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INFORMATION SYSTEM FOR PUBLIC PLACES AND INSTITUTIONS VISUALIZATION WITH OPPORTUNITIES OF INCLUSIVE ACCESS AND OPTIMAL ROUTING

Inclusive access has been considered essential and relevant for decades. However, this issue has been in demand in the past years, both in Europe and Ukraine. One of the popular means of providing inclusive access within the city is information systems that are friendly to people with disabilities. The theoretical basis of such systems is the smart city concept, which has been briskly developed recently. It contains the principles of accessibility of public places, institutions, and establishments for people with special needs. In this work, it is analyzed the well-known algorithms for building optimal routes and available information services and mobile applications that solve the problem of visualizing public places and institutions with inclusive access and paving optimal routes to them.

Key words: *inclusive access, optimal routing, shortest path search algorithms.*

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ІНФОРМАЦІЙНА СИСТЕМА ВІЗУАЛІЗАЦІЇ ГРОМАДСЬКИХ МІСЦЬ ТА ЗАКЛАДІВ З МОЖЛИВОСТЯМИ ДЛЯ ІНКЛЮЗИВНОГО ДОСТУПУ ТА ПРОКЛАДАННЯ ОПТИМАЛЬНИХ МАРШРУТІВ ДО НИХ

На сьогодні питання інклюзивного доступу до громадських місць та закладів та прокладання оптимальних маршрутів до них є актуальним для багатьох міст України. Упродовж останніх десятиліть Україна та Європейський Союз активно займаються розробленням інформаційних систем, що є прийнятними для використання для людей з обмеженими можливостями. Концепція розумного міста, яка останнім часом розвивається, включає також принципи доступності громадських місць, об'єктів та закладів для людей з обмеженими можливостями. У процесі дослідження проведено порівняльний аналіз готових наявних вебплатформ та мобільних застосунків, що доводить, що в Україні наразі бракує таких спеціалізованих інструментів і технологій. Тому розроблення інформаційної системи візуалізації громадських місць та установ із можливостями інклюзивного доступу та оптимальної маршрутизації є вкрай актуальним завданням. Зроблено висновок, що основну проблему необхідно розділити на дві підсистеми – підсистему візуалізації місць та підсистему визначення оптимальних маршрутів. Кожна підсистема поділяється на дві підзадачі. Для кращої візуалізації розроблено дерево розбиття проблем. Для розроблення підсистеми визначення маршрутів обрано алгоритми оптимальної побудови шляхів на основі виконано порівняльного аналізу. Встановлено, що програмне забезпечення для визначення оптимальних маршрутів необхідно виконати такі кроки: 1) інтеграція підсистем; 2) вибір засобів реалізації – апаратне забезпечення, тип платформи, операційна система, тип програмного забезпечення (вебінформаційна система, автономне програмне забезпечення або мобільний додаток); 3) дизайн програмного забезпечення; 4) реалізація програмного коду. Насамкінець, робота над усіма зазначеними вище підзадачами та розроблення інформаційної системи візуалізації громадських місць та установ із можливостями інклюзивного доступу та оптимальної маршрутизації є метою подальших досліджень.

Ключові слова: *інклюзивний доступ, оптимальна маршрутизація, алгоритми пошуку найкоротшого шляху.*

Introduction

Currently, the problem of inclusive access to public places and paving the best routes to them is relevant for cities in Ukraine and around the world.

It is difficult for people with disabilities to reach vital places without assistance, such as a grocery store, a pharmacy, the Department of Social Protection, the Pension Fund, and public utilities. In many cases, these are working-age people who could perform work in a sitting position at least part-time. However, it is difficult for such people to find a job, because it is primarily due to the difficulty of moving and the inability to use public transport without outside access, especially during rush hour. That is why such people are often on social security. The study [1] examines the link between the lack of infrastructure development for people with disabilities and poverty in the country.

Thus the research related to visualization opportunities of public places and institutions with inclusive access facilities and the most optimal routes paving is currently an urgent and relevant task.

Domain analysis

According to the official data of the State Statistics Service of Ukraine, as of January 1, 2019, the number of people with disabilities amounted to 2,659.7 thousand or 6.3% of the total population. Since the beginning of 2015 alone, the number of people with disabilities has increased by 91.2 thousand people, including children – by

10.5 thousand people. In particular, in Ukraine, there are no accurate official statistics on the number of people with visual and hearing impairments. According to unofficial data, there are about 300,000 visually impaired people in Ukraine, of which about 40,000 are blind, and more than 100,000 are hearing impaired (fig. 1).

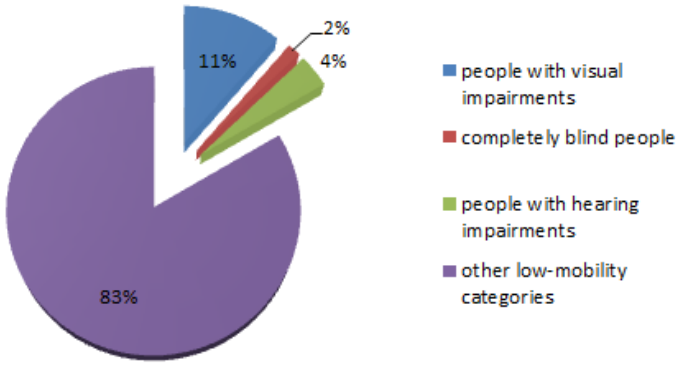

Fig. 1. Quantitative distribution of people with disabilities in Ukraine by category

Due to the presence of health problems, persons with disabilities need to take specific measures by state and public institutions to ensure their full participation in society on a par with others [2]. Much attention has been paid to solving these problems recently, but their lack of resolution outlines the main tasks for the near future. Thus, for people with hearing and visual impairments, the issue of accessibility of transport, street, and social infrastructure remains relevant. After all, ensuring the accessibility of all modes of transport and transport infrastructure is essential for the full integration of people with disabilities into public life. The concept of "accessible transport" is considered the accessibility of the vehicles themselves and their equipment according to current standards and needs of people with disabilities. "Street and social infrastructure" includes parking spaces, entrances to terminals, elevators and escalators, telephone booths, trade and catering establishments on the territory of railway stations, recreation parks, cultural establishments, sidewalks, pedestrian and underground crossings [3]. The construction of new, reconstruction, and overhaul of existing transport, road, street, and social infrastructure should consider the unique requirements of building codes and standards, considering the needs of people with disabilities. Some improvements in accessibility for people with disabilities of rail, road, passenger road transport, sidewalk equipment, underpasses, and pedestrian crossings have recently been observed, especially in large cities. However, there are still several issues in this area that need to be addressed.

Analysis of existing solutions and technologies for the construction and visualization of the best routes to public places with opportunities for inclusive access

With the development of new technologies and the constant increase in the informatization of society, this problem has become possible. An analysis of existing solutions was conducted, namely information platforms, websites, and mobile applications [4] that would solve the problem of visualizing public places and institutions with opportunities for inclusive access and paving the best routes to them (Table 1).

The comparative analysis of the data given in Table 1 allowed concluding that there is no single information system (website or mobile application) in Ukraine that would enable the user to simultaneously obtain information about the availability of a particular public place or institution and pave the best route to it. Therefore, the issue of developing visualization of public spaces and institutions with opportunities for inclusive access and paving the best routes to them is currently relevant.

The situation analysis regarding the accessibility of Ukrainian cities conducted by the initiative group Dostupno.ua (The Toster project) showed that not all institutions of even the largest cities in Ukraine are equipped with special facilities for access to low mobility groups [7].

Fig. 2 shows the accessibility rating for 2020 of Ukrainian cities in a bar chart. According to the chart, Chernivtsi is the most friendly to disabled people. Almost 20% of public places and institutions are equipped with unique means of inclusive access. The lowest in the rating is Kherson; it has only 5.5% of public spaces and institutions are disabled people friendly.

As can be seen from fig. 2, the chart still does not contain information about all major cities (regional centers of Ukraine), and the rating of cities is quite low – on average in Ukraine less than 20% of public places and institutions are equipped with special means of access for people with disabilities. Moreover, it does not contain any information about the city of Khmelnytskyi.

Therefore, the work aims to develop an information system, which will consist of a web-based information platform and a mobile application with an interactive map of the optimal routes for visualizing public places and institutions with opportunities for inclusive access.

Table 1

The summary of existing solutions and technologies for the construction and visualization of the best routes

Name of the service	Presentation form	Functionality	Free or paid	Where is used (countries, cities)
DOSTUPNO.UA	Websie and mobile application for Android and iOS	Orienteering in Ukrainian cities and finding barrier-free friendly locations for people with disabilities, parents with young children, wheelchairs, and other members of the less mobile population. The service considers the level of convenience of entry – the presence of a ramp, stairs; barrier-free space inside; the convenience of toilets, facilities for people with small children and prams, the availability of parking, bicycle parking, pet-friendly locations, etc. The map includes cinemas, cafes, restaurants, shopping and entertainment centers, regional state administrations, city councils, administrative service centers, courts, museums, libraries, parks, banks, pharmacies, supermarkets, railway stations, and more [5].	free	26 Ukrainian cities, in the expansion process
GOOGLE MAPS	Website and mobile application for Android and iOS	Provides routes paving between destinations, taking into account modes of transport, optimality, and speed also includes time calculating to complete the route.	free	worldwide
RouteXL	Extension for Google Chrome, a mobile application for Android and iOS	RouteXL is a service for delivery drivers for small businesses, allows them to plan trips with multiple destinations. When users enter destinations, RouteXL places them as quickly as possible, automatically optimizing the route.	Free	The USA only
MapQuest	iMAC, PC, iOS, Android	MapQuest is a tool for creating routes, locating restaurants, grocery stores, gas stations, and even booking hotels. The limit of MapQuest is the limited number of stops that can be connected for optimized routes. MapQuest was not designed to compete with more specialized routing programs.	Free with paid extensions	Mostly the USA
PLOTAROUTE	Website [6]	Recreational routes, interactive maps, paving alternative bike and running routes, green routes.	Free standard membership	worldwide

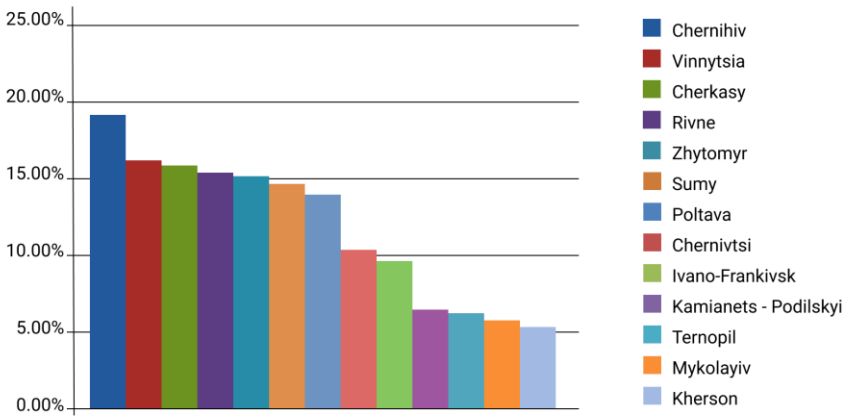

Fig. 2. Accessibility rating of Ukrainian cities [0]

The scheme of information system for public places and institutions visualization

To develop the system, decomposition will be carried out – the system will consist of part of the visualization of institutions and part of the construction of optimal routes.

To develop a system for visualizing data on institutions equipped with special means for access of low-mobility groups, open data was used, i.e., the information contained in open access and provided upon request to the city government or in [8-10]. Data is provided in machine-readable format – CSV, XML, JSON, or API for easy access during programming. Web service that allows marking specific points or objects on a map using open data also has been used. The plan of work with open data to create user-oriented services is shown in fig. 3.

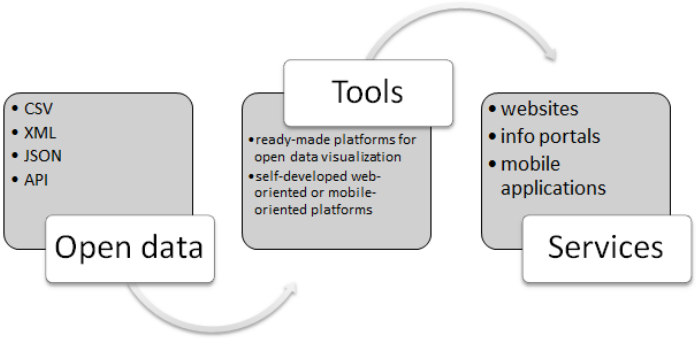

Fig.3. Scheme of work with open data for creating user-oriented services

Thus, this study has the following two vectors – work on the visualization subsystem of institutions equipped with unique means for inclusive access and find the best algorithms for optimal routing and improve the existing algorithms (fig. 4).

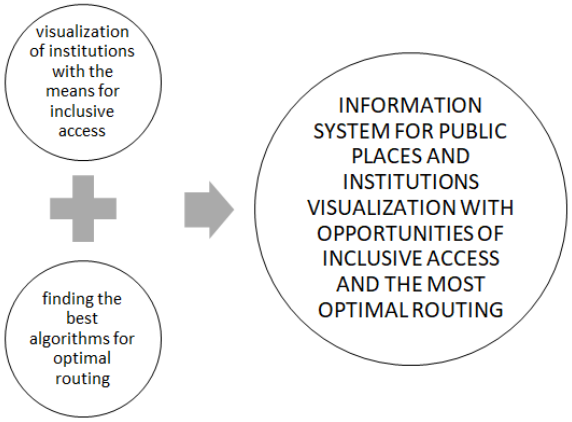

Fig. 4. Ñomponents of the Information system of visualization of public places and institutions with opportunities for inclusive access and proposals

Subsystem for the visualization of disabled-friendly places and institutions

To create the visualization, a web service [11] has been used. With the help of this tool, necessary information has been applied to the finished map of streets and houses using markers and the exact address of the location. The color, symbol, and method of display on the map are chosen by the developer. The dot with the marker is displayed in the right place with a caption that is best for displaying information to the user. The scale of the map can be changed depending on the needs.

The prototype of the information system has been developed. Currently, it consists of a web-based information platform, where the map of Khmelnytskyi has been marked with the places where the entrance to the institution is equipped with special aids (ramp, railing) for people with disabilities. The data for the map has been taken from [0]. The map is shown in fig. 5.

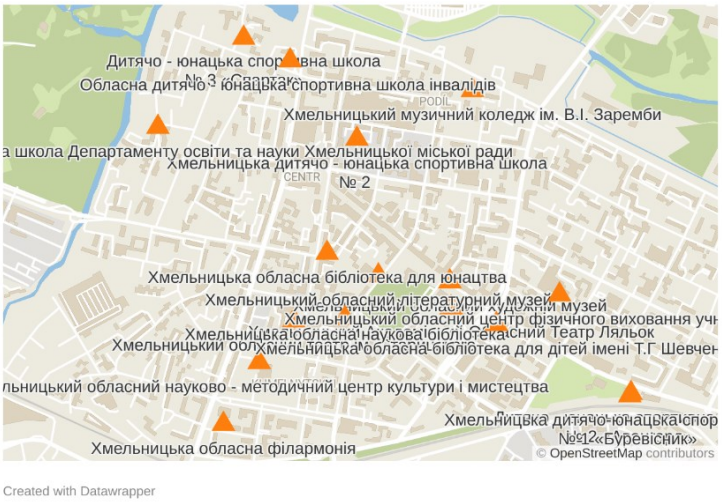

Fig. 5. Map of Khmelnytskyi city with marked places, equipped for inclusive access Subsystem for Routes setting

To build the optimal routes, several algorithms for building optimal routes have been considered [0] and summarized in table 2:

Table 2

The summary of the comparative analysis of algorithms for building optimal routes

Name	Peculiarities	Algorithm tasks
Terry's algorithm for finding the route	The algorithm can have the following solutions: 1) going along an arbitrary edge, each time mark the direction in which it was passed; 2) starting from some vertex v1, always move only along the edge that was not traversed or was traversed in the opposite direction; 3) for each vertex v1 different from v, mark the edge that enters v1 first if the vertex v1 is encountered for the first time; 4) based on some vertex v1 different from v, move along the first edge that enters v1 only when there are no other possibilities.	One pair of nodes
Lee wave algorithm	Wave propagation is a breadth-first search in which cells are denoted by the step number of the method at which the cell is visited. During the reverse move, starting from the final vertex, the path is restored along which it was hit by including cells with a minimum mark in it. A feature of the Lee algorithm is that recovery starts from the end (initially, it is often impossible)	One pair of nodes
Dijkstra's algorithm	First, the initial vertex is selected, and the path to all the others is unknown. The main disadvantage of this algorithm is that it only works for graphs in which all edges have only a positive value.	One entry
Bellman-Ford algorithm	The advantage of this algorithm is the ability to work with edges with a negative weight. The algorithm uses the dynamic programming method (the main task is divided into subtasks, where a solution is sought for each subtask, then the result of the subtasks is transferred to the entire main task).	One entry. The weight between nodes can be negative.
Floyd-Worschel algorithm	It has a low speed and does not provide for the calculation of edges with a negative weight. A short path consists of other shortest paths in a graph with a positive weight of any non-elementary edge (containing more than 1 edge). Given a matrix that is filled with edge weights for each of the vertices. After that, each vertex is iterated, where the weight of the edges between vertices A and B is compared through vertex C. The shortest path between A and B is the minimum value of these options. The translation of the algorithm is its ease of implementation; the weakness is in the algorithm's complexity.	All pairs of nodes
Johnson's algorithm	Finds the shortest paths between all pairs of vertices in a graph. The algorithm works if the graph contains edges from positive or negative weight, but there are no negative cycles.	All pairs of nodes. The weight between nodes can be negative.
Danzig algorithm	The algorithm uses several principles that allow it to find the critical path efficiently: 1) any short path is either an arc between the start and end vertex or a faster path in the subgraph from the start vertex to a vertex that has an arc to the end vertex; 2) if there are negative cost cycles, then there is a negative cost path; 3) the shortest path between any two points in a graph, or the same as in a subgraph, or a sequence of shortest paths in a chart. The complexity of the algorithm is the number of elementary operations, performed by the algorithm for solving a particular problem.	All pairs of nodes

Thus the conclusion from the Table 2 can be made that the most acceptable way to determine the shortest distances from a particular vertex to all vertices of the graph is the Bellman-Ford algorithm. Therefore this algorithm will be chosen for further work.

Discussion and directions of further work

To develop the prototype of the Information System for Public Places and Institutions Visualization with Opportunities for Inclusive Access and Optimal Routing, the first step is to investigate the needed functionalities and requirements important for this type of system. Researching these functionalities and requirements would enable understanding the complete system's development process.

Therefore the problem breakdown tree has been designed to get a general overview of different subproblems of the system. Each subproblem contains a set of tasks that are needed to solve. The problem breakdown tree is shown in fig. 6.

To solve the main problem, the system has been divided into two subsystems – Subsystem for Visualization of Places and Subsystem for Routes Setting. Each subsystem is divided into two subproblems. To develop the Subsystem for Visualization of Places, the Information about the most relevant and frequently used places with the abilities of inclusive access must be collected and structured. Then these places must be marked on the Custom Map.

To develop the Subsystem for Routes Setting, the algorithms for optimal routing must be selected using the analysis as mentioned above from tables 2 and 3. Once the appropriate algorithm is selected and customized, the server-side software must be developed. To tackle the main issue, the following steps must be taken: 1) integration of the subsystems as mentioned above; 2) choosing the means of implementation – hardware, type of platform,

operating system, type of software (web-based information system, standalone software, or mobile-based application); 3) design of the software; 4) websystem implementation.

The main focus of this study is to solve the subproblem of integration of the subsystem for visualization of the places and subsystem for routes setting.

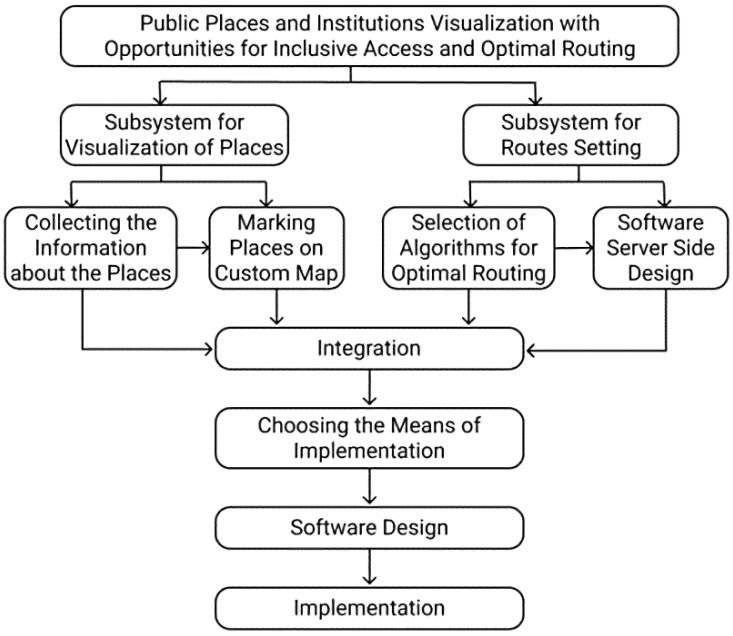

Fig. 6. Problem Breakdown Tree

Conclusions

Nowadays, the issue of inclusive access to public places and institutions and paving the best routes to them is relevant for many cities in Ukraine and around the world. In recent decades, Ukraine and Europe have been actively engaged in developing information systems friendly to people with disabilities. The concept of a smart city, which has recently been actively developed, also includes the principles of accessibility of public places, facilities, and institutions for people with disabilities. During the research, a comparative analysis of the ready existing web platforms and mobile-based applications has been conducted, proving that Ukraine currently lacks such specialized tools and technologies. Therefore, developing the information system for public places and institutions visualization with opportunities for inclusive access and optimal routing is an urgent task. It has been concluded that the main problem should be divided into two subsystems – The Subsystem for Visualization of Places and the Subsystem for Routes Setting. Each subsystem is divided into two subproblems. For better visualization, the problem breakdown tree has been designed.

The work on all the subproblems as mentioned above and development of the information system for public places and institutions visualization with opportunities of inclusive access and the optimal routing is the aim of further research.

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