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Review Paper

A Review on Localization Strategies in Wireless Sensor Networks using Beacon nodes

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Abstract: An abstract is a short summary of your research paper, usually about a paragraph (150-300 words) long. A well-written abstract can let readers get the essence of your paper, prepare readers to follow the detailed information, analyses, and arguments in your full paper, and help readers remember the key points. Note: -Special symbols, mathematical formulas, and equations are not allowed in the "Abstract" section. References should not be cited in the abstract

Keywords: The authors must provide up to 6-8 keywords for indexing purposes (vital words of the article)

1. Introduction

Finding the positions of sensor nodes in WSNs is crucial for network operations as well as the majority of application level tasks. This is due to the extremely limited utility of sensory data lacking spatial and temporal synchronization [1]. Wireless sensor networks require extensive research in the domain of node localization technology, one of their key supporting technologies. We can localize a group of network nodes whose exact position is unknown by calculating or measuring the distance between them, the number of hops, or by utilizing the information exchange between nodes. We have two localization methods: beacon-based algorithms and beacon-free algorithms, depending on whether the beacon nodes should be used in the localization process. The position data of a select few known nodes in sensor networks is primarily used by localization techniques based on beacon nodes to determine the locations of additional unknown nodes (called unknown nodes). While other unidentified nodes can determine their own positions by using the beacon nodes' locations, we can receive beacon node locations by pre-configuration, GPS, etc. Node localization frequently does not use GPS because of problems with impediments causing non-line-of-sight, the limited energy and size of nodes, the large number of nodes, and other variables.

If the location of the beacon node is identified using a pre-configured mechanism, the movability of the networks will be diminished, and to curtail localization error in real life implementations, a large number of beacon nodes must be deployed. Localization technology based on beacon-free nodes has modest hardware requirements and can significantly reduce network expenses. The localization accuracy is, however, rather poor. As a result, one of the ultimatums which needs to be addressed in node localization strategy research is how to balance localization accuracy and hardware requirements while taking benefits of various localization technologies to support the implementation of wireless sensor networks. In this paper, based on the potential drawbacks of the non-beacon node localization technology, we offer a probability-based wireless sensor network localization technique without beacon nodes. Target tracking is a networking application where positional data is crucial.

As described by Akyildizet al. in [2], developing wireless sensor networks involves a number of difficulties at different levels and stages. For instance, there are numerous difficulties in designing the physical layer of a wireless sensor node, which must be very compact and fit all the functionalities that are required of it. Data transport from sensor nodes to base stations is one of the tasks that consumes the most energy, necessitating the implementation of an energy-aware and effective routing algorithm. Geographic location-based routing, which is depend upon mathematical modelling of sensor locations rather than employing IDs, is one of the methods being developed and has a lot of potential. Existing localization technologies, like GPS, cannot be utilized to localize wireless sensor nodes due to a number of limitations. Therefore, it is necessary to create new methods and algorithms for sensor node localization. The constraints mentioned as well as the properties of the sensor nodes and sensor network should be used as guidelines when designing the algorithms. To track their shifting positions as they move across the sensor field, however, the moving sensor nodes in the sensor network require the localization approach to be applied. As a result, mobile sensor node localization algorithms demand more energy than static sensor node methods. For portable wireless sensor networks, Amundson and Koutsoukos [3] provide an overview of localization strategies.

2. Background Study

A sensor network's nodes can be classified as one of the following types:
Dumb Node: The node that is unsure of its position would ultimately determine it from the outcomes of the investigated localization procedure. Free and nameless nodes are additional terms for dumb nodes.

Settled Node: A dumb node that has settled is one that first employed the localization algorithm to establish its location.

Beacon Node: Without the aid of a localization mechanism, a beacon node has a constant sense of its location from the beginning. In addition to the localization method, it contains another way for determining its location. For instance, the beacon node might have a GPS or be positioned at a location with predetermined coordinates. Reference nodes, anchor nodes, and landmark nodes are other names for the beacon nodes. The localization problem for sensor nodes can now be stated as follows:
The diagram $G = (V, E)$ demonstrates a sensor network of multiple hop. A set of beacon nodes B with known coordinates are present in the network and are represented by (x_b, y_b). Discovering the position set (x_d, y_d) of every dumb node with a $d \in D$ can solve the localization problem. To pinpoint a node's location, we need to know its latitude, longitude, and height.If every node in a sensor network has a GPS device, the problem of node localization and placement can be resolved.

The utilized protocols and the GPS receiver are not made to be effective or energy-conscious. Since batteries are a limited resource in sensor networks, sensor nodes may be installed for years before any kind of battery replacement is necessary. Therefore, the localization issue in wireless sensor networks cannot be resolved by GPS devices. However, it is probable that some beacon nodes, which make up a small percentage of all nodes, have GPS to act as reference nodes for other nodes when the localization approach is used to address the location awareness problem[7].

Much more money is spent on GPS gadgets. If these are somehow integrated into each sensor node in a network environment, the deployment costs can hike to the point where the sensor network solution is no longer practical for a given issue.

- The requirement that sensor nodes be extremely small is one of their essential characteristics. A GPS device would significantly increase the size of sensor nodes, again in violation of one of the fundamental specifications for a sensor node[8].
- Satellites are necessary for the operation of GPS systems. When there is no satellite connectivity available, GPS stops working in those situations or situations.
- For the reasons outlined above, GPS devices are usually exclusively utilized in a select few reference nodes that serve as intermediary nodes to address localization issues in other nodes. Additionally known as beacon nodes, these nodes. A small number of nodes can be placed in fixed locations where their coordinates can be known in advance and used as beacon nodes to completely avoid using GPS. The sensor field can then make use of a localization algorithm to determine the locations of the sensor nodes either by making use of their built-in radio frequency (RF) capabilities or by making use of additional techniques.

3. Methodologies used in WSN

The world is filled with sensor nodes that are used for sensing and data collection. Knowing where sensor nodes are located is frequently useful. Localization offers the following benefits:
• Object tracking is one of several applications that heavily depends on location. Location-based Routing is turned on, which can help save energy.
• Security is typically improved by location awareness; locations are useful for managing and monitoring sensor networks. New applications are encouraged by locations. Classification of Localization is depicted in Figure 1.

3.1 Centralized Scheme

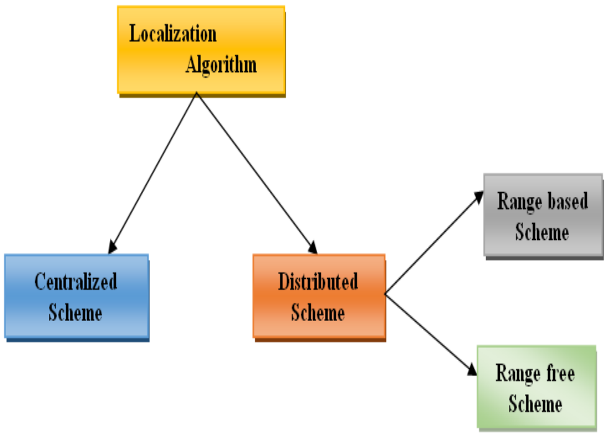

Figure 1. Types of localization algorithm

In this system, the sensor nodes communicate control signals to the central nodes, which then receive them. The central node then determines each sensor node's location and notifies the nodes of it.

a) **MDS-MAP:** As a centralized method, MDS-MAP is not well adapted to real-world uses of wireless sensor networks and is an enhanced version of the MDS-based localization algorithm [4][5].The advantage of this method is that anchor or beacon nodes are not initially necessary. It creates a relative map of the nodes even in the absence of anchor nodes, and with three or more anchor nodes, it transforms the relative map into absolute coordinates. When there are few anchor nodes present, this approach performs effectively. The fact that MDS-MAP needs centralized computation and network-wide information is a disadvantage.
b) **A centralized localization method based on RSSI:** The benefit of this technique is that it is practical, self-sufficient, and enables dealing with any outside situations. Because it needs to generate and send a

lot of information to the central unit, this system has the drawback of using a lot of power.

3.2. Distributed Scheme

Each sensor node chooses a certain location on its own. Range-based techniques and range-free procedures are other subcategories of distributed localization.

a) The range-based technique requires some range information, such as the arrival time, arrival angle, or arrival time difference.
b) Calculates the location using absolute point-to-point distance estimates.
c) More costly and more precise.

Following is how the range-free algorithms operate: In WSNs, numerous seed nodes are dispersed. After receiving these control messages, sensor nodes can determine their own placements.

3.2.1 Distributed algorithms based on beacons:

It is classified into three parts:

• **Diffusion:** The centroid of its nearby known nodes is where the node will most likely be found in diffusion. To obtain a reliable position estimate, APIT needs a lot of beacons compared to nodes, as well as longer-range beacons. For low beacon density, this approach won't deliver trustworthy results.

• **Bounding box:** In order to optimize each node's placement, bounding box first constructs a bounding region for it. By using well-known beacon locations that are many hops distant and distance measurements to nearby nodes, collaborative multiliterate enables sensor nodes to precisely calculate their position. Also rising concurrently is the price of computing.

• **Gradient**: error in the distance matrices for the hop counts when there is a barrier.

3.2.2 Relaxation-based distributed algorithm:

The algorithm's vulnerability to local minima is a drawback of this strategy.

3.2.3 Co-ordinate system stitching based distributed algorithm: Since no global communications or resources are required, this strategy has one advantage. High mobility nodes may be difficult to cover and take longer to converge, which is one downside.

3.2.4 Hybrid localization algorithm: This scheme's flaw is that it struggles to function when there aren't many anchors.

3.2.5 Interferometry ranging based localization: This method of localization necessitates a much bigger set of measurements, which restricts its solution to a smaller network.

4. Research Methodology

The process of localization process is basically takes two steps into account, which are as follows:

Step 1: In the process of ranging, the normal nodes determine their angle and distance with the help of anchor nodes based on the strength of the signal received and various methods.

Step 2: In the process of position estimation the sensor nodes employ distance estimates to calculate their real position. The process of localization locates sensor nodes depending on input data and other inputs, as illustrated in Figure 2 below.

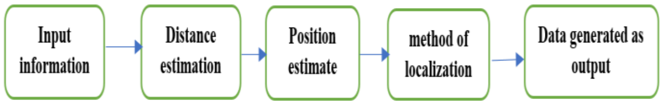

Figure.2 Steps of localization process

4.1 Parameters for localization:

The following are the localization parameters:

• **Precision and accuracy:** Accuracy and precision are important criteria for localisation. Accuracy is defined as the distance between the expected and actual positions. A measured position's precision is its consistency and dependability.

• **Scalability:** It refers to the speed with which the localization process gives location information. This is also referred to as responsiveness.

• **Self Organization:** Ability of system to monitor, control and arrange the activities of the elements without the assistance of any third party.

• **Power:** Power is an important characteristic in a wireless sensor network. Each sensor node is powered by a battery.

• **Density of nodes:** Performance of algorithms also depend on node density. Some algorithms such as hop-count based require high node density for accurate results.

• **Mobile nodes:** WSNs are made up of a small number of GPS-enabled nodes on movable state those are all of the same type. Mobile nodes outperform static nodes in terms of battery power and coverage. Furthermore, movable nodes use less energy.

5. Localization Methods

A localization algorithm that determines node position can make use of this time synchronization. The localization and temporal synchronization problems are actually combined in a number of recommended algorithms, including Synapse by De Oliveira, Nakamura, Loureiro& Boukerche [9], which offers a single solution for localization in time and space. Range-based, anchor-based, centralized, decentralized, GPS-based, GPS-free, fine-grained, coarse-grained, using fixed, mobile sensor nodes, or both, localization techniques can be categorized. We shall discuss each of these approaches briefly.

Basic Localization Measurement Techniques in WSNs A variety of distinct measurement techniques are used by WSN localization algorithms. A number of factors, including the algorithms' accuracy, affect the choice of localization algorithms to be used in various applications. The accuracy of the localization algorithm is actually greatly influenced by the type of measurement and the accompanying precision. Angle-of-arrival (AoA) measurements, Distance-related metrics, and Received signal strength (RSS) profiling techniques can essentially be categorized into three groups [6] for the purposes of measuring distance and bearing, measurements based on angle of arrival (AOA), measurements based on distance, and profiling methods using radio signal strength (RSS). Triangulation is used to establish the position of the node when we have directional information rather than distance information, such as in Angle of Arrival (AoA) systems [9], by applying trigonometrical relationships to estimate the angle of arrival of the received signal. Figure 3 shows the different types measurement techniques used for localization algorithm. One of numerous additional strategies for halting error propagation is the error propagation aware (EWA) algorithm [10]. Several suggested localization techniques, such localization based on particle dynamics [13], make use of a significant number of beacon nodes. These algorithms' underlying ideas can be used to develop novel, efficient techniques that use fewer beacon nodes.

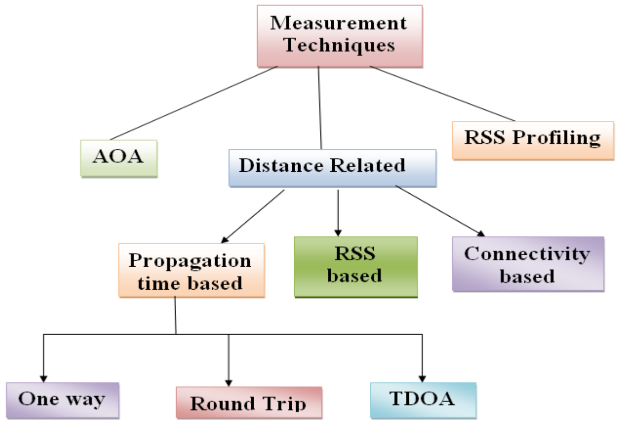

Figure 3. Types of measurement techniques

5.1 Angle of Arrival (AOA)

The bearing measurements and direction of arrival measurements are other names for the AOA measurement methods. The amplitude response and phase response of the receiving antenna are two categories of methodologies that can be used to determine the AOA measurements. These methods determine the angle at which the signal leaves the anchor node and travels to the unidentified sensor nodes. The area where the unidentified sensor is situated is then a line that angles away from the anchor node. To determine the position in AOA measurement systems, at least two anchor nodes are required. If there is a slight measurement error, the localization error could be substantial. Accuracy is impacted by the antenna's directionality, and the measurement environment's shadowing and multipath effects make tests even more difficult. The transmitted signal's multipath component could imitate a signal coming from a completely other direction, which would result in a very considerable error in the measurement's precision. So, the transmitted signal's AOA multipath component may cause the signal to appear to be travelling in an entirely different direction, which leads to a very large measurement accuracy mistake. Therefore, unless it is utilized with huge antenna arrays, the AOA approach is of little interest for localization. This option is not at all energy efficient for WSNs with small sensor nodes. When estimating a node's direction rather than its distance, as in AoA systems, the triangulation approach is utilized. The node positions in this case are computed using the sine and cosine trigonometric rules [11].

5.2 Distance Related Measurement

Additional categories for measuring distance include one-way, round-trip, and TDOA propagation times, measurement based on RSS and connectivity.

5.2.1 Estimation of Propagation time

Calculating the time elapsed between the signal's sending and reception at the receiver is the main technique for determining the length of a one-way propagation path. In light of this time difference and the signal's transmission rate across the medium, it is possible to calculate the range between receiver and transmitter. It is a relatively advanced field to measure time delays. However, the requirement to synchronize the local times at the transmitter and receiver severely limits the implementation of the one-way propagation time measurement. Any local time delay between the transmitter and receiver causes a considerable error in determining distance, which causes a significant error in estimating location. A very tiny synchronization fault of 1 nanosecond will result in a measuring error of 0.3 meters at the speed of light. The need for an extremely precise clock or a complex synchronization mechanism may result in an increase in the cost of the sensor nodes or complexity of the sensor network due to the accurate synchronization requirement. This drawback makes this alternative less desirable for WSN localization.

5.2.2 Round trip propagation time measurement

By using the same local clock at the transmitting sensor node to calculate the time difference, this approach does not require time synchronization. The second sensor node's requirement for time to handle, process, and send back the signal is the method's primary flaw. This internal delay can either be determined by previously completed calibration, In addition to the synchronization issue, environmental factors such as signal bandwidth, noise, non-line-of-sight conditions etc have an impact on the one-way and round-trip propagation times. It has proven possible to get past some of the limitations by using transmissions over the ultra wide band (UWB) to track precise propagation times. Extremely high precision is made possible by UWB's extraordinarily wide bandwidth and, as a result, its brief pulse duration. To untangle multipath signals, this feature offers precise time resolution of UWB signals.

5.2.3 Measurement of arrival time disparity

Assuming the two receivers are fully synchronized and that their positions are known, it calculates the difference in the times at which a transmitting signal reaches each of the two receivers, respectively. Transmitter position can only be identified using this method with three receivers. Multipath and synchronization problems have an impact on accuracy. Due to the greater variability in arrival timings, accuracy rises as receiver distance increases [12, 13-21].

5.2.4 RSS based measurement

By measuring the received signal strength using the transmission's received signal intensity, It is possible to determine the separation between two sensor nodes. Often, sensors can be used to measure RSS. The expected separation from A monotonically declining function can be used to represent the RSS. The following is how the log-normal model depicts the relationship:

$Pr(d)[dBm] = P0(d0)[dBm] - 10nplog10(d /d0) + X\sigma(1)$

Where X is set to zero mean Gaussian random variable with standard deviation that takes into account the random effect brought on by shadowing, P0(d0)[dBm] indicates a reference power in dB milliwatts with a reference distance d0 from the corresponding transmitter, np indicates the path loss exponent, which estimates how quickly the attained signal strength diminishes with distance, and It is possible to assess the separation between two sensor nodes using the RSS data. This distance and the multiliterate technique may then be used to estimate the position using the localization procedure. The lighthouse method is another interesting method for calculating the separation between an optical transmitter and optical receiver. By figuring out how long the receiver will be in the optical beam, this method determines the distance. The optical receiver has advantages due to its small size and affordable price.

5.2.5 Measurement based on connectivity:

It is one of the most straightforward measurement technique. If two sensors are close enough to one another to be reached by radio transmission, they are connected using this method. This measurement is regarded as a binary measurement. If a sensor node is outside the radio transmission range in this method, it is either not directly connected or connected to another sensor node. A variety of methods are used to represent the distance between two sensors as the hop count in order to calculate the average hop distance as precisely as feasible [14]. The range free localization algorithm is the common name for this class of WSN localization algorithms.

5.2.6 RSS profiling-based measurement

It establishes the sensor nodes' spatial separation, as was covered in the section above. The location of the sensor nodes is then established using this distance by the localization algorithms. However, there are two significant obstacles to using this type of technology. First, it is quite challenging to determine the distance from RSS in wireless settings, especially in indoor and outdoor wireless situations with unpredictable objects inside the measuring range. Finding the model parameter is another really difficult task. To get around these issues, RSS profiling measurement techniques are employed. Like was mentioned in the part before, it establishes the separation between sensor nodes. The localization algorithms will then estimate where the sensor nodes are based on this distance. By estimating sensor position from a map of RSS readings, RSS profiling measurement techniques improve accuracy. The signal intensity of the anchor nodes throughout the measuring area is first shown as a map-like representation before the RSS profiling measurement is completed. Sniffer devices deployed at predefined places are used to either generate the map online or offline using measurements taken in advance. They appear to be appealing for WSNs even though this kind of method is often used for WLAN. With the nth item matching to the nth anchor node, each sample point receives information from a separate anchor node on the RSS signal intensity. Since many entries are far from the anchor nodes, their signal intensities vary as expected, and they frequently have zero or values extremely close to zero. The targeted area's RSS map is made by adding up these data points, and it serves as a distinctive identity for the anchor locations and wireless environment. A central position offers model storage. The non-anchor node uses the RSS map as a reference to locate itself. The area on the relevant map with the signal strength that comes the closest to matching the signal strength of its current position is chosen after estimating the signal strength of the area.

6. Future Research Challenges

The various viewpoints and localization-related issues are summarized here. In several possible applications, the difficulties might be very varied. The environment can change and the network scale can be tiny or very huge in different applications. For many important applications with a wide range of environmental issues, conventional localization techniques are worthless. The position estimation of WSNs is a popular area of research right now, and there are many different strategies for doing it. There are recent publications by Amundson & Koutsoubos[3] and Pal[12].The issues listed below need to be resolved:

6.1 Merging of verities non different radio frequency techniques:

Many non-radio technologies, including ocular sensors, can be used to alleviate the shortcomings of the current localization algorithms. Accuracy will increase with the addition of more expensive equipment. The cost-effective solution will therefore be a useful area of research in the future [13, 14]. The employment of several wireless sensors is possible for localization. Different sensors use various physical measurement approaches. In order to increase the system's total location accuracy, measurement techniques from several sensors might be combined.

6.2 Scalability: Typically, a localization system will need to be scaled in two dimensions: geographically and in terms of sensor density. Expanding the network region is known as geographic scaling. But on the other side, rising a localization system that is scalable, keeps functioning appropriately as its scope expands. The two dimensions in which a localization system must typically be scaled are the sensor density and the geographic distribution. Geographic scaling is the process of enlarging the network area. Increasing sensor density, on the other hand, means cramming more sensors into a limited space. An increase in sensor density results in numerous localization problems. One of these problems is information loss brought on by wireless signal collision. Sensors in crowded situations should therefore account for such collisions while calculating position information. The third scaling metric is system dimension. For 2D systems, the bulk of localization methods were developed. Localization in a 3D environment is urged by recent guidelines, like those from the FCC. due to the possibility that measurement noise may cause the estimated coordinates of the sensor nodes in a 3D environment to flip and reflect [13, 14-20].

6.3 Computational Complexity: Localization algorithms' complexity is influenced by both the hardware and the software. Software complexity is equivalent to computational complexity. the speed at which a localization algorithm can find a sensor node. When performing the computation in a scattered manner, this is an essential component. It is also desired to have a localization mechanism with a minimal level of computing complexity because processing uses energy and some sensors have limited battery lives. In the future, the researcher will need to take on the extremely challenging challenge of analytically articulating the computing difficulty of multiple localization approaches.

6.4 Accuracy vs. cost effectiveness: Depending on the measuring methods used to estimate distance, different localization systems have positional precision that varies. The number of anchor nodes in the network area that come preinstalled with GPS devices determines how precise range free localization methods may be. It should go without saying that increasing the system's number of anchor nodes will raise its cost and accuracy.

7. Result and Discussion

Using location data for target monitoring, location-based applications, data tagging, etc., is a core task of localization in WSNs. Many applications, where challenging channel and environment requirements necessitate unique approaches, cannot be fulfilled by traditional range-free algorithms for localization in WSNs. Many other localization strategies have recently been put forth in an effort to partially match the requirements. Since there are many different range free algorithms for localization measurement methods, and assessment criteria, we have presented a thorough survey of them in this study. We initially classify the localization algorithms according to the measuring methods. After that, we divided the localization approaches into two main groups: centralized and dispersed. Since distributed localization methods are more suitable as compared to centralized methods for online monitoring, the majority of WSN applications demand them. Range-based and range-free methods are subcategories of distributed and centralized localization systems, respectively. Range-based techniques are more precise than range-free techniques.

Table 1. Comparison between Distributed and Centralized method of localization

Criterion	Distributed	Centralized
Cost	Less	More
Energy consumption	Less	More
Accuracy	75-90%	70-75%
Reliance on extra hardware	yes	no
Ability to deploy	easy	hard

Range-free approaches are therefore preferred in many WSN applications. Range free localization systems may still face difficulties in the future while trying to achieve more accuracy in areas with various obstacles and poor channel conditions. Furthermore, merging data from different positioning systems with diverse physical principles resulted in the creation of the hybrid data fusion category, which was created to improve the overall system's accuracy and robustness. Additionally, we have included a key inside the problems for future research. A comparative analysis between centralized and decentralized methods has been shown in table 1.

8. Conclusion

Utilizing location data for target monitoring, location-based applications, data tagging, and other purposes is the primary goal of localization in WSNs. Numerous localization strategies have recently been put out to partially satisfy the requirements. As a result, we have presented a thorough overview of different range free localization algorithms, measurement methods, and localization assessment criteria in this study. The localization algorithms are initially categorized according to the measuring methods. The localization approaches were then divided into two main groups: centralized and dispersed. Since distributed localization methods are more practical for online monitoring than centralized systems, they are required for the majority of WSN applications. Compared to range-free methods, range-based methods are more accurate. But range-based techniques consume more energy and are utterly unsuitable for many applications because they need additional hardware to attain accuracy. Range-free techniques are therefore favoured in many WSN applications. However, improving accuracy in demanding channel circumstances and environments with varied barriers will continue to be a challenge for range free localization algorithms in the future. The localization metric must be taken into account in order to satisfy the varying requirements of various applications in order to achieve the best level of localization accuracy.

Conflict of Interest

The authors declare no conflict of interest.

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Authors' contribution

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