Issue 17, 2025

https://doi.org/10.23939/sisn2025.17.114

УДК 004.8

CONCEPTUAL MODEL OF THE INFORMATION SYSTEM FOR INDOOR NAVIGATION AND POSITIONING BASED ON TWO-DIMENSIONAL MATRIX CODES

Oleh Veres [1], Yuriy Veres [2]

[1, 2] Lviv Polytechnic National University,
Information Systems and Networks Department, Lviv, Ukraine,
[1] E-mail: Oleh.M.Veres@lpnu.ua, ORCID: 0000-0001-9149-4752
[2] E-mail: Yurii.O.Veres @lpnu.ua, ORCID: 0009-0007-7750-7159

In densely populated areas or indoors, the accuracy of GPS signals can be significantly reduced. This is because satellite signals can be obscured by buildings and reflected from them, which creates so-called multi-layer reflections. As a result, the system can incorrectly determine the position, which leads to a significant error. This creates serious problems for indoor navigation, especially if high accuracy is required. Alternative indoor navigation technologies are being actively developed to solve this problem. Since Wi-Fi routers are often found in indoor environments, they can be used to determine location. This allows you to choose the approximate location with an accuracy of several meters. However, this system requires many access points for accurate operation, which is a problem in the case of Lviv Polytechnic National University buildings. There is incomplete or no coverage, large wall thickness, underground passages between buildings, and classrooms in underground rooms. Therefore, there was an objective need to develop a project for the implementation of navigation and positioning in enclosed spaces by developing a mobile application for searching for classrooms and offices, forming and visualizing routes based on two-dimensional matrix codes and taking into account the Location Services indicators overlaid on the plans of the academic buildings of Lviv Polytechnic National University. It is proposed that a QR or Aztec code be used to determine the location and provide brief information about a particular office or classroom of an academic building. The location can also be set manually or determined using data from the saved plans of the university buildings and campus. The Dijkstra algorithm is used to calculate the shortest path. This made it possible to develop a conceptual model of the information system, considering the stakeholders' requirements.

Keywords - Navigation, Positioning, Two-Dimensional Matrix Codes, Conceptual Model, UML Diagrams

Problem Statement

Satellite navigation is not the best solution in densely populated areas or indoors. In densely built-up areas, the accuracy of GPS signals can drop from 5 to 10-15, and sometimes even up to 30 meters (Barnes et al., 2003). And indoors, the accuracy of the aforementioned signals is out of the question since there is practically no signal there. However, while navigation in densely populated areas of cities can still be carried out using Wi-Fi access points, indoor navigation is not so simple. Almost the only unsolved problem in geopositioning is the inability to use satellite navigation indoors.

Lviv Polytechnic National University is one of the largest higher education institutions in Ukraine and Eastern Europe. A large number of educational buildings (most of which are architectural monuments built in the first half of the XIX century) (*University Presentation Materials | Lviv Polytechnic National*

University, 2025), an increase in the number of foreign students, applicants, and participants of conferences and various events who enter these atypical premises and get lost in endless corridors, determine the objective need for technologies that help to navigate in buildings and premises.

Existing indoor navigation solutions are based on data obtained from Wi-Fi access points, IMES, and network towers (Khalil, 2023; Khalil, 2025). Given the fact that the density of Wi-Fi points in the buildings of Lviv Polytechnic National University is quite low (coverage is incomplete or non-existent), the large thickness of the walls, underground passages between buildings, and the presence of classrooms in underground premises, we can objectively conclude that the accuracy of the data obtained from access points will be pretty low, and triangulation by cell towers will not provide sufficiently accurate coordinates, which is simply unacceptable in our case.

It is for these reasons that there is an objective need to develop an information system for the implementation of navigation and positioning in enclosed spaces by developing a mobile application to search for classrooms and offices, form and visualize routes based on two-dimensional matrix codes (Normand & Viard-Gaudin, 2002; Falas & Kashani, 2007), and taking into account the indicators of Location Services (Marbutt & Schiefer, 2011; Yang, 2012), superimposed on the plans of academic buildings of Lviv Polytechnic National University.

GPS provides excellent positioning results when a sufficient number of satellites are in the line of sight. In recent decades, Assisted GPS (A-GPS) has been showing good results, which is why it has become the predominant technology for consumers. However, developers are still faced with the issue of positioning in urban areas and indoors.

Other technologies are needed to solve the problem of positioning indoors, especially. Many startups and companies are actively working to solve these problems. However, despite the progress, accurate indoor navigation remains a challenge due to the limitations of each of these technologies, especially in large or complexly structured spaces. The main disadvantages of these programs are that navigation and positioning in these systems require a Wi-Fi network, which incurs additional costs for its acquisition and setup. Therefore, they are unavailable for organizations with a small budget and low turnover.

The rapid development of mobile platforms and the emergence of powerful phones have provided developers ample opportunities to create multifunctional software solutions. The developed conceptual model of the information system should consider the possibility of implementing a software solution for Windows Phone.

Therefore, it is relevant to develop algorithms for the implementation of navigation and positioning in closed rooms to search for audiences and offices, form and visualize routes based on two-dimensional matrix codes, and consider the indicators of Location Services.

Analysis of Recent Studies and Publications

There are different approaches to improving navigation accuracy in densely populated areas or indoors.

Integration of different technologies. For example, combining GPS with other technologies, such as Wi-Fi, Bluetooth, or cellular networks, can improve location accuracy in difficult environments.

Advanced positioning systems. For indoor and tall buildings, systems based on internal localization (e.g., UWB – ultra-wideband technology) are used to achieve accuracy of up to several centimeters.

Network corrections. To improve accuracy, you can use so-called differential correction systems (DGPS) when data is transmitted through ground stations to correct satellite signal errors.

Such innovations are being actively developed to facilitate navigation in urban environments, including autopilots, mobile devices, and delivery services.

Positioning Technologies

Alternative indoor navigation technologies are being actively developed to solve the problem of indoor navigation, and there are several main ones.

Technologies that help detect the coordinates of users' current location and navigate the terrain are developing rapidly (Khalil, 2023; Khalil, 2025). As we all know, Global Navigation Satellite Systems (GNSS), such as GPS technology, are practically flawless for positioning only as long as we are in a clear field. Even cell phones can provide meter accuracy for positioning outdoors. A-GPS technology makes it possible to work within a second after a cold start and, in some cases, to work indoors.

However, modern positioning technologies still have many shortcomings, especially when working inside buildings and in densely built-up neighborhoods. Not every room has sufficient conditions for GPS signal reception (Khalil, 2023; Khalil, 2025).

The last decade has seen tremendous changes in the availability and diversity of satellite navigation systems, both regionally and globally. Along with the legacy GNSS GPS, three regional systems (QZSS, BeiDou-2, and IRNSS/NavIC) provide operational services in the Asia-Pacific region. Together with BeiDou-3 and Galileo, a total of four systems provide services on a global scale. Today, most navigation satellites support dual-frequency open service signals for civilian users, which satisfies the growing interest in high-precision navigation in mass applications. IGS has recognized this evolution and has been systematically building new capabilities in support of multi-satellite GNSS data collection (or simply multi-GNSS) and product development through its Multi-GNSS Working Group and Multi-GNSS Experiment (MGEX), which has since evolved into the Multi-GNSS Pilot Project.

Satellite Positioning Technologies. Most likely, in the next two to three years, combined multi-GNSS systems will displace single-system systems (Pratap Misra & Per Enge, 2001; Morton et al., 2021). And not because it will solve the problem of indoor navigation, but because it gives a real advantage when navigating in densely built-up areas.

The QZSS system (Satoshi Kogure et al., 2020; Yamasaki & Noguchi, 2023) uses an inclined geostationary orbit to ensure that the satellite is close to the zenith in Japan (and, as a result, in the surrounding areas). In this respect, it is unique among the main GNSS: it is designed exclusively to maintain reliable reception in cities in the home region.

These next-generation GNSS (Grewal et al., 2020) include the modernized GPS-III system of the United States, the European Galileo system, and the Chinese BeiDou system. In addition, several regional navigation satellite systems (RNSS) and space-based augmentation systems (SBAS) will broadcast additional signals for PNT users (Manglik, 2024).

Wi-Fi localization. Since Wi-Fi routers are often found indoors, you can use them for location. This method involves measuring the signal strength of multiple Wi-Fi access points and comparing them to a database that contains information about the distance to various access points in the room. This allows you to determine the approximate location with an accuracy of several meters. However, this system requires a large number of access points for accurate operation, which can be a problem in some cases (Khalil, 2023; Khalil, 2025). Wi-Fi positioning is used in many smartphones, along with GPS.

Accelerometers and Gyroscopes, which are referred to as microelectromechanical systems (MEMS) (Bao, 2005), are sensors with moving parts that can determine the orientation of a device in space or its movement. Both sensors are widely used in smartphones, where they are used to set the correct screen orientation (portrait or landscape), as well as for gaming. Since they are already included in most devices, they are a natural complement to positioning technology, and many companies are trying to link motion sensors with GPS to improve the accuracy of indoor and urban navigation. This augmentation principle is already used in most smartphones and some navigation devices.

Magnetic compass. Similar to the accelerometer and gyroscope, a magnetic compass is already built into many smartphones. Various technologies are used to determine the earth's magnetic field, including Hall sensors, induction compass, and MEMS (Bao, 2005). The performance of such devices is, to some extent, affected by the proximity of metal objects and even more so by nearby magnets. Users may not notice the magnets around them, but there are quite a few in the modern technical environment, especially in cars. Any system that reproduces sound contains a magnet, and the more powerful the system, the stronger the magnet. Based on this, magnetic sensors alone are not very reliable positioning assistants, but in combination with other sensors, such as gyroscopes and accelerometers, they can be very useful (Khalil, 2023; Khalil, 2025).

Altimetry is another type of MEMS sensor (Bao, 2005). Typically, their principle of operation is based on measuring the level of deformation of the indicator surface due to atmospheric pressure using piezoelectric sensors. Integrating altimeters with GPS has already proven itself in devices such as tourist navigators. Such integration is also proving to be useful in other user devices, especially smartphones.

Cellular Positioning Technologies. Three cellular wireless technologies, AFLT, MRL, and Cell-ID (LaMarca & Eyal de Lara, 2022), are components of A-GPS (Caffery & Stuber, 1998). A-GPS is used to accelerate the start of GPS operation in a mobile device or to directly determine the coordinates of a mobile device without receiving data directly from the satellites. In this case, information about the current state of navigation satellites comes from the network of the cellular operator. For this purpose, an Internet connection must be configured on a mobile device, smartphone, or communicator.

The need for the development and implementation of A-GPS was caused by the long delay time that occurs when a device with GPS navigation searches for a satellite signal (Motroni et al., 2021) and data with coordinates from satellites. The delay can range from tens of seconds to several minutes in areas with many high-rise buildings.

Digital television and Radio. Positioning with digital television (DTV) is accomplished by estimating the distance from the DTV tower, similar to GPS and AFLT. However, DTV towers are not precisely synchronized with each other, and positioning by DTV requires building an infrastructure that links the clock offsets of different towers (Khalil, 2023; Khalil, 2025).

Pseudo-Satellites or Pseudolites broadcast GPS-like signals from ground-based transmitters (Ladd et al., 2004). Usually, these signals differ slightly from GPS signals in frequency, but otherwise, they are similar and can be received by a regular GPS receiver without additional equipment.

The positioning accuracy of the pseudo-planes can reach five centimeters when measuring the phase of the carrier. The operation requires sophisticated and precise transmitter equipment, which greatly increases the cost. However, pseudolites are highly valued and have their place in the market.

IMES and Lighthouses. IMES technology (Ni et al., 2004) allows for full-fledged indoor positioning, and from this point of view, it is the most interesting of all. IMES uses beacons, which are radio transmitters that emit a very weak signal that is intended only for data transmission (but not for distance determination, and this is its main difference from pseudo-liters). The power of each IMES transmitter is so low (from 0.1 to 0.4 nanowatts) that the signal can be received only within a radius of 10 meters from the transmitter. The positioning system works on the principle "If you can hear me, you are here". As is obvious, the accuracy of such a system does not exceed ten meters.

Bluetooth i BLE (Bluetooth Low Energy). Bluetooth is also used for indoor navigation. The system works on the principle of determining the distance between the device and several Bluetooth beacons installed in the room. This makes it possible to create accurate indoor maps and track the user's movement with high accuracy (up to several centimeters in some cases).

Ultra-Wideband Technologies (UWB). It is one of the most advanced technologies for indoor navigation, which can provide accuracy of up to several centimeters. UWB technology allows you to determine the exact location by measuring the signal propagation time between devices. UWB is used to create indoor localization systems in complex environments, such as large shopping centers or complex architectural spaces.

Infrared Systems. Infrared sensors can be used to track the location of people or objects indoors. They allow for very accurate navigation systems, but they are limited in use in open spaces due to their short range.

Combination of Different Technologies. One of the most effective ways is to combine different methods. For example, Wi-Fi can be used to determine a general location in a room and then move to more precise systems, such as Bluetooth or UWB, for more accurate positioning.

Developers still need to address the issue of positioning in urban areas and indoors. This can be achieved by increasing the number of satellites, sensors, and wireless positioning methods.

Analysis of existing information systems for indoor navigation

The most common software products for indoor navigation include «Google Maps», «My Way Aéroports de Paris», and «American Museum of Natural History Explorer».

«Google Maps» – an application for indoor navigation (Google, 2012). The main innovation in Google Maps is, of course, the introduction of indoor navigation. Google Maps can guide customers to the right shopping mall or airport and help them find the right place inside these buildings. At the moment, this feature is in test mode and is available only for a limited number of buildings.

In addition to navigation inside buildings, Google Maps has a redesigned interface, added building diagrams of some airports and hypermarkets; a drop-down list of basic functions at the top of the screen; and the ability to turn off the screen darkening function in navigation mode.

«**My Way Aéroports de Paris**» (2025) – The official geolocation and positioning program, both indoors and out. My Way Aéroports de Paris is a free service for passengers using Android and iOS mobile phones. It is available in French and English. This is the official geolocation and positioning program, both inside and outside Charles de Gaulle Airport. This software solution covers all departure and arrival terminals, including TGV stations and parking lots. Geolocation around the airport uses NAO Campus technology based on WiFi rather than GPS.

«**American Museum of Natural History Explorer**» – is a mobile application for the American Museum of Natural History. AMNH Explorer contains all kinds of information about the museum's collections for all exhibits without exception, from the T-Rex to the Star of India Sapphire (*Explorer App | American Museum of Natural History*, 2019). The app contains both original and pragmatic functionality. The Explorer app can use the museum's Wi-Fi network to determine the user's location. In this case, the app works much like a GPS navigator, but only indoors, and offers step-by-step instructions for moving to the object the user is looking for with arrows and maps. Unlike GPS, the museum system uses Wi-Fi triangulation (Santi et al., 2021), allowing for indoor location determination.

According to the developers of the Mall Buddy software solution, now you no longer need to constantly waste your precious time looking for directions in the retail chains of your city. The mobile application will help users find their way inside shopping centers as well. The program tells the user where they are, what is happening around them, and how to get to the store or restaurant they are trying to find. It is also possible to register via Facebook if the user suddenly wants to brag about his new purchase.

The main **disadvantages** of the programs under consideration are that navigation and positioning in these systems require a Wi-Fi network, which incurs additional costs for the purchase, configuration and maintenance of this network. Therefore, they are not available for organizations with a small budget and low turnover.

Another important disadvantage of these systems is that most of them are built on a thin client architecture, which in turn has several significant drawbacks: the need for constant communication with the network; limited user interface; rather low performance due to network costs; critical problems on the server; high communication costs; testing a mobile application is significantly complicated due to the large number of micro-browsers.

Formulation of Article's Objectives

The work aims to develop algorithms and a conceptual model of an information system to enable users to build an optimal route when navigating indoors. With the help of the designed information and navigation system, the owner of a mobile device will be able to view building plans and navigate them. Considering that the initial requirements and data for the project development are based on the implementation of indoor navigation at Lviv Polytechnic National University, it is necessary to take into account all possible options for technologies and methods for determining location coordinates in various types of indoor spaces.

This will allow you to perform the following navigation tasks: search for the desired classroom, department, dean's office, or administration; route planning according to the user's current location; visual representation of the route on building diagrams; the ability to quickly find the exit from the building in case of emergency. This system will be relevant for users, as it will significantly speed up and simplify the process of finding the best route, providing students and employees, applicants, and participants of conferences and various events with contact information about departments, deans' offices, reception offices and various public organizations of the university.

The scientific novelty and innovation of the work are the implementation of navigation and positioning in enclosed spaces, the formation and visualization of routes based on two-dimensional matrix codes, and taking into account the indicators of Location Services superimposed on the plans of educational buildings of Lviv Polytechnic National University.

Today, it is vital to develop a conceptual model and implement a project for indoor navigation and positioning since a comparative analysis of existing navigation and positioning methods has not revealed any analogs for this system, given the special conditions of navigation in the premises of Lviv Polytechnic National University.

Main Results

Most navigation giants have long been looking toward indoor navigation (Fig. 1).

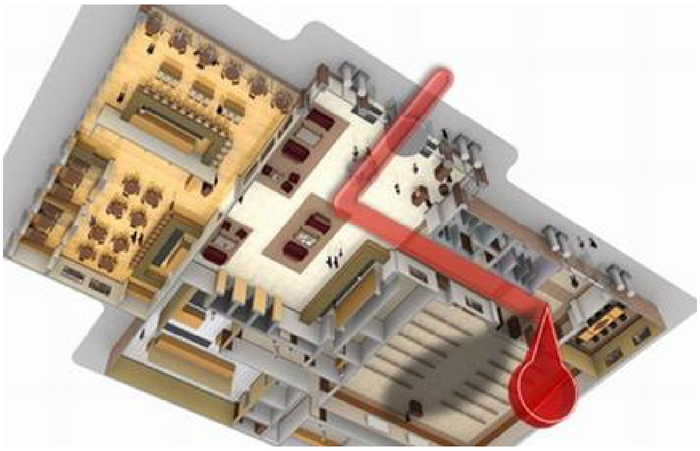

Fig. 1. An example of indoor navigation

Until recently, it was impractical, but a solution has been found. A user sees a large number of different access points when trying to connect to the Internet using Wi-Fi (Ladd et al., 2004) in the city center. It is their indexing and determination of their coordinates that Google has been engaged in for quite some time. Knowing the exact coordinates of these access points, it is quite easy to navigate them because you can calculate your coordinates based on the measurement of signal strength from the three nearest Wi-Fi access points (Ni et al., 2004).

In this case, all you need to do is use access point navigation, which is a program that can analyze signal strength data and calculate coordinates. Google has again met the developers of this positioning system by releasing the Google Maps Geolocation application program interface. This interface allows developing applications for Wi-Fi navigation (Elsanhoury et al., 2022; Risang Yudanto et al., 2023) and linking the obtained coordinates to Google Maps.

The only problem is building maps, and then you can get a full-fledged indoor navigation system. It should also be noted that the accuracy of the data obtained by this system will depend heavily on the density and power of access points in the building.

However, for all its obvious advantages, the wireless hotspot navigation system also has its drawbacks. Because the density of Wi-Fi hotspots in the buildings of Lviv Polytechnic National University is quite low, and taking into account the factor of different types of premises both in terms of wall thickness and location, the accuracy of the data obtained from the access points will be pretty low, which complicates the solution of the positioning problem.

For these reasons, there is a need for a method of navigation and positioning in enclosed spaces for mobile platforms. The software solution will be implemented to search for classrooms and offices and generate and visualize routes, taking into account the indicators of Location Services (Yang, 2012) overlaid on the plans of the academic buildings of Lviv Polytechnic National University.

Methods for Recognizing Matrix Codes

In the modern world, information can be presented in the most bizarre forms. There are various reasons for this, and these reasons are not always shorthand. A cell phone has now become an essential attribute of almost every citizen.

There are two fundamentally different types of encoding:

Linear (one-dimensional). Its most common representative is the "*barcode*";

Two-dimensional, which is divided into *stacked* and *matrix*.

Two-dimensional matrix codes appeared in the early 1990s. In terms of compactness and reliability of information storage, they are better than linear (one-dimensional) codes (e.g., EAN13, Code 39, Interleaved 2 of 5). While linear barcodes usually allow encoding 10-30 characters (usually only numbers or letters of the Latin alphabet), two-dimensional codes can hold 100 times more data.

In addition, two-dimensional codes contain error correction information (Ni et al., 2004), i.e., the data is encoded in such a way that it can be read even if the target is partially damaged (for example, if part of it is erased or torn off). Thus, with the same amount of encoded data, a two-dimensional code will be both more compact than a linear code and more resistant to damage. Two-dimensional matrix codes look like a matrix made up of square modules.

Linear and multi-level codes are simply "multi-layer" linear codes. Matrix encodings "pack" information both horizontally and vertically, which makes it possible to radically increase the amount of stored data and, accordingly, remove restrictions on their type - now it becomes possible to encode text data.

In the process of developing a method of navigation and positioning in enclosed spaces to store data on the user's current location and brief information about a particular office at Lviv Polytechnic National University (*University Presentation Materials | Lviv Polytechnic National University,* 2025), there was an objective need to use containers that would contain this data. Two-dimensional matrix codes were chosen as such containers (Huo et al., 2021; Anita Sondhi & Dr. Ravindra Kumar, 2022).

The term Matrix Code refers to a two-dimensional bar code based on the location of black elements inside a matrix (Saha et al., 2003; Jiang et al., 2021). Each black element has the same size, and the element's position encodes data.

A two-dimensional code contains coded information both horizontally and vertically. Since both directions are informative, we lose the ability to use the so-called vertical redundancy. However, the fight against errors when reading a barcode is quite simple - most standards for two-dimensional codes use checksums to guarantee the reliability of the input information (Huo et al., 2021; Anita Sondhi & Dr. Ravindra Kumar, 2022). The most common are two-dimensional matrix barcodes:

QR Code – a two-dimensional matrix code (2D barcode), which is depicted as a set of light and dark elements – modules (Waters, 2012);

EZcode – 2D matrix code created by ETH Zurich and exclusively licensed by Scanbuy in 2006. This code was created specifically for camera phones because of its simpler design compared to other two-dimensional matrix codes. The EZ code specification for encoding and decoding is publicly available and open;

MaxiCode (originally called UPSCode, Code6) is a two-dimensional matrix code developed by United Parcel Service in 1992, created for shipping and receiving systems;

Data Matrix – The two-dimensional matrix code was developed in 1991 and is depicted as a set of light and dark elements – modules (Neelima & Subhas, 2022; Son & Choi, 2024). This matrix code allows the encoding of alphanumeric and byte data;

Aztec Code – a representative of the family of two-dimensional matrix barcodes ("ISO/IEC 24778:2024," n.d.-b), the image of such a barcode is a square monochrome matrix composed of dark and light modules, in the center of which is a set of square central rings;

PDF417 – a two-dimensional matrix code, the symbolism of which provides good opportunities for encoding data in a compact and convenient form for further automatic reading (Hahn & Jung, 2006).

Matrix codes (Normand & Viard-Gaudin, 2002; Falas & Kashani, 2007) are not only a new method of obtaining additional information about the user's current location and general information about the office of interest, which in turn will help foreign students, applicants, participants of conferences and various events who enter these atypical premises not to get lost in endless corridors.

By placing a matrix code image with the latitude and longitude coordinates of the collection point next to the pointer, any user can now transmit the location coordinates in any way available to them (SMS, E-mail, Twitter, FaceBook, etc.) (Ni et al., 2004).

Algorithms for Finding the Shortest Paths

Having received the coordinates of the points to form the route, the task of finding the optimal route for navigation arises. When solving a wide range of applied problems, it is often necessary to find a route that connects the given vertices in the graph *G*. Here is an algorithm for solving such a problem. In this algorithm, the problem is reduced to finding a route in a connected graph $G = (V, E)$ that connects the given vertices v, u, V, where $v \neq u$. The number of vertices is m, and the number of edges is n.

The choice of a particular algorithm depends on the graph's characteristics and the task's requirements, such as the presence of negative weights, the need for speed of execution, or the need to calculate all pairs of shortest paths. Types of algorithms for selecting shortest paths (Wang, 2018; Chemes& Vetrov, 2023):

Terry's algorithm — is a method for finding the shortest paths in graphs with negative weights, which is an improvement of classical shortest path algorithms, such as the Dijkstra and Bellman-Ford algorithms. It allows the processing of graphs containing negative edge weights with high efficiency compared to other methods. The algorithm uses an iterative approach, updating the values of distances to vertices step by step. The main idea is to adapt the distances to vertices step by step and ensure that at each step, the current shortest paths take into account even negative weights;

Wave algorithm (or width search algorithm) — is one of the classic algorithms for finding shortest paths in unweighted graphs (where all edges have the same weight, usually weight 1). It is based on the principle of breadth-first search and is commonly used to find the shortest paths from an initial vertex to all other vertices in the graph;

The Dijkstra Algorithm (Siklichuk & Senyk, 2023) – is designed to find the shortest paths from one initial vertex to all other vertices in a graph with non-negative edge weights. It uses a greedy approach, choosing the vertex with the smallest known distance from the initial vertex at each step and updating the distances to neighboring vertices;

The Bellman-Ford Algorithm (AbuSalim et al., 2020) – is suitable for graphs with negative edge weights. It can detect negative cycles in a graph, which is important for tasks where such cycles may occur;

Floyd-Warshall Algorithm – is designed to find the shortest paths between all pairs of vertices in a graph. This algorithm is useful when you need to know the shortest paths between all possible pairs of points in a graph;

Johnson's Algorithm – combines the advantages of the Dijkstra and Floyd-Warshall algorithms to efficiently find the shortest paths between all pairs of vertices in graphs with negative edge weights. This algorithm can be faster than Floyd-Warshall on sparse graphs;

Search Algorithm A* (A-star) (Alpert & Onyshchenko, 2023) – an extension of Dijkstra's algorithm that uses a heuristic function to speed up the search for the shortest path between two specific vertices. This approach is especially useful in tasks where you must quickly find a route between two points, such as in navigation diagrams.

If you need to find the distance from one vertex to another or all vertices of a graph and the weights of all edges are positive or equal to zero, then the Dijkstra algorithm is the most efficient with a running time of $O(m \log n)$. If the weights of the edges can be negative, then the Bellman-Ford algorithm should be used, which has a running time of $O(mn)$.

If you need to find the distances between all pairs of vertices in a graph, the graph is sparse, and all edges have nonnegative weights (Thrun, 2000; Sahoo & Choudhury, 2023), you can run the Dijkstra algorithm n times. If the graph is sparse, but there may be edges with negative weights, then you need to use the Johnson algorithm. If you need to find the distances between all pairs of vertices, the edge weights can be negative, and the graph is not sparse (m goes to n^2), then you should use the Floyd-Warshall algorithm.

None of the above algorithms can be applied to graphs containing negative cycles. However, the Bellman-Ford algorithm (as well as the Johnson algorithm) and the Floyd-Warshall algorithm can detect such cycles.

In our case of indoor navigation, Dijkstra's algorithm proved to be the most effective for finding the shortest paths in a graph with non-negative edge weights. The simplest implementation of the Dijkstra algorithm uses an array of distances and an array of labels. The algorithm has the following steps.

Step 1. *Initialization*: create an array of distances $d[\ ]$, where we set the distance to all vertices to ∞ (infinity), except for the starting vertex *start*, for which the distance $d[start] = 0$. Create an array of $visited[\ ]$, where each vertex initially has a value of 0 (not visited).

Step 2. *Basic cycle.* There are still unexplored peaks:

Step 2.1. We find the vertex u with the minimum distance $d[u]$;

Step 2.2. Mark the vertex u as visited ($visited[u] = 1$).

Step 2.3. For all the neighbors v of vertex u, we check:

If v is unvisited and there is a shorter path through u to v than the previously known one:

$$d[v] > d[u] + w(u, v),$$

then update the distance value to v:

$$d[v] = d[u] + w(u, v),$$

where $d[u]$ – current minimum distance to the top u, $w(u, v)$ – weight of the edge between the vertices u and v.

Step 3. *Finish.* The cycle ends when all vertices are visited (all marks are equal to 1). As a result, the array of distances $d[\ ]$ contains the shortest paths from the initial vertex *start* to all other vertices.

Conceptual Model

Developing a conceptual model of an information system makes it possible to identify its main entities and determine possible relationships between them (PMI, 2021; Avi Parush, 2015)[50-53]. Identifying and taking into account requirements at this stage helps to optimize resources in subsequent phases of the development life cycle. This helps to avoid unexpected changes and the addition of new components to the recommender system, which usually requires significant additional time and resources (de Schipper et al., 2021; (Veres et al., 2019)).

During the development of the system's conceptual model, UML diagrams (Unified Modeling Language) were created to simplify the understanding of the information system project (*The OMG® Specifications Catalog*, n.d.). Using such diagrams increases the convenience of project support and facilitates documentation development. A use-case diagram was developed to describe the functionality of the information and navigation system of Lviv Polytechnic National University (Fig. 2), which reflects the user's interaction with the information system and shows the connections between the user and various use cases.

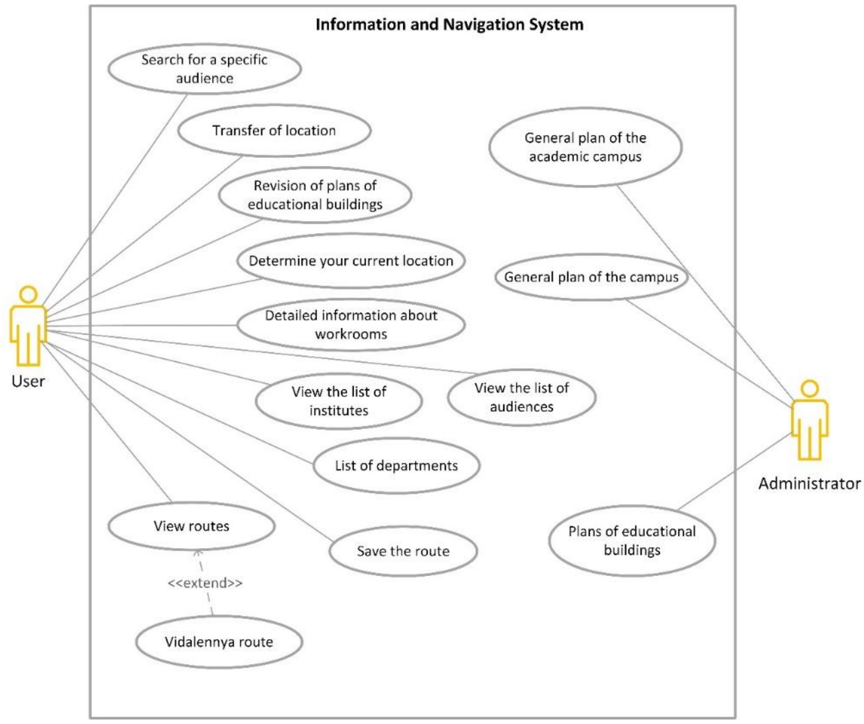

Fig. 2.Use case diagram

There are two actors in the system: "User" and "Administrator".

The "User" is a person who has all the capabilities to control the program. This entity directly serves as a source of influence on the modeled system. In turn, the use case describes the services the system provides to the actor. Each use case defines a specific set of actions the system performs in a dialog with the "User" actor. Accordingly, the following use cases have been formed: "Search for a specific classroom"; "Transfer location"; "View plans of educational buildings"; "Determine current location"; "Detailed information about classrooms"; "View list of institutes"; "View list of departments"; "View list of classrooms"; "Save route"; "View routes"; "Delete route". The options for using "View routes" and "Delete route" are related by the relation of extension because the user in some cases, but not always, at his discretion, can delete a route due to its inexpediency for himself.

An "Administrator" is a user who configures the information and navigation system. The set of its use cases is as follows: "General Campus Plan"; "General Campus Plan"; "Academic Building Plans".

Since writing software solutions involves the use of an object-oriented approach, the architecture of the main classes of this information and navigation system was designed and developed (Fig. 3).

The **ISOLoader** class is designed to load a local database into an isolated storage. Its methods: CopyFromContentToStorage – loads the database into an isolated storage; CopyStream – copies data from one file to another.

The **Searcher** class is designed to search for academic buildings, institutes, departments, offices, and employees of a higher education institution using the specified parameters. It implements six functions:

GetBuildingByName – searches for an educational building by its name in the database and returns general information about this educational building and geographical coordinates that are necessary to draw a path on the map to the specified building;

GetInstituteByName – searches for an educational institute by its name in the database and returns general information about this institute and its coordinates on the plan of the educational building, which is necessary to draw a path on the map to the institute dean's office;

GetDepartmentByName – searches for an academic department by its name in the database and returns general information about this department and its coordinates on the plan of the academic building, which is necessary to draw a path on the map to the department (teaching);

GetCabinetByName – searches for a study room by its name and the building to which it belongs in the database and returns general information about this study room and its coordinates on the plan of the educational building, which are necessary to draw a path on the map to this study room;

GetWorkerByName – searches for the office of a certain employee of a higher education institution by name in the database and returns general information about this employee of the university and the coordinates of his/her office (if the employee does not have his/her own office, it is assumed by default that he/she belongs to a certain department, i.e. the teacher of this department will be considered his/her office) on the plan of the academic building, which is necessary to draw a path on the map to the office of a certain employee of a higher education institution;

SimpleSearch – finds the path from the given point 1 to the endpoint 2.

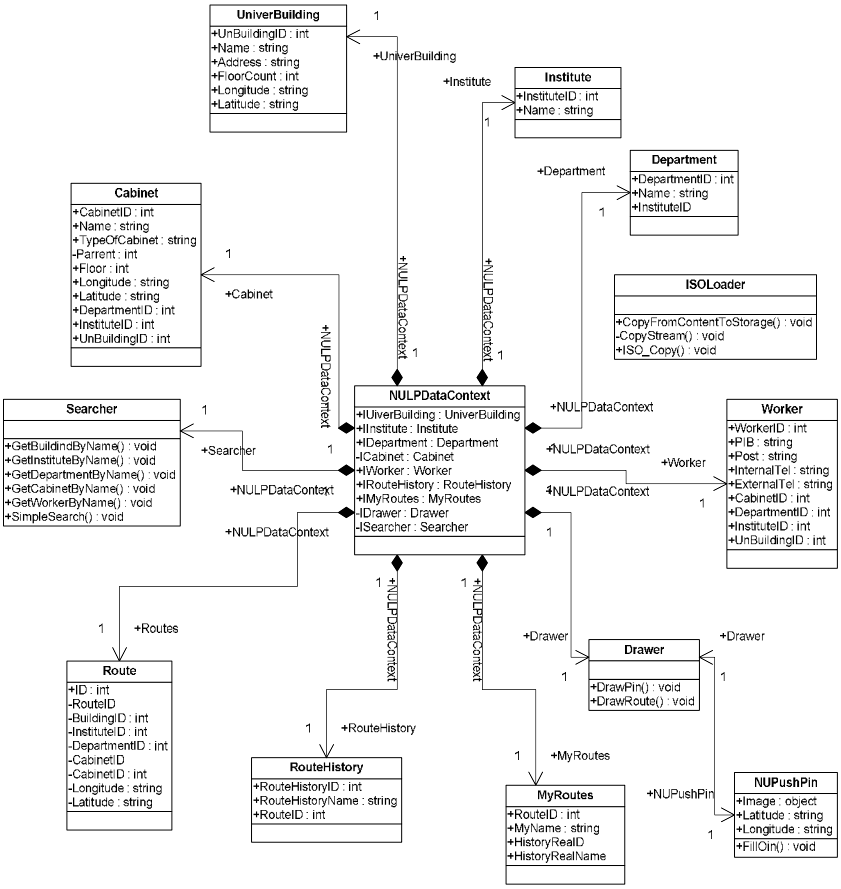

Fig. 3. Class diagram

The **Drawer** class is designed to visualize a path on a map. Its main functions are: *DrawRoute* – draws a path on the map; *DrawPin* – draws a mark on the map.

The **NUPushPin** class characterizes a pin on the map. Its main fields are *Latitude* and *Longitude*, which indicate the coordinates of the pin on the map, as well as the image field, which stores information about what image to display on the pin.

The **RoutesHistory** class is designed to store information about the user's last five routes. It contains fields: *RoutesHistory ID* – the identifier of one of the five last routes; *HistoryRealName* – a name that is assigned by the program automatically (for example, 102 room of the Main building – 302 room of the Fifth building); *RoutesID* – route identifier.

The **MyRoutes** class is designed to store information about the user's routes. It contains fields: *RouteID* – route identifier; *MyName* – user-defined name; *HistoryRealID* – identifier of one of the last five routes; *HistoryRealName* – a name that is assigned by the program automatically (for example, 102 room of the *Main Building* – 302 room of the *Fifth Building*).

The **University Building** class is designed to store information about academic buildings. It contains fields: *UnBuildingID* – identifier of the academic building; *Name* – name of the building; *Address* – address of the building; *FloorCount* – number of floors; *Longitude* – geographical longitude of the academic building; *Latitude* – geographical latitude of the academic building.

The **Institute** class is designed to store information about academic buildings. It contains fields: *InstituteID* – identifier of the educational institute; *Name* – building name.

The **Department** class is designed to store information about academic buildings. It contains fields: *DepartmentIID* – identifier of the academic department; *Name* – name of the department; *InstituteID* – identifier of the educational institute to which the department belongs.

The **Cabinet** class is designed to store information about classrooms and offices. It contains fields: *CabinetID* – identifier of the cabinet; *Name* – the name of the cabinet; *TypeOfCabinet* – type of cabinet (classroom, laboratory, office, etc.); *Parent* – address of the building; *Floor* – floor on which this cabinet is located; *Longitude* – X coordinate of the location of the cabinet of the academic building on the map; *Latitude* – Y coordinate of the location of the cabinet of the academic building on the map; *DepartmentIID* – identifier of the academic department to which the cabinet belongs; *InstituteID* – identifier of the academic institute to which the cabinet belongs; *UnBuildingID* – identifier of the academic building in which the cabinet is located.

The **Worker** class is designed to store information about employees of Lviv Polytechnic National University. It contains fields: *WorkerID* – employee identifier; *PIB* – employee's name and initials; *Post* – employee's position; *InternalTel* – internal phone number; *ExternalTel* – external phone number; *CabinetID* – cabinet number (Dean, Vice-Rectors, Rector); *DepartmentIID* – identifier of the academic department to which the employee belongs; *InstituteID* – identifier of the academic institute to which the employee belongs; *UnBuildingID* - identifier of the academic building to which the employee belongs.

The **NULPDataContext** class is designed to store general information about all academic buildings, institutes, departments, offices, employees of a higher education institution, the history of recent routes, and the user's routes.

Fig. 4 shows an **Activity Diagram** that explains how the process of building the shortest route for users of this system takes place. The activity diagram can be used to describe the dynamic behavior of the system.

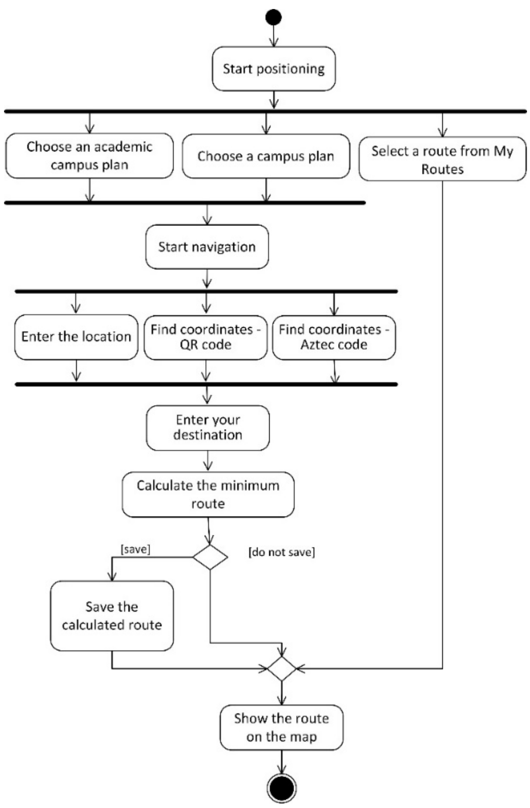

Fig. 4. Activity Diagram

After the user launches this information and navigation system, he/she should select the general campus plan and the campus plan of Lviv Polytechnic National University. You can also select a plan saved in My Routes. After that, you can see where the selected entity is located (academic building (on the general plan of the Lviv Polytechnic National University campus); institute, department, etc., on the maps of academic buildings of the university) and start navigation by drawing a route to this entity. The next step is to determine (obtain) your current location by setting your coordinates manually or using two-dimensional matrix codes (QR code, Aztec code). To calculate the minimum route, you need to get the coordinates of your destination. This action can be performed manually using two-dimensional matrix codes or by obtaining the coordinates of the selected entity from the description of its characteristics. After obtaining the coordinates, we apply the Dijkstra algorithm to build the minimum route. It is possible to add a new route to My Routes. The calculated route is superimposed on the corresponding plan as a line.

Means of Realization of the System Prototype

To develop a mobile application, we recommend Flutter (Flutter, 2024). Flutter is a set of development tools and an innovative framework developed and maintained by Google. It allows you to create cross-platform applications for Android, iOS, the web, and desktop computers. Flutter differs from other cross-platform solutions in that it uses its engine for rendering native elements. This framework uses the Dart programming language. Dart offers a wide range of customizable widgets and tools for creating native interfaces for both mobile and web applications. Use Drift as a database. Drift (formerly known as Moor) is a powerful ORM library for Flutter and Dart that simplifies the work with SQLite databases through reactive data flows and code generation.

Generally, Flutter together with Drift provides a powerful and efficient platform for developing mobile applications with efficient data storage.

Conclusions

This study analyzes modern positioning methods and describes technologies for recognizing matrix codes and algorithms to find the shortest paths.

A conceptual model of an information system for navigation and positioning in the academic buildings of Lviv Polytechnic National University was developed. Class, activity, and use cases diagrams are provided to demonstrate the main scenarios of using the system and its key elements. Based on this project, a prototype information and navigation system was implemented. This software solution provides a wide range of features for a potential user, namely:

- Viewing the general plan of the academic campus and the campus of Lviv Polytechnic National University;
- Viewing general information (address, telephone number of reception offices, etc.) about academic buildings, institutes, departments, offices, and employees of Lviv Polytechnic National University;
- Search for academic buildings, institutes, departments, offices, and employees of the university, which is carried out by entering the name of the academic building, institute, department, or classroom number from/to which the user needs to get;
- the possibility of laying the shortest path to a particular office by entering the name of the building and the number of the classroom from which the user wants to go (or by pointing the phone camera at two-dimensional matrix codes that will be posted on the entrances to the buildings, doors of deans' offices, teaching rooms, and offices of the university administration) and entering the name of the endpoint. As a result, one shortest path is displayed;
- a visual representation of the path from one point to another, including a route line displayed on the plan of the educational building of interest to the user.

The potential user of this software product can be any owner of a Windows Phone device who is a student or employee of a higher education institution, an applicant, or a participant in conferences and various entertainment and information events. For these people, this software solution will be a good assistant in navigating the academic buildings of Lviv Polytechnic National University. The information and navigation system of Lviv Polytechnic National University implements a small part of the functionality used for navigation and positioning inside the premises, which, if necessary, can be expanded in future versions with the necessary functionality.

REFERENCES

1. (2025). Parisaeroport.fr. https://www.parisaeroport.fr/en/passengers/services/book-a-service
2. AbuSalim, S. W. G., Ibrahim, R., Zainuri Saringat, M., Jamel, S., & Abdul Wahab, J. (2020). Comparative Analysis between Dijkstra and Bellman-Ford Algorithms in Shortest Path Optimization. *IOP Conference Series: Materials Science and Engineering*, *917*, 012077. https://doi.org/10.1088/1757-899x/917/1/012077
3. Alpert, M., & Onyshchenko, V. (2023). Finding the best shortest path algorithm for smart suitcase. *Management of Development of Complex Systems*, *55*, 92–97. https://doi.org/10.32347/2412-9933.2023.55.92-97
4. Bao, M. (2005). *Analysis and Design Principles of MEMS Devices*. Elsevier.
5. Barnes, J., Rizos, C., Wang, J., Small, D., Voigt, G., & Gambale, N. (2003). High Precision Indoor and Outdoor Positioning using LocataNet. *Journal of Global Positioning Systems*, 2(2), 73–82. https://doi.org/10.5081/jgps.2.2.73
6. Caffery, J., & Stuber, G. (1998). Overview of radiolocation in CDMA cellular systems. *IEEE Communications Magazine*, *36*(4), 38–45. https://doi.org/10.1109/35.667411
7. Chemes, V. S., & Vetrov, O. S. (2024). Comparison of shortest path search algorithms. *Computer technologies of data processing*, 284-287. https://jktod.donnu.edu.ua/article/view/16287
8. de Schipper, E., Feskens, R., & Keuning, J. (2021). Personalized and Automated Feedback in Summative Assessment Using Recommender Systems. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.652070
9. Elsanhoury, M., Makela, P., Koljonen, J., Valisuo, P., Shamsuzzoha, A., Mantere, T., Elmusrati, M., & Kuusniemi, H. (2022). Precision positioning for smart logistics using Ultra-Wideband Technology-Based indoor navigation: a review. *IEEE Access*, *10*, 44413–44445. https://doi.org/10.1109/access.2022.3169267
10. *Explorer App | American Museum of Natural History*. (2019). American Museum of Natural History. https://www.amnh.org/plan-your-visit/explorer
11. Falas, T., & Kashani, H. (2007, March 1). *Two-Dimensional Bar-Code Decoding with Camera-Equipped Mobile Phones*. IEEE Xplore. https://doi.org/10.1109/PERCOMW.2007.119
12. Flutter. (2024). *Flutter - Beautiful native apps in record time*. Flutter.dev; Google. https://flutter.dev/
13. Google. (2012, May 9). *Shop and travel smarter with Google Maps 6.7 for Android - now with Google Offers and indoor walking directions*. Google Lat Long. https://maps.googleblog.com/2012/05/shop-and-travel-smarter-with-google.html
14. Grewal, M. S., Andrews, A. P., & Bartone, C. G. (2020). *Global Navigation satellite systems, inertial navigation, and integration*. https://doi.org/10.1002/9781119547860
15. Hahn, H. I., & Jung, J. G. (2006). TWO-DIMENSIONAL BARCODE SYMBOLOGY PDF417 IMPROVING PERFORMANCE OF THE DECODER FOR. *Kluwer Academic Publishers eBooks*, 233–237. https://doi.org/10.1007/1-4020-4543-3_28
16. Huo, L., Zhu, J., Singh, P. K., & Pavlovich, P. A. (2021). Research on QR image code recognition system based on artificial intelligence algorithm. *Journal of Intelligent Systems*, *30*(1), 855-867. https://doi.org/10.1515/jisys-2020-0143
17. ISO/IEC 24778:2024. (n.d.-b). Retrieved from https://www.iso.org/standard/82441.html
18. Jiang, H., Li, J., Zhao, P., Zeng, F., Xiao, Z., & Iyengar, A. (2021). Location privacy-preserving mechanisms in location-based services: A comprehensive survey. *ACM Computing Surveys (CSUR)*, *54*(1), 1-36. https://doi.org/10.1145/3423165
19. Khalil, J. (2023, August 28). *Syntony doubles multi-GNSS simulation solution computation power - GPS World*. GPS World. https://www.gpsworld.com/syntony-doubles-multi-gnss-simulation-solution-computation-power/
20. Khalil, J. (2025, February 10). *EUSPA launches GNSS and secure SATCOM user technology report - GPS World*. GPS World. https://www.gpsworld.com/euspa-launches-gnss-and-secure-satcom-user-technology-report/
21. Khalil, J. (2025, February 11). *Taoglas launches multi-band GNSS antennas - GPS World*. GPS World. https://www.gpsworld.com/taoglas-launches-multi-band-gnss-antennas/
22. Khalil, J. (2025, February 14). *Topcon launches GNSS receiver for precision applications - GPS World*. GPS World. https://www.gpsworld.com/topcon-launches-gnss-receiver-for-precision-applications/
23. Khalil, J. (2025, February 19). *MIKROE unveils Click Board for precision applications - GPS World*. GPS World. https://www.gpsworld.com/mikroe-unveils-click-board-for-precision-applications/
24. Khalil, J. (2025, February 4). *GMV to develop Galileo High Accuracy Service data generator - GPS World*. GPS World. https://www.gpsworld.com/gmv-to-develop-galileo-high-accuracy-service-data-generator/
25. Khalil, J. (2025, January 23). *FrontierSI releases LEO PNT state of the market report - GPS World*. GPS World. https://www.gpsworld.com/frontiersi-releases-leo-pnt-state-of-the-market-report/

26. Kogure, S., Kawazu, Y., & Sakai, T. (2020). Quasi-Zenith Satellite System. *Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications*, *1*, 187-204. https://doi.org/10.1002/9781119458449.ch8
27. Ladd, A., Bekris, K., Rudys, A., Wallach, D., & Kavraki, L. (2004). On the feasibility of using wireless ethernet for indoor localization. *IEEE Transactions on Robotics and Automation*, *20*(3), 555–559. https://doi.org/10.1109/tra.2004.824948
28. LaMarca, A., & De Lara, E. (2022). *Location systems: An introduction to the technology behind location awareness*. Springer Nature.
29. Manglik, R. (2024). *Global Navigation Satellite System*. EduGorilla Publication.
30. Marbutt, J., & Schiefer, R. (2011). *Windows Phone 7 Silverlight Cookbook*. Packt Publishing Ltd.
31. Misra, P., & Enge, P. (2006). Global positioning system: Signals, measurements and performance (lincoln, ma: Ganga. *Global Positioning System: Signals, Measurements and Performance Lincoln, MA: Ganga*.
32. Morton, Y. J., van Diggelen, F., Spilker Jr, J. J., Parkinson, B. W., Lo, S., & Gao, G. (Eds.). (2021). *Position, navigation, and timing technologies in the 21st century: Integrated satellite navigation, sensor systems, and civil applications, volume 1*. John Wiley & Sons.
33. Motroni, A., Buffi, A., & Nepa, P. (2021). A survey on indoor vehicle localization through RFID technology. *IEEE Access*, *9*, 17921–17942. https://doi.org/10.1109/access.2021.3052316
34. Neelima, K., & Subhas, C. (2022). Half diagonal matrix codes for reliable embedded memories. *International journal of health sciences*, (II), 11664-11677. https://doi.org/10.53730/ijhs.v6ns2.8117
35. Ni, L. M., Liu, Y., Lau, Y. C., & Patil, A. P. (2004). LANDMARC: Indoor location sensing using active RFID. *Wireless Networks*, *10*(6), 701–710. https://doi.org/10.1023/b:wine.0000044029.06344.dd
36. Normand, N., & Viard-Gaudin, C. (1994). A two-dimensional bar code reader. In *Proceedings of the 12th IAPR International Conference on Pattern Recognition, Vol. 2-Conference B: Computer Vision & Image Processing. (Cat. No. 94CH3440-5)* (pp. 201-203). IEEE. https://doi.org/10.1109/icpr.1994.577158
37. Parush, A. (n.d.). *Conceptual Design for Interactive Systems: Designing for Performance and User Experience*. Morgan Kaufmann.
38. PMI. (2021). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Seventh Edition and the Standard for Project Management (7th ed.). Project Management Institute.
39. Saha, S., Chaudhuri, K., Sanghi, D., & Bhagwat, P. (2003). Location determination of a mobile device using IEEE 802.11 b access point signals. In *2003 IEEE Wireless Communications and Networking, 2003. WCNC 2003.* (Vol. 3, pp. 1987-1992). IEEE. https://doi.org/10.1109/wcnc.2003.1200692
40. Sahoo, S. K., & Choudhury, B. B. (2023). A review of methodologies for path planning and optimization of mobile robots. *Journal of process management and new technologies*, *11(1-2)*, 122-140. https://doi.org/10.5937/jpmnt11-45039
41. Santi, S., De Koninck, T., Daneels, G., Lemic, F., & Famaey, J. (2021). Location-based vertical handovers in wi-fi networks with ie 802.11 ah. *IEEE Access*, *9*, 54389-54400. https://doi.org/10.1109/access.2021.3071639
42. Siklichuk, A. S., & Senyk, I. O. (2024). Application of the Dijkstra algorithm for finding the optimal route. *Applied aspects of modern interdisciplinary research*, 181-184. https://jpasmd.donnu.edu.ua/article/view/14814
43. Son, K., & Choi, W. (2024). Coded Matrix Computation in Wireless Network. *IEEE Transactions on Wireless Communications*, *23*(6), 6394-6410. https://doi.org/10.1109/twc.2023.3331263
44. Sondhi, N. A., & Kumar, N. D. R. (2022). QR codes in Education : a review. *International Journal of Scientific Research in Science and Technology*, 193–205. https://doi.org/10.32628/ijsrst229118
45. *The OMG® Specifications Catalog*. (n.d.). Www.omg.org. Retrieved March 11, 2023, from https://www.omg.org/spec/
46. Thrun, S. (2000). Probabilistic Algorithms in Robotics. *AI Magazine*, *21*(4), 93–109. https://doi.org/10.1609/aimag.v21i4.1534
47. *University Presentation Materials | Lviv Polytechnic National University*. (2025). Lpnu.ua. https://lpnu.ua/en/lviv-polytechnic/university-presentation-materials
48. Veres, O., Kunanets, N., Pasichnyk, V., Veretennikova, N., Korz, R., & Leheza, A. (2019, September 1). *Development and Operations Modern Paradigm of the Work of IT Project Teams*. IEEE Xplore. https://doi.org/10.1109/STC-CSIT.2019.8929861
49. Wang, X. Z. (2018). The comparison of three algorithms in shortest path issue. *Journal of Physics Conference Series*, *1087*, 022011.
50. Waters, J. (2012). *QR codes for dummies*. John Wiley & Sons.

51. Yamasaki, Y., & Noguchi, N. (2023). Research on autonomous driving technology for a robot vehicle in mountainous farmland using the Quasi-Zenith Satellite System. *Smart Agricultural Technology*, *3*, 100141. https://doi.org/10.1016/j.atech.2022.100141
52. Yang, Z. (2012). Windows Phone 7 XNA Cookbook. Packt Publishing Ltd. (Yang, 2012)
53. Yudanto, R., Cheng, J., Hostens, E., Van Der Wilt, M., & Cavey, M. V. (2023). Ultra-Wide-Band localization: advancements in device and system calibration for enhanced accuracy and flexibility. *IEEE Journal of Indoor and Seamless Positioning and Navigation*, *1*, 242–253. https://doi.org/10.1109/jispin.2023.3339602

КОНЦЕПТУАЛЬНА МОДЕЛЬ ІНФОРМАЦІЙНОЇ СИСТЕМИ НАВІГАЦІЇ І ПОЗИЦІОНУВАННЯ ВСЕРЕДИНІ ПРИМІЩЕНЬ НА ОСНОВІ ДВОВИМІРНИХ МАТРИЧНИХ КОДІВ

Олег Верес[1], Юрій Верес [2]

[1,2] Національний університет «Львівська політехніка»,
кафедра інформаційних систем та мереж, Львів, Україна
[1] E-mail: Oleh.M.Veres@lpnu.ua, ORCID: 0000-0001-9149-4752
[2] E-mail: Yurii.O.Veres @lpnu.ua, ORCID: 0009-0007-7750-7159

В умовах густонаселених районів або в приміщеннях точність сигналів GPS може суттєво знижуватись. Це пов'язано з тим, що супутникові сигнали можуть бути затінені будівлями, а також відображатись від них, що створює так звані багатошарові відображення. В результаті, інформаційна система може неправильно визначити позицію, що призводить до великої похибки. Це створює серйозні проблеми для навігації в закритих приміщеннях, особливо якщо потрібно забезпечити високу точність. Для вирішення цієї проблеми активно розвиваються альтернативні технології навігації для приміщень. Оскільки Wi-Fi маршрутизатори часто є у приміщеннях, можна використовувати їх для визначення місцезнаходження. Це дає змогу визначити орієнтовне місцезнаходження з точністю до кількох метрів. Проте, для точної роботи цієї системи необхідна наявність великої кількості точок доступу, що є проблемою у випадку корпусів Національного університету «Львівська політехніка». Тут покриття є не повним або взагалі відсутнім, через велику товщину стін, підземні переходи між корпусами та наявністю аудиторій у підземних приміщеннях. Тому виникла об'єктивна необхідність розроблення проєкту реалізації навігації та позиціонування в закритих приміщеннях, шляхом розроблення мобільного застосунку для пошуку аудиторій і робочих кабінетів, формування та візуалізації маршрутів на основі двовимірних матричних кодів та з врахуванням показників Location Services, накладених на плани навчальних корпусів Національного університету «Львівська політехніка». Запропоновано для визначення місцезнаходження та подання стислої інформації про певний робочий кабінет чи аудиторію навчального корпусу використовувати QR або Aztec код. Місцезнаходження можна також задавати вручну або визначити як дані зі збережених планів навчальних корпусів та кампусу університету. Для обчислення найкоротшого шляху застосовується алгоритм Дейкстри. Це дало змогу розробити концептуальну модель інформаційної системи з врахуванням вимог зацікавлених сторін.

Ключові слова – навігація, позиціювання, двомірні матричні коди, концептуальна модель, діаграми UML