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# RESEARCH OF METHODS AND TECHNOLOGIES FOR DETERMINING THE POSITION OF THE MOBILE OBJECT IN SPACE

*Об'єктом дослідження є процес відстеження положення мобільного об'єкта в просторі. Одним з найбільш слабких місць в системах відстеження положення мобільного об'єкта в просторі є проблема усунення неоднозначності визначення ключових точок при скануванні навколишнього середовища. Ця проблема особливо важлива при одночасному застосуванні декількох методів (або технологій) відстеження положення. З'являється потреба в додатковому калібруванні та налагодженні.*

*У ході дослідження використовувалися результати аналізу методів і технологій автоматичного визначення положення і орієнтації тривимірних об'єктів з використанням систем технічного зору. Аналіз розглянутих популярних систем і методів вимірювання просторового положення об'єктів, а також алгоритмів та технологій навігації мобільного робота, показав, що кожна з розглянутих систем має свої переваги і недоліки. Кожна з них використовується в залежності від поставлених перед даною системою цілей.*

*Проведено порівняльний аналіз основних різновидів алгоритмів методу SLAM. Перспективи даного методу – використання методів штучного інтелекту та розширеного фільтра Калмана – покращують швидкість SLAM-методу. Підтвердженням цьому – величезна кількість відкритих проектів по створенню даного типу навігації в рамках різноманітних конкурсів:*

- *VSLAM – реалізація методу SLAM на основі методів комп'ютерного зору;*
- *RGBDSLAM – пакет для реєстрації хмари точок з RGBD датчиків, таких як Kinect або стерео-камери;*
- *hector_mapping – SLAM для платформ без одометра – тільки на основі даних від LIDAR та ін.*

*Оскільки більшість сучасних технологій все частіше використовують стандартизовані формати сигналів Wi-Fi, Bluetooth, GPS, можна стверджувати, що застосування і аналіз інформації з великої кількості датчиків дозволить збільшити точність визначення координат об'єкта в кілька разів. Створення необхідного інформаційного поля навігації і маршрутизації дозволить картографувати і локалізуватися мобільному об'єкту на місцевості з великою точністю.*

**Ключові слова:** *алгоритми методу SLAM, визначення положення, мобільний об'єкт, технічний зір.*

## 1. Introduction

Robotics is the traditional scope of computer vision. Modern robotics requires the solution of a wide range of computer vision tasks, which includes, in particular:

- set of tasks related to orientation in outer space, determining distances to objects, and so on;
- tasks of recognizing various objects and interpreting scenes in general;
- task of identifying people, recognizing their faces and analyzing emotions.

Determining one's position in space is one of the most difficult tasks necessary for a mobile robot control system. This task enters the four main stages of the functioning of a mobile robot system:

- data acquisition (the robot must use certain sensors to obtain meaningful data);
- data processing (the robot must determine its position in the environment);
- decision making (based on the results of processing, the robot must determine how to act to achieve the set task);
- action (the robot must use the necessary mechanisms for the implementation of the task).

Compared to robotics, computer vision tasks for personal mobile devices such as smartphones, tablets, etc. are even more widespread. In particular, the number of mobile phones is steadily growing and has already almost exceeded the world's population [1].

Therefore, the study of issues of identification by a mobile object of its position in space, as well as computer emulation of the environment, is relevant.

## 2. The object of research and its technological audit

*The object of research* is the process of tracking the position of a mobile object in space. This is especially important to identify your position with a mobile robot.

When controlling the movement of an autonomous mobile robot or a group of robots, they often rely on an accurate assessment of the state of the robot in space or accurate information about the environment. However, in a large number of situations, this information may be missing. In this case, in order to solve the tasks of planning a trajectory when fulfilling a mission with an autonomous robot, it is first necessary to determine its location and assess the environment.

Positional tracking is a combination of hardware and software that allows to determine the absolute position of an object in space. This technology is critical to achieve the effect of immersion in virtual reality, as well as to control the movement of an autonomous mobile robot.

In conditions when there are no reference points, for example, stationary beacons, traditional navigation tools: encoders, inertial sensors, GPS, beacons, range finders, do not always provide a fairly accurate measurement of current coordinates of work. Therefore, given the current trends in the development of robotics, which require increasing the autonomy of mobile robots (especially in non-deterministic environments), one of the key points is their use of access to as many navigation tools as possible.

One of the weakest points in tracking systems for the position of a mobile object in space is the problem of eliminating the ambiguity of determining key points when scanning the environment. This problem is especially important when several methods (or technologies) of position tracking are applied simultaneously. There is a need for additional calibration and adjustment.

## 3. The aim and objectives of research

*The aim of research* is the study of methods and technologies for tracking the position of an object in space.

To achieve the aim it is necessary to solve the following objectives:

1. To analyze the methods and approaches to solving the problem of determining the position of an object in space.
2. To conduct a comparative analysis of existing SLAM algorithms.
3. To determine the optimal navigation technologies of the mobile robot and possible ways for further development.

## 4. Research of existing solutions of the problem

The task of constructing an emulation of the environment by a robot is promising and is being actively investigated. Many works are associated with dense and semi-free methods of simultaneous localization and mapping (eng. Simultaneous localization and mapping – SLAM) in images from a single camera [2–4]. In [5], one of the classifications of the SLAM algorithms and the reconfiguration approach for switching between existing SLAM implementations are presented.

The task of automatically determining the position and orientation of three-dimensional objects using technical vision systems is important in areas such as the control of technological processes in industry, security systems, human-computer interaction, navigation of vehicles, the entertainment industry, etc. Solving this problem in automatic mode will ensure the autonomy of the systems, improve the accuracy of control, increase productivity, reduce the cost of preparatory operations service.

New applications are of great interest that were previously absent from the market. A wide class of such applications for personal mobile devices is associated with the tasks of augmented reality, which can be very different. These include game programs (requiring a consistent display of virtual objects above the image of the real scene when the camera moves) and various entertainment programs in general, travel programs (recognition of monuments with information about them). As well as many other applications related to information retrieval and object recognition:

- recognition of inscriptions in foreign languages with the display of their translation;
- recognition of business cards with automatic entry of information in the phone book;
- also face recognition [6, 7];
- recognition of movie posters, etc.

Augmented reality systems can be created in the form of specialized devices such as Google Glass, which further increases the innovative potential of computer vision techniques. The global market for immersing technology is still in a growth stage. In [8] it is indicated that technologies of mixed and augmented reality, as before, are considered by various industrial sectors. These technologies are especially important in areas such as manufacturing. And this growth is likely to continue. Improved vision technologies have reduced workload and improved performance. The report notes that the widespread use of augmented reality helmets is currently hampered by problems with battery life and image latency. Although with the development of technologies and new solutions, such as determining the depth and at the same time localization and comparison, such devices become widespread.

One of the ways to navigate the work, moves in open areas, global satellite navigation [9]. To do this, a GPS receiver must be installed at work, which allows to immediately get the absolute coordinates of the work. It is enough to record these coordinates with a certain time interval, and then follow them in reverse order. But the use of global navigation can't always solve the problem of spatial orientation of the object. In [9, 10], it is noted that GPS is not the best solution for local navigation, working at short distances and indoors. First, inexpensive little receivers give too low accuracy. Accuracy can be significantly improved by a differential receiver, but such a receiver is more expensive and more. And the more accuracy it is necessary to get from the GPS, the more expensive and more will be the receiver. The accuracy and frequency of measuring global coordinates may not be enough to refine the local trajectory. In addition, satellite navigation is sensitive to the presence of objects in the signal path. If the robot moves along buildings or indoors, the coordinates are measured with a big error.

Global satellite navigation can be replaced by a local absolute navigation system, for example, from radio or ultrasonic beacons [11]. To do this, beacons should be installed in advance around the perimeter of the territory, and the receiver of their signal should be installed in operation. The robot measures its own absolute coordinates in the coordinate system associated with the beacons. This allows to record the traveled distance and return for it. The advantage of this approach is that the error does not accumulate over time. A robot can perform an unlimited number of maneuvers in such a deterministic space without reducing the accuracy of measuring coordinates. Obvious disadvantages include the need to install beacons and their limited range, especially when moving in an environment with large objects and in rooms.

Thus, the results of the analysis of literature data allow to conclude that the systems described in them have low significant drawbacks:

1) accuracy and frequency of measurement of spatial coordinates may not be enough for the implementation of automatic movement of a mobile object;

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2) very often there is a need to establish lighthouses (especially when moving in an environment with large objects and in rooms), and they have a limited radius of action.

The lack of an optimal solution to the problem of eliminating these shortcomings underscores the prospects of the chosen research aim.

## 5. Methods of research

The set of methods and approaches to solving the problem of determining the position of an object in space can be divided into several groups [12–14]:

– acoustic;
– radio frequency;
– magnetic;
– optical;
– inertial;
– hybrid.

In turn, optical methods are based on the use of marker technologies:

– passive (use sensors that reflect the light falling on them);
– active (light is emitted by markers);
– markerless technologies:
1) trackers (track the state of the object from frame to frame);
2) detectors (determine the position of the object in the current frame without regard to the state in the previous frames).

In addition, there are two approaches to tracking the situation:

1. Outside-in tracking (the presence of an immovable external observer, determines the position of a moving object at characteristic points).

2. Inside-out tracking (provides for the presence on the moving object of an optical sensor that monitors the movement relative to fixed points).

Let's consider the technology of navigation work on the data on the absolute coordinates. These include: global GPS satellite navigation, radio and ultrasound beacons being installed, as well as simultaneous SLAM localization and mapping.

Simultaneous localization and mapping is the task of building and updating a map of an unknown environment and simultaneously determining the position of work on this map [15]. The task of SLAM is one of the most promising tasks of modern robotics, and today a huge number of people are working on its solution, as evidenced by the emergence of many publications with the most diverse approaches to solving. In general, for building a map, a description of the objects is made next to the robot, the coordinates of these objects are determined, the objects are plotted on the map. And when the robot again appears in the same place, these objects are recognized by the recorded signs and the current coordinates of the work on the map are calculated. For the description of objects simultaneously used various sources of information:

– environment profile with a laser rangefinder and ultrasonic sensors;
– single or stereo image of the object from the camera;
– information on the presence of obstacles from contact sensors;
– update global position by GPS and compass;
– correction of measurement of small displacements by relative sensors, etc.

The advantage of this approach is obtaining an absolute navigation system without accumulating errors over time in non-deterministic environments without the need to install additional equipment.

An important feature of SLAM is that most algorithms can be implemented only in a static environment, that is, the room or area on which the robot is located should not change.

At the moment there are many different SLAM algorithms that differ both in the type of input information, the representation of the surrounding space in the form of a map, and in the methods of processing this information. Let's give a classification of localization algorithms by the dimension of the mapped space:

– two-dimensional localization on the plane (2D-SLAM);
– three-dimensional localization in space (3D-SLAM);
– color localization on R, G, B components of the image (Color-SLAM);
– color three-dimensional localization in space (6D-SLAM).

These characteristics depend directly on the used sensor. When using the simplest laser range finders, the input information for the algorithm is a two-dimensional horizontal cross-section of the relief of surrounding objects, respectively, 2D-SLAM is used for processing. If there is an additional scanning axis, it is possible to get a three-dimensional cloud of points, gives an idea of the objects in the room, taking into account their relative position in space, so 3D-SLAM can be used here. Color localization algorithms evaluate the state of work on the image from a color video camera installed on it. However, sensors are now gaining popularity, allowing to obtain a three-dimensional color image of objects, for example, TOF cameras, Kinect and the like. For the processing of such images in order to localize and construct a map, the 6D-SLAM algorithms are used. It should be noted that the vast majority of localization algorithms on the plane can be extended to three-dimensional space.

In addition, it is necessary to distinguish between global and sequential localization. Global localization allows to determine the position of work on the map without an initial approximation. Another feature of the SLAM algorithms of this type is the possibility of loop closure, that is, the recognition of already passed sections of the card with the subsequent relaxation of the entire card along the work path. Sequential (relative) localization determines the change in position of work between two consecutive scans.

Algorithms of this type, as a rule, give a more accurate result of determining the position of a mobile robot, compared with global SLAM methods, but should be performed in real time. However, if this algorithm has not converged at least once, its further use is impossible without additional amendments. To achieve the best result in terms of accuracy and reliability of localization, it is necessary to use both methods together. Global localization methods are based on the selection of landmarks from the scan and their recognition in order to obtain the geometric position of the work. The methods of this type include: Markov localization, localization using the extended Kalman filter (EKF), localization by the particle filter method.

The process of sequential localization has several variants of names: scan matching or scan registration, since the algorithm was first designed to scan a certain object sequentially in order to obtain its three-dimensional geometric model. The following main sequential localization algorithms are distinguished [5]:

- Iterative Closest Point algorithm;
- Iterative Dual Correspondences Algorithm for Nearest Dots;
- Hector mapping algorithm;
- Distributions Transform;
- extreme navigation methods;
- GMapping algorithm;
- recurrent filter method.

*Iterative closest point (ICP)*. This algorithm is based on the method of successive approximations to significantly minimize the sum of squares of the distances between the corresponding points of the two scans. The main disadvantage of ICP is that the nearest point in the general case does not correspond to the same point of the scanned surface, especially if two results are obtained from positions distant from each other.

*Iterative Dual Correspondences (IDC)*. The main goal is acceleration of the convergence of the rotation angle of the position estimate, when comparing two-dimensional long-range scans. The IDC algorithm is implemented by two rules for matching. An estimate of the relative movement of the observer is performed at each iteration by minimizing the distance of the nearest points of the two scans. A search is conducted for points according to the new criterion – the coincidence of distances from the observer to the point. The criterion uses polar coordinates with the center coinciding with the position of the observer, and is determined by the difference of the distances to the corresponding points of the two scans within a certain angular range.

*Hector Mapping algorithm* uses the entire accumulated map as a working environment model. The map is represented as an occupation grid, where the value of the map function is 1 if an object is in the corresponding cell, and 0 if the cell is free. To simulate the probabilistic nature of the distribution of points belonging to objects on the map, the developers of this algorithm suggest using bilinear interpolation. In this case, the map function becomes continuous, and it is easy to calculate its gradient at any point. As a measure of the coincidence of the scan and the map, the root-mean-square error of all points of the scan is used. Then to estimate the position of the mobile robot, it is necessary to use the method of least squares. Given the ease of calculating the gradient, minimization of this function is performed by the Gauss-Newton method.

*Normal Distributions Transform (NDT)*. This algorithm simulates the probability of finding a relief point at a certain position using a linear combination of normal distributions. Such an approach makes it possible to use standard optimization methods for finding correspondence with the cross-correlation function. An additional advantage of the construction of normal distributions is the ability to use the accumulated information in the same form without increasing the computational complexity, that is, the construction of the map is the basis of this algorithm. Since the points of the reference scan are mapped indirectly, there is no need to use computationally complex methods of searching for the corresponding points, such as, for example, in the ICP method. Calculation of normal distributions is a task that is performed once for the points of the reference scan when reading the sensor information, and there is no need to enumerate at each iteration of the algorithm. The disadvantages of this algorithm include the strong dependence of convergence on the initial approximation and discretization of space.*Extreme navigation methods*. The basis of such methods is the comparison of two successive scans by optimizing the cross-correlation function. Three methods are distinguished – turning the scan into three histograms (rotation angle and two displacements along the axes of the coordinate system), solving the localization problem in three-dimensional space, probabilistic approach for comparing scans. It is worth noting that the error that accumulates is rather small, and it is possible to use these methods without complicated heuristic methods of closing loops. In general, the use of cross-correlation functions for registering scans in SLAM tasks is a promising direction, and this underlies practically all modern navigation algorithms.

*GMapping algorithm*. The basis of this algorithm is the method of recurrent filtering of Rao-Blackwell particles on a lattice map. Each particle is a potential trajectory of work and contains information about the state of the map of the working environment at the current time. Two approaches are proposed that allow the filter to increase its performance in order to be able to solve the SLAM problem in real time; it is an auxiliary distribution function and adaptive resampling technique. The algorithm is designed to filter the assessment of the position of the work, which is calculated by some method of registering scans, and serves to increase the accuracy of localization. The advantage of this algorithm is the high accuracy of the map. However, the disadvantage is that the considered algorithm has a rather high computational complexity.

*Recurrent filtering method*. A method for determining the motion parameters of an observer (a range finder installed at work) using a series of scans. Two models of the robot's movement are considered: a kinematic model of a three-wheeled operation with the condition that the wheels do not fit in relation to the floor and the model of voluntary movement on a plane. The recurrent filtering method is based on the use of:

- equations of proper motion;
- equations describing the relative motion of points;
- components of the fixed part of the visible sensor system work relief.

In the process of the robot movement, after receiving each scan, the angular and linear velocities are restored, after which a relief map is constructed in an absolute coordinate system, which coincides with the associated coordinate system, work at the initial moment of time. The main advantage of the recurrent filtering method is, undoubtedly, the simplicity of calculations, which is possible due to inexpensive on-board computers. The disadvantages include the accumulation of integration errors of the estimated linear and angular velocity values to obtain the current position of the work.

## 6. Research results

In robotics, there are three types of navigation systems [16]:

1) global – determination of the absolute coordinates of the device;

2) local – determining the coordinates of the device relative to the base point;

3) personal – the positioning by the robot of parts of its body and interaction with adjacent objects is important for devices equipped with manipulators.

Navigation systems are classified by one more attribute – they can be passive and active. The passive navigation system performs reception of information about its coordinates and other characteristics of its movement from external sources, and the active one is designed to determine the location only on its own. As a rule, all global navigation schemes are passive, local ones are both, and personal schemes are always active.

The simplest option for the navigation device is the odometer. In the 1950s, the passive radio beacon navigation scheme and then the satellite navigation system became widely used. A similar concept for a local navigation system is to place in the zone of operation the operation of sources of ultrasonic signals processed by the onboard microprocessor. To build the image of the space most often used laser rangefinder or ultrasonic sensor. In addition, each system has its own advantages and disadvantages.

The results of the analysis of the basic principles on which the above methods are based are given in Table 1.

The analysis of methods for determining the position of an object in space allows using the optimal algorithm depending on the current environmental conditions.

It is determined that the question of justifying the numerical values of the indicators (accuracy of localization, stability limits, when solving a problem), while operating the position tracking systems of an object in real time, has not been sufficiently studied today. The authors have begun a series of previous studies on assessing the accuracy of determining the position of a mobile object and the effect of error accumulation when applying the synthesis of the above methods, algorithms, systems [17].

Further development of technologies and models of mobile systems will expand the scope of application of function-oriented SLAM algorithms. This will expand the functionality of mobile objects without significant changes in their software and hardware components.

**Table 1**

Analysis of methods for determining the position of an object in space

| Group of methods (methods, systems) | Basic tracking technology | Advantages | Disadvantages |
|---|---|---|---|
| **Acoustic**:<br>ISO-900 System, RUCAP UM-5 | Use ultrasonic (high-frequency) sound waves. Measure the time of flight of the sound wave from the transmitter to the receiver, or the phase difference of a sinusoidal sound wave | Simple enough, reliable, cheap. High speed calculation of coordinates. Ease of processing, low power consumption | Have a low update rate caused by the speed of sound in the air. Retain restrictions related to the number of simultaneously used devices, the size of the working space |
| **Radio frequency:**<br>UWB (Ultra-WideBand) systems: BW1000, Part, Series.<br>Methods: TDoA/ToA/AoA/ToF | Similar to acoustic tracking methods. Radio signals are used to determine the location of objects | Remain effective in areas with complex geometry. High level of noise immunity and safety. It has no barriers to other communications. The higher the frequency, the greater the accuracy, but the smaller the range | Accuracy reaches only about centimeters. Not applicable for virtual reality. Small radius of action (up to 10 m). Complicated infrastructure. GPS obstacle |
| **Magnetic**:<br>Rarer Hydra STEM, trakSTAR, Polhemus system | Based on measuring the intensity of the magnetic field in different directions | Accuracy is quite high under controlled conditions. Measurements of object coordinates are possible with 6 degree of freedom | Prone to deterioration from conductive materials near the emitter or sensor, from magnetic fields. Variable sensitivity of sensors depending on the position, limited working space |
| **Optical:**<br>– Passive: Smart-DX, Raptor-12HS Digital Real Time System, Bonita, TrackIR;<br>– Active: Certus HD, Visualeyez system, HeadJoy, A.R.T.<br>The outside-in approach is used in the Oculus Rift (Constrellation), PSVR, OSVR and a variety of Motion Capture systems.<br>The inside-out approach is used in Oculus Rift Microsoft Hololens, Project Tango (SLAM), SteamVR Lighthouse | A set of computer vision and tracking algorithms for devices (visible or infrared cameras, stereo cameras and depth cameras).<br>Based on the use of marker methods: passive and active and markerless methods: trackers and detectors. There are two approaches to tracking the situation:<br>1. Outside-in approach.<br>2. Inside-out approach | The most popular methods are widely used in robotics, convenient for mobile solutions in virtual/augmented reality. Give stable accuracy over long periods of time. Markerless optical methods are the most promising in terms of ease of use and versatility | Greater computational complexity. Not always provide a fairly accurate measurement of current coordinates. The inability to use sensors with the constant observation of many scenes, significantly limits their use.<br>To implement passive optical methods, it is necessary to use predefined information about the scene structure and the conditions for obtaining an image. The use of a specific markerless optical method depends on the scene observation conditions |
| **Inertial:**<br>IGS-Cobra, MVN Awinda | Based on MEMS technology, complementary filter or Kalman filter. Use gyroscopes, determine not only the position of the sensor, but also its angle of inclination. Allow to track orientation (roll, pitch, yaw) in space. Inertial tracking is combined with other methods that periodically adjust the accelerometer drift | Resistant to interference of various kinds, it is possible to track the orientation with great accuracy and minimal delays. Provide a high refresh rate. Data on the gyroscope and accelerometer successfully correct each other and provide accuracy for both short-term measurements and for a long period | Determination of coordinates (displacement) due to double integration of linear acceleration, calculated from data from the accelerometer, does not meet the accuracy requirements for long periods of time. Drift while driving leads to an accumulation of error. high price |
| **Hybrid:**<br>Sensor Fusion algorithm, Extended Kalman Filter (EKF).<br>TAU Tracker (magnetic inertia) | Combine various tracking methods. They build their own image of the environment, after which they form a route and movement along it, constantly comparing their space map with the data received from navigation devices | Hybrid methods intelligently take advantage of the combined methods. All kinds of navigation tools are used. The presence of the intellectual component | Primarily concerned with the assessment of the environment, the analysis of the completed task and the adoption of a decision. high price |

## 7. SWOT analysis of research results

*Strengths*. Further increase in the performance of mobile processors allows to set new tasks for computer vision systems in everyday work, the number of sales of which throughout the world amounts to millions of copies a year. Many of these tasks are far from complete and promising from an innovative point of view.

In connection with the need to use groups of mobile robots, interest in the problems of group navigation and intelligent control of the movement of mobile robots as agents of complex multi-agent robotic systems collectively solving a common task has increased significantly. In such circumstances, each agent contributes to the construction of the map. Shared global navigation can be done by distributed computing.

The increase in the volume of tasks for mobile robots sets the role of multi-agent robotic systems to a new level. The use of artificial intelligence methods will allow complexes of information from various types of sensors, not using large computational powers, but in conditions of great uncertainty. Multi-agent system will provide the principle of redundancy of navigation information, and expert systems will allow to filter information in different operating conditions of a mobile robot.

*Weaknesses*. There are two interconnected disadvantages of SLAM [15, 18].

The first is computational complexity, which also increases with increasing map size. This problem is especially acute if the system has accumulated some error and is located next to similar objects that are difficult to distinguish from each other, for example, when the robot moves along the road next to the trees. Objects on the map may be similar to each other. To find such objects in an unfavorable environment for SLAM, it is necessary to apply more sophisticated algorithms for processing data from sensors, which increases with increasing map size. As a result, the robot or is oriented on a limited number of objects with low accuracy, or can't quickly move and build a large map.

The second is sensitivity to changes in the environment. This disadvantage is associated with the first. If use complex information processing algorithms and describe as many surrounding objects as possible, study the space from all angles, then even significant changes in the environment can be correctly processed when returning to the same point. But through the computational complexity and limitations of the working area of the sensors, especially cameras, with straight-line motion without stopping and additional movements, it is possible to describe a limited number of objects. Their real-time SLAM implementations are sensitive to changes in the environment.

*Opportunities*. Since most of the above technologies are increasingly using conventional Wi-Fi, Bluetooth, GPS-devices, and they, in turn, are found almost everywhere, we can say that using and integrating information from such a large number of sensors will increase the accuracy of determining the coordinates in several times. Creating some kind of information field of navigation and routing will allow to map and localize on the ground with great accuracy. The future is the integration of information about the position of an object from different instruments of data type.

*Threats*. One of the main factors affecting the process of tracking the position of a mobile object in space is the conditions under which the scanning of the surrounding space is carried out. To reduce scan ambiguity, it is necessary to use expensive high-precision equipment. When using standard sensors, the ambiguity of determining one's position increases sharply. Moreover, this figure will vary within large limits depending on the «pollution» of the surrounding space (the presence of a large concentration of dust, gas, elevated temperature, abrupt changes in atmospheric pressure, etc.).

## 8. Conclusions

1. Methods and approaches to solving the problem of determining the position of an object in space using technical vision systems are analyzed. Analysis of the considered popular systems and methods for measuring the spatial position of objects, as well as algorithms and navigation technologies of a mobile robot, has shown that each of the considered systems has its advantages and disadvantages. And it is used depending on the objectives of this system.

2. A comparative analysis of the main types of algorithms of the SLAM method is carried out. The perspectives of this method – the use of artificial intelligence methods and an extended Kalman filter – improve the speed of the SLAM method. Proof of this is the huge number of open projects to create this type of navigation in various competitions:

– VSLAM – implementation of the SLAM method based on computer vision methods;
– RGBDSLAM – package for registering a cloud of points with RGBD sensors, such as Kinect or stereo cameras;
– Hector_mapping – SLAM for platforms without odometer – only based on data from LIDAR, etc.

3. The optimal navigation technologies of the mobile robot and possible ways of further development are determined. Creating a centralized information field of navigation and routing will allow to map and localize on the ground with great accuracy. The future is the integration of information about the position of an object from different instruments of data type.

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# DEVELOPMENT OF INFORMATION AND ANALYTICAL MODEL OF THE STIMULATING INTERNET MARKETING

*Об'єктом дослідження є Інтернет маркетинг у сучасному інформаційному мережному просторі. На тлі бурхливого розвитку інформаційних технологій мережа Інтернету все більш займає провідні позиції у сферах просування та продажу різноманітних товарів. Водночас з цим класичні методи та підходи маркетингу зазнають очевидних втрат домінуючих позицій. Одним з найбільш проблемних місць є ефективне застосування сучасних методів та підходів для розвитку Інтернет маркетингу та, зокрема, стимулюючого Інтернет маркетингу, який сприяє просуванню товарів відповідно до уподобань потенційних споживачів. Також існує потреба у збалансуванні задіяних ресурсів щодо упровадження Інтернет маркетингу відповідно до можливих обсягів отриманого результату.*

*В ході дослідження використовувалися класичні методи ведення маркетингу та новітні інформаційні технології розповсюдження та обробки інформації у мережевих системах. З метою усунення недоліків було запропоновано поєднання класичних та новітніх підходів воєдино, маючи на меті зробити стимулюючий Інтернет маркетинг більш простішим в управлінні процесом.*

*Узагальнено інформаційну модель стимулюючого Інтернет маркетингу. Ця модель складеться з окремих, взаємопов'язаних блоків, що спрямовані як на задоволення потреб потенційних клієнтів, так й дотримання вимог тих, хто надає відповідні інтернет-послуги. Саме врахування потреб та вимог усіх сторін, задіяних у стимулюючому Інтернет маркетингу у вигляді окремих взаємопов'язаних блоків моделі, дозволяє розкрити особливості такого процесу.*

*Відтак, забезпечується можливість визначення аналітичного опису інформаційної моделі стимулюючого Інтернет маркетингу. Це дозволяє визначати шляхи розвитку стимулюючого Інтернет маркетингу, напрями оптимізації його ведення. Це забезпечує такі переваги, як гнучкість процесу ведення стимулюючого Інтернет маркетингу та точкове доведення інформації до обраної цільової аудиторії.*

**Ключові слова:** *інформаційна модель, стимулюючий Інтернет маркетинг, кількість переходів (відвідувань сайту), цільова аудиторія, пошукова оптимізація.*

## 1. Introduction

Internet marketing is developing rapidly in a practical way as well as from a theoretical point of view.

The basis of this development is:
– traditional marketing methods [1];
– methods of searching and analyzing information, making decisions in various areas and areas of human activity [2, 3];