time for the person with given restrictions. By analyzing trip planning requests the service will discover travel bottlenecks, i.e., unfriendly areas for persons with disabilities that result in most inconveniences, e.g., need to take longer alternative routes. Such information could also be summarized and provided to relevant authorities to help improving the infrastructure for persons with disabilities in the most demanded areas.

Navigation solutions could be illustrated on the following example, when the person with disabilities needs to move from home to a hospital. The optimal route depends on the type of disability and type of obstacles. Each disability requires that information about each obstacle is duplicated for other sensory organs. Each obstacle increases time and complexity of the route and may make the route impossible.

Assume for this example that short route from home to the target place has several crossroads, stairs, direction indicators, road defects and seasonal obstacles like snowdrifts. If the person is blind, then most of traffic lights, stairs and road defects are not a critical problem, but using uncontrolled crossroads and walk throw seasonal obstacles increases complexity of the route and requires increased attention. Visual direction indicators without duplication to other senses make the route impassable.

For the deaf-mute persons all obstacles are passable, but some obstacles require increased attention.

For persons with physical disabilities most of obstacles are also passable, but may increase complexity of the route and in the worst cases (like high stairs without rampant) make the route impassable.

Thereby the problem of finding the route requires full information about all obstacles including seasonal obstacles and the list of disability types. Unfortunately, full information about all obstacles does not always provide a solution because most of the city streets are not yet prepared for persons with disabilities. In this case warning of the problem places is very important for disabled people.

B. Service architecture and functions

The "Social Navigator" service has the following main functions:

- Route planning. The service uses current user position, road graph and complexity factors for each road section and provides optimal route using the navigation algorithm. Optimal route is recalculated every time when the user moves or changes the destination point.
- Off-line work. All required data can be downloaded to the user device for off-line work, because Internet connection may be slow or disabled during the trip.
- Report a new obstacle. The service allows saving information about a new obstacle, when it is found. New obstacle is stored into user's private space and can be copies to the public space and/or shared with friends.
- Route sharing. The service allows sharing route between friends using social networks. The shared route includes complexity estimations and found obstacles.

The high-level architecture is shown in Fig. 8.

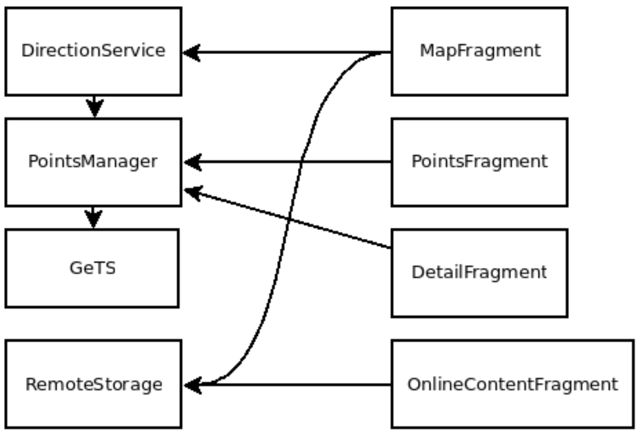

Fig. 8. “Social navigator” architecture

The user interface includes the following modules:

- MapFragment for displaying the map. It supports on-line and off-line modes.
- PointsFragment for browsing nearest social facilities. The list of social facilities supports user filters.
- DetailFragment for getting more information about the point of interest. In this module user can briefly connect to on-line databases like Wikipedia.

- OnlineContentFragment is used to download off-line data to the application storage.

DirectionService module calculates optimal routes to target point synchronously. It uses the navigation algorithm from GraphHopper library [13]. Also the complexity factors for all nearest road sections are calculated in this module.

PointsManager is used for asynchronous communication with "Accessibility Passports" service and other public services that provide information about the target point.

GeTS module implements application programming interface for GeTS service. This module authenticates the user via Google Auth service, if it is requested. The module also downloads information about a group of nearby obstacles and uploads information on the nearest found obstacle to the user's private space.

RemoteStorage module is used for downloading archives with off-line data. The list of available downloads is stored in GeTS service. The module uses gzip compressing, and integrity control with sha1 algorithm.

The service uses the following external libraries:

- graphhopper – navigation library [13]. The library uses road graph from OpenStreetMap service.
- Osmdroid – library for showing OpenStreetMap maps [14]. It is used in on-line mode together with MapQuest Open service and in off-line mode together with mapsforge library.
- Mapsforge – library for rendering maps and generation map tails [14].
- Simple XML – library for parsing XML data [16]. It is also used for working with GeTS service.

C. The route accessibility estimation algorithm

The "Social Navigator" service uses accessibility estimation algorithm based on subjective user assessments extended to a mathematical model for evaluation of routes accessibility for each category of persons with disabilities.

Let us denote $\boldsymbol{R}$ – a set of not coincident routes connecting two geographical points A and B. The set $\boldsymbol{R}$ is defined on a graph $G(V, E)$, where V- a set of nodes (geographical points), E – the set of edges connecting the nodes. The route $\boldsymbol{r} \in \boldsymbol{R}$ contains m edges with corresponding distances l_k between graph nodes, $k = 1,2, \dots, m$.

Let's denote a value of accessibility of edge k for category i as:

$$r_k^i = \frac{1}{N} \sum_{j=1}^{N} e_{kj}^i,$$

where e_{kj}^i – an assessment of user j of the edge k for category i of disabled person, $e_{kj}^i \in [0; 1]$, $k = 1, \dots, m, i = 1, \dots, n, j = 1, \dots N$.

The weights of edges can be defined as follows:

$$w_k^i = l_k \cdot \left(1 - r_k^i\right)^q, q > 0;$$

$$w_k^i = l_k \cdot \left(1 - \ln r_k^i\right), \qquad r_k^i > 0;$$

$$w_k^i = l_k \cdot \exp\left(1 - r_k^i\right),$$

where $k = 1, \dots, m, i = 1, \dots, n$.

All these approaches increase weight of an edge with low level of accessibility and reduce it to distance l_k, if $r_k^i = 1$.

The optimal route for category i of disability is defined with:

$$\boldsymbol{r}^i{}_{opr} = \left\{\boldsymbol{r}\text{: } l_i\left(\boldsymbol{r}^i{}_{opt}\right) = \min_{\boldsymbol{r} \in \boldsymbol{R}} l_i(\boldsymbol{r})\right\},$$

where $l_i(\boldsymbol{r}) = \sum_{k=1}^{m} w_k^i$ – length of route $\boldsymbol{r}$ for category $i = 1, \dots, n$.

Currently the algorithm is being elaborated and tested.

D. Ratings and promotion

The common problem of Social navigator service is data reliability. The simple way is to gather data for public usage by project members, but technically it's hard to implement, because the amount of data is very large. Another way is to provide regular user a possibility to add data. In this case the core problem is user's confidence.

The proposed solution is to divide all users into groups, add corresponding possibilities and restrictions for each group and use rating system for moving users between groups (see Fig. 9.).

In general, "Social Navigator" service users can be divided into the following 3 groups:

- Administrative group. Each user in this group can manage public data and other users. Project management is a common part of administrative group. Users in this group have high trust level.
- Trusted group. This group includes members of community-based organizations, volunteers and so on. The trusted group can provide data for public usage automatically.
- Regular user. This is a largest group, which includes all registered and anonymous users.

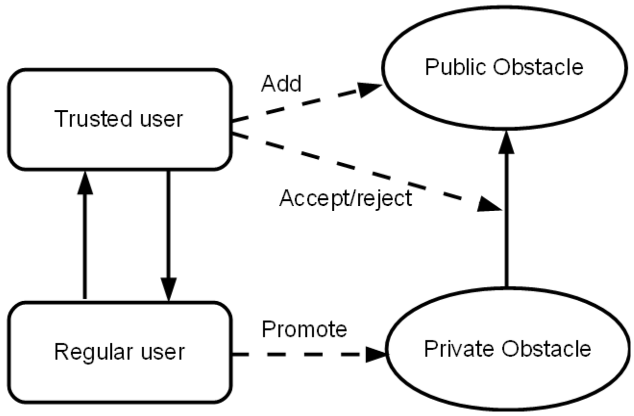

Fig. 9. Private data promotion

Users in regular group can add obstacle or other data into the private space. This data can be used by this user or shared with friends or other people, e.g. via social network.

If a regular user finds an obstacle, which should be known by other persons, he/she can promote this obstacle. If this obstacle is really important, a member of administrative or trusted group can accept it and add this obstacle to the public space.

Also each person can express his/her opinion by voting. The obstacle rating is calculated as a linear combination of positive and negative votes and users ratings.

To highlight important promoted obstacles, they are being rated. The user's rating is calculated as a linear combination of accepted and rejected obstacles which he/she promoted. If obstacles are accepted by trust user or administrator, then each user, who votes positively, increases the rating and each user, who votes negatively, decreases the rating.

Therefore we can rate also users. If a regular user has high rating, he/she can be moved to the trusted group. Also if trusted user gets low rating, he/she can be excluded from the trusted group.

There are 2 nonstandard cases, which should be solved manually: when a trusted user provides non-existed obstacle or accepts it, and when a trusted user rejects an existing obstacle. In these cases administrative users can verify this obstacle and change the decision.

V. Conclusion

At present the information infrastructure, which contains several mobile and web services, is being developed. “Accessibility Passports” service has been developed and put into operation by the Ministry of Healthcare and Social Development of Karelia. Currently, the service database contains information on 450 socially significant objects with geographical coordinates and accessibility levels.

At this stage of development, the main difficulty is making strategically correct decisions regarding the program architecture of services, the information models and utilized technologies.

The information is provided by authorities, volunteers and other users. “Accessibility Map” and “Social Navigator” service use the same data model, which includes description of route parts and roads and objects accessibility information. The main aim of the services is to provide the required information on social objects and routes to the users with various types of restrictions. The functions are developed by means of Geo2Tag LBS platform and Open Street Map.

“Accessibility map” service provides well-structured information on accessibility level of socially significant objects.

In “Social navigator” service the routes are described as a graph with weighted edges. The weight is the accessibility rate of path parts. The mathematical method for estimation of routes accessibility is based on user assessments and implemented in the service. The method uses the graph theory and provides approaches for formal rating of the routes according to the level of accessibility for persons with limited mobility.

The “Social navigator” service uses user and obstacle ratings for new data management. Any person can propose new information that may be accepted. Data from trusted group of users can be approved automatically. Also any user can share own data to other persons via social networks.

Initially, the database is filled by the project team. After that information will be gathered via community-based organizations, social volunteers and regular users.

Acknowledgment

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