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# Information system for seamless positioning inside of objects under construction

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**Abstract.** Methods for seamless positioning of objects inside objects under construction to ensure the implementation of the principle "always and everywhere" and achieving centimetre positioning accuracy is proposed. The current state of work on the development of experimental samples of hardware and software complexes for seamless indoor and outdoor positioning of objects is presented. It is proposed to use radio-frequency technologies to solve the problem. The main methodological approaches and their first implementations are presented. The main feature of algorithms proposed is the implementation of a seamless transition when determining the position of the object in indoor and outdoor space with usage of an inertial system and radio-frequency positioning systems (in real time regime and without real time regime).

## 1 Introduction

There are substantial evidences in the construction industry, that conventional construction methodology has reached its limits. The research, development and application of industrialization to construction shows that usage of information technologies for seamless positioning of objects on site construction will be able to achieve customized building products at affordable construction costs and constant quality and human oriented working conditions [1]. There are many technical solutions of the problem of localization a physical object in space, which are united under a single term - positioning systems - systems of global and local positioning [2]. The main advantages of global positioning systems, such as GPS, BeiDou and GLONASS, include a large area of positioning (location in the open area) and a sufficiently high accuracy (up to 2 meters - GPS, BeiDou and GLONASS) [3]. However, some shortcomings in these technologies do not allow each of them to become a universal system for searching an object in an arbitrary location: 1) limited possibility of their receipt from state and commercial structures to which the systems belong; 2) weak signal for receiving global positioning systems inside buildings and structures [4]. These shortcomings are not found in local positioning systems (LPS). Such systems are used in the case of the need to build positioning systems with high accuracy, on the order of 0.1-1 meter within a limited area (in closed rooms with reinforced concrete partitions, tunnels, basements, mines), where there is no possibility for direct unimpeded propagation radio signal from out-side [5-7].

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In recent years, there has been a significant increase in publications in the field of research of the problem of positioning indoors. Problems of positioning indoors are in focus of dedicated the international annual conference "Indoor Positioning and Indoor Navigation Conference" (IPIN). The last conference was held in France in 2018 (http://ipin2018.ifsttar.fr/).

Positioning systems using passive and active radio frequency identifiers (RFID) are widely used for indoor object positioning [8]. In [9] a study showing that for all existing technologies of radio-frequency positioning and positioning by using disparate velocity sensors, the earth's magnetic field and acceleration, the maximum attainable value is tens of centimeters at a significant cost is presented. The authors conclude that the use of hybrid multisensory systems based on technologies of micro-electro-mechanic systems (MEMS) is an actual task of the future, not realized at the present time. In [10] an integrated hybrid solution for inferring indoor and outdoor location of objects by means of heterogeneous wireless networks and satellite-based location systems is presented. Many authors also have been pointed out that increasing the accuracy and speed of positioning is an actual and unsolved problem [11-13].

The internal building environment is very complex, and as a result, a wide variety of technologies for solving indoor positioning problems are offered in studies and literature, but so far, no solution has been established that can be recognized as standard and the best [13-17]. It can be argued that the problem with indoor positioning is more difficult than the problem of only localization [18, 19]. The reason is simple: from the set of measurements, it is necessary to estimate not one location but a number of correlated mobile node locations [20]. Also, localization models are needed to improve the management of construction objects [21-27].

In this paper, based on the experience of developing hybrid laser scanning systems [28-30], it is proposed to use radio-frequency technologies to solve the problem of positioning within objects under construction [33-38]. The methods proposed for development will allow achieving centimeter positioning accuracy and creating hardware and software complexes for seamless positioning of objects inside the premises to ensure the implementation of the principle "always and everywhere". The paper presents the main methodological approaches and their first implementations.

## 2 Method

Significant differences in the accuracy of the determination of coordinates and the lack of flexible solutions for the integration of global and local positioning technologies do not allow for seamless localization of objects when moving inside and outside premises in real time in the centimetre range. All known indoor positioning technologies, as shown in Table 1 [9], allow determining the location of an object, and all of them have their characteristics, the most important of which are: accuracy, range, energy consumption, cost and quality of indoor operation [31]. There are two global approaches to positioning indoors: the use of computer vision and the use of radio frequency methods. Existing indoor positioning systems based on optical solutions and technical vision are largely environment-dependent, do not have high performance and are very expensive, due to the need to use high-sensitivity cameras with high resolution. Therefore, the radio frequency method is chosen as more hopeful.

**Table 1.** Comparison of indoor positioning technologies

| Technology | Type of measurement | Accuracy | Pros | Cons |
|---|---|---|---|---|
| GPS | TDOA (Time | 10-20m | All over the earth | Expense infrastructure. |

| Technology | Type of measurement | Accuracy | Pros | Cons |
|---|---|---|---|---|
| | Difference Of Arrival) | | | Only outdoor |
| Galileo | TDOA (Time Difference Of Arrival | 1-5m | All over the earth | Expense infrastructure. Only outdoor |
| A-GNSS | TDOA (Time Difference Of Arrival | < 5m | Over the country | Low indoor precision |
| Cellular technologies (2G/3G) | E-OTD / OTDOA Enhanced Observed Time Difference /Observed Time Difference Of Arrival | 50-500m | Over all cellular(2G\3G) coverage | Special synchronization of base stations required. Low accuracy |
| Cellular technologies (LTE) | OTDOA (Observed Time Difference Of Arrival | 20m | Over all cellular (LTE) coverage | Special synchronization of base stations required. Low accuracy |
| General cellular technologies | CellID | Cell size | Over all cellular (LTE) coverage | Low accuracy |
| Wi-Fi | RSS–Fingerprinting (relative received signal strength) | 1-5m | Indoor possible, low price | Preliminary building of special fingerprint database required, low accuracy |
| Wireless Sensor Networks (ZigBee) | RSS/PDOA phase difference of arrival | 1-5m | Inside one room, low price, low power consumption | Low accuracy, special roaming service required for seamless positioning |
| UWB | TOA/TDOA/AOA Time of arrival /time difference of arrival/angle of arrival | 0.1-1m | Quite high accuracy, indoor positioning | Low range, problems of non-linear signal propagation. |
| RFID/Bluetooth | Near Field/RSS/PDOA | Connectivity range | Indoor, low power consumption, quite low price | Low accuracy, one tag for each anchor point |
| NFR (near field radio) | EM parameters of near field | 1-5m | Indoor, quite low price, | Low frequencies – big antennas |
| INS (inertial systems) | Acceleration Magnetic field Angular speed | 1-5% of traveled distance or angle | Works everywhere | Drift of position /orientation due to the influence of magnetic disturbances inside the buildings. Expensive, and dimensional solutions. |

The method is based on fact, that in many practical situations, it is not interesting that at a given time instant $t$ one can get the posterior distribution of the previous states $x_n$. The marginal posterior distribution $p(x_n|y1{:}n)$ of the current state $x_n$ given all the past measurements $y1{:}n$ is sufficient. This posterior quantifies is based on Bayes' theory. In case that there are measurements acquired by different types of sensors, the information from these measurements can be combined to improve on the tracking. Suppose the *m*-th node has different types of sensors with measurements about node *k* as shown in fig.1 [11]. Let the measurements of these sensors is denoted: $y_n^{(k,m)j}$ $j=1, 2, \ldots J_m$. Then, if the measurements are conditionally independent, the perception model can be written as [9]:

$$p(y_n^{(m,k)} \mid x_n) = \prod_{j=1}^{J_m} p(y_n^{(m,k)j} \mid x_n) \tag{1}$$

If the conditions of independence are not met, then for example, an attaching weight to the information provided by each sensor and combining linearly the likelihoods can be used.

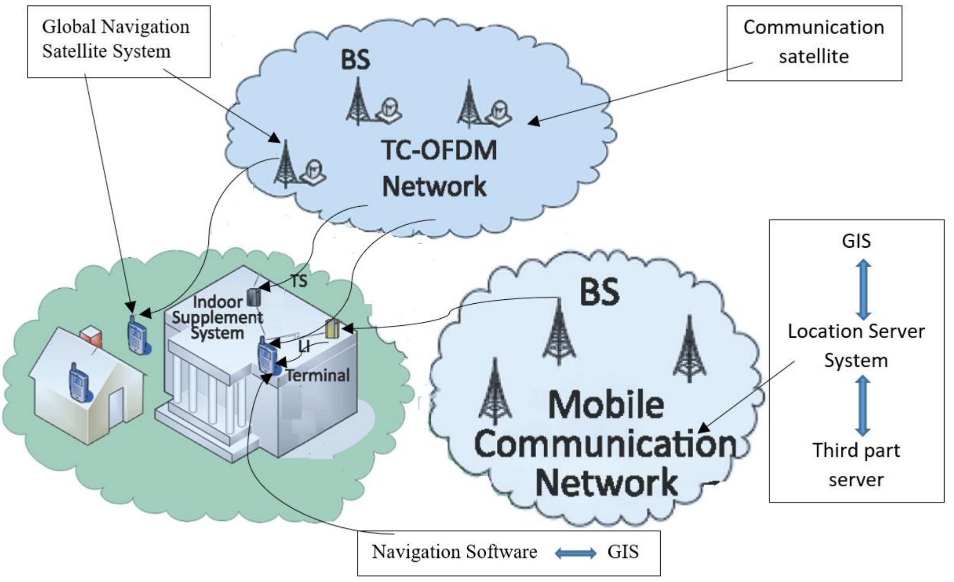


**Fig. 1.** Fusion methods Time & Code Division-Orthogonal Frequency Division Multiplexing (TC-OFDM). LI – location information, BS – basic station.

The method proposed is based on such components that implement new algorithms for seamless hybrid positioning of objects inside buildings with the highest accuracy in the centimeter range in real time. The novelty of the proposed is to create a unified methodology for positioning objects inside premises and ensuring a seamless tracing of object locations. The technical feasibility of hardware solutions for the proposed technologies of precise positioning in Russia is confirmed by the presence of the elemental base of navigation equipment for consumers developed and tested by domestic samples of high-precision positioning equipment with accuracy of positioning about 10 cm in real time and in the three-dimensional (3D) space [32]. The algorithms of seamless hybrid positioning of increased accuracy provide calculations of local three-dimensional coordinates of objects inside the premises according to radio frequency positioning and multisensory positioning and integration of global and local coordinates for positioning inside any premises with accuracy of +/- 10 cm both in real time and without it.

## 3 Results and discussion

As a result development of new algorithms and software and hardware for hybrid seamless positioning inside buildings based on radio frequency and multisensory positioning methods makes it possible to solve the following problems: 1) increasing the speed and accuracy of horizontal positioning to centimetre values at a speed equivalent to the average speed of traffic in industrial areas (about 30 m / s); 2) increase the accuracy and speed of vertical positioning at speeds that exceed current requests from civil engineering consumers; 3) high-precision local positioning without reference to global space positioning systems.

Currently, at the development stage there are hardware and software systems for high-frequency radio-frequency 2D positioning of indoor objects and hybrid positioning for increased accuracy of indoor facilities in real time. These systems increase the accuracy and ability to share several technologies of global and local positioning, which will improve the efficiency of solving the following tasks in a number of industries:

obtaining an adequate picture of the movement of people and material objects participating in the process under control to optimize the reengineering or the regulation of complex interrelated processes;

identification of key objects, which in future can be identifier on all steps of technological processes and its behavior can help to receive timely signals in case of deviations;

control compliance with schedules for the supply of products and complexes (including control of the movement of components in any areas of the enterprise);

prompt notification of the presence of deviations from the graph and the location of critical (key) objects for the process;

instrumental control of the movement of the object along the technological chain allowing detailed recording of the progress of the process (up to the numbers of the components and executors of each operation).

It should also be specially noted that the lack of methods and hardware/software systems of high-precision positioning of objects in the range of centimetre accuracy has a negative impact on the efficiency of a number of works on objects under construction. Among such works it should be noted such as: transport and storage activity using floor transport means hoisting-and-transport machines and units; control and management of the movement of people and mobile equipment within the complex under construction; geodetic surveys on determining boundaries coordinate of different objects.

## 4 Conclusions

The current state of work on the development of experimental samples of hardware and software complexes for seamless indoor and outdoor positioning of objects to ensure the implementation of the principle "always and everywhere" are presented.

The specific scientific results of research presented are following:

The algorithms of high-precision radio-frequency 2D indoor positioning of objects are designed to determine the location of objects inside the buildings on the basis of radio frequency technologies in the horizontal plane.

The algorithms for seamless hybrid high-precision indoor positioning of objects with the use of inertial systems and radio-frequency technologies are designed.

The main feature of these algorithms is the implementation of a seamless transition when determining the position of the object in indoor and outdoor space with usage of an inertial system and radio-frequency positioning systems (in real time and without real time).

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