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Evaluation of UWB Indoor Location Algorithm Based on 6G Edge Cloud and Computer Vision

Wei Zhang[1,2,a*] **and Xiaolong He**[3,b]

[1] *School of Urban Construction Engineering, Chongqing Technology and Business Institute, Chongqing Open University, Chongqing 401520, Chongqing, China*
[2] *MB Test Laboratory Div., Alpha Networks(Chengdu) Co., Chengdu 610000, Chengdu, China*

In the field of interior design, precise spatial positioning technology is essential for the creation of spaces that are both functional and aesthetically pleasing. Given the difficulty of positioning signal propagation in the indoor environment, it is particularly critical to study an ultra-wideband (UWB) indoor positioning algorithm that combines 6G edge cloud and computer vision technology. In this article, an indoor visual positioning technology for 2D-3D feature point matching is proposed. Through the binocular visual information obtained by the depth camera, the indoor image submitted by the user is accurately matched with the feature points stored in the database, thereby determining the coordinate position of the image in three-dimensional space. To improve the operating efficiency of the ultra-wideband system, 6G edge cloud technology is used in this study. When the ultra-wideband ranging module deviates greatly, the positioning accuracy is guaranteed by switching to the vision subsystem. The federal Kalman filtering program applied in the study enables the root mean square deviation between the estimated coordinates and the actual coordinates to be controlled within 0.3 meters, which significantly improves the reliability of the positioning system. The ultra-wideband indoor positioning algorithm developed in this study is not only suitable for a variety of indoor environments, but also provides important technical support for interior design, helping designers to more accurately grasp the spatial layout and improve the overall quality of design works.

Keywords: ultra-wideband indoor positioning algorithm, computer vision, 6g edge cloud, 2d-3d feature point matching, interior design

1. INTRODUCTION

As architecture continues to become more complex, designers face huge challenges in integrating creativity with physical space. The limitations of traditional interior design methods are becoming increasingly obvious in large-scale or complex projects, although modern technology has made several breakthroughs. The combination of computer vision technology and ultra-wideband technology is leading the digital innovation of the interior design industry. Through computer vision technology, designers can build detailed three-dimensional models, using ultra-wideband technology to achieve high-precision positioning, and greatly improving the alignment of the design plan with the actual environment. The advantage of 6G edge cloud computing technology is that it makes big data processing faster, ensuring real-time interaction and dynamic design adjustment. The application of these advanced technologies not only significantly improves the design efficiency and accuracy, but also offers customers an unprecedented intuitive experience. The purpose of this article is to explore how this technology can revolutionize our design concepts and practical methods.

This research combines UWB technology and computer vision to investigate high-precision positioning in complex indoor environments. Through the binocular vision technology of the depth camera, we obtained the depth information of the feature point, and used the 2D-3D feature point matching algorithm to construct an indoor visual positioning system.

*Corresponding author. Email: [a]zhangw@cqtbi.edu.cn, [b]jackiehe1125@126.com

The system successfully achieved the conversion from two-dimensional images to three-dimensional spatial coordinates, thereby improving the positioning accuracy. In addition, the ultra-wideband system combined with 6G edge cloud technology has significantly improved the accuracy of indoor positioning in real time. In settings containing more obstacles, by switching to the vision subsystem and using the federal Kalman filter program, we effectively reduced the positioning error and verified the feasibility and stability of the technology in different application scenarios. The research innovation combines 6G edge cloud computing, UWB and computer vision technology to provide high-precision positioning solutions for interior design and help designers accurately plan the layout for a particular space. Through the 2D-3D feature point matching algorithm, the indoor positioning accuracy is significantly improved, and the accuracy and speed problems associated with traditional technologies applied to complex environments are solved. At the same time, the technology enhances the real-time interaction and dynamic adjustment capabilities of the design, greatly improves the flexibility and practicality of the design, and opens up a new technical path for the field of interior design.

This research makes the following contributions:

- Improved design accuracy: The integration of 6G edge cloud, ultra-wideband (UWB) and computer vision technology provides interior designers with high-precision positioning tools, enabling them to accurately conduct spatial measurement and create layout in complex indoor environments, thereby improving the accuracy and professionalism of design.
- Enhanced real-time interactivity of design: With the help of real-time positioning and data processing, designers can quickly obtain spatial information (essential for the dynamic adjustment of plans) and instant feedback on customer needs, and improve customer experience as a result of better design efficiency and quality.
- Promoted the development of interior design technology: The application of advanced positioning technology in interior design not only provides designers with new methods, but also demonstrates the potential of integrating technology in the design process, which is expected to lead the development of interior design in a more intelligent direction.

2. RELATED WORK

The indoor positioning technology based on computer vision has broad application prospects and a rich scientific theoretical foundation. Guo found that the demand for indoor positioning services in the commercial and military fields spawned many positioning systems and technologies, and proposed a multi-system positioning technology based on fusion to improve positioning performance in complex electromagnetic environments [1]. Liu believed that with the rapid development of wireless communication technology, various indoor positioning services gradually penetrated people's daily lives, and made a detailed summary of positioning technology [2]. Kunhoth comprehensively investigated the development of indoor navigation and indoor positioning technology and summarized different indoor navigation and positioning systems based on computer vision, as well as indoor scene recognition methods that could assist indoor navigation [3]. Maheepala concluded that due to the poor performance of mature navigation systems such as global positioning systems in indoor environments, research emerged in recent years to develop new indoor positioning technologies. Although several technologies were being studied, a practical and reliable indoor positioning system had not yet emerged [4]. Cengiz found that the location of targets in an indoor environment was an important aspect of estimating the determining the es of targets in outdoor locations. He believed that accurate location estimation of objects in indoor spaces had the potential to enhance several emerging Internet of Things applications [5]. Jang stated that fingerprint-based wireless indoor positioning methods were widely used in location-based services, and proposed the research direction of indoor positioning technology in the future [6]. However, the angle of feature points was not included in the intrinsic vector, so this research needed to be followed up.

With the development of machine vision technology, vision-based indoor positioning technology has been accepted by more and more people, and gradually become a hot topic of current image matching. Tao proposed that a WiFi fingerprint indoor positioning system based on received signal strength could be a feasible solution for indoor positioning [7]. Li proposed an indoor visible light real-time positioning system based on optical camera communication. The system transmitted coordinate data in on-off keying format through light-emitting diode-based lamps and captured it using a smartphone camera [8]. Yao believed that in the era of the Internet of Things, accurately and efficiently locating objects in the real world and identifying objects in the virtual world will become increasingly important. However, the multipath propagation of radio waves in indoor environments might lead to serious location estimation errors, so it was not easy to accurately locate indoor targets using radio technology [9]. Feng discovered that independent positioning and navigation systems were unable to achieve high accuracy in indoor environments [10]. Zhu found that although UWB received widespread attention in indoor positioning due to its high temporal resolution, its accuracy was easily affected by the indoor environment [11]. However, this research did not take into account the various factors that affect indoor positioning, such as angles, etc. The aforementioned studies incorporated only a few of these factors.

3. UWB INDOOR POSITIONING ALGORITHM EXPLORATION METHOD

3.1 UWB Technology

In a line-of-sight environment, due to its high temporal resolution characteristics, UWB signals have accuracy ranging from centimeters to decimeters. By accurately determining the ranging characteristics of UWB signals, precise spatial positioning of targets can be achieved, requiring a high-precision positioning technology [12–13]. Countries around the world have conducted relevant research and paid great attention to UWB positioning technology since the causes of measurement errors and multipath effects in UWB positioning technology need to be analyzed [14].

(1) Superiority

UWB positioning systems are generally comprised of three parts: a positioning tag, a fixed base station, and a solution platform. The positioning tag is fixed to the vehicle to be located. The base station is fixed in the surrounding environment, and the location of the base station is known. The solution platform needs to read the ranging information from the UWB module and achieve real-time solutions to obtain the positioning results. In practical applications, the fixed base in the UWB module emits a pulse at a certain frequency, which is received by the location tag, and then transmits its ranging data to the solution platform through a universal serial bus port. Based on the determined distance data of the location tag, the corresponding positioning is ascertained.

(2) Indoor positioning system

Server layer: The information transmission between the server layer and the base station layer is based on an Ethernet network. It can transfer information and commands between each layer in both directions, thereby achieving control over the base station layer. At the same time, it can also perform real-time switching in both directions; while receiving and processing the location data and image information sent from the base station, the federated Kalman filtering algorithm is used to calculate the location information of the tag to be located and display it in real-time, thereby achieving server-level data processing and real-time display.

Base station layer: The base station layer is the communication interface between the base station and the server, as well as between the base station and the user. This level divides regions according to the principles of time and space division, and forms alternate regions on this basis. The base stations in each area are divided into primary base stations and secondary base stations according to their functions. At the same time, the system also has multiple functions such as image acquisition, wireless data transmission, and online parameter modification.

User layer: The user layer is mainly composed of hand-held tags. The main task is to complete the data interaction function with the base station layer as follows: the positioning data is regularly sent to the base station layer, and the UWB transmission method is used to issue the electronic fence warning and enable one-click rescue functions.

(3) 6G technology and edge cloud

With the rapid development of mobile networks and the widespread application of mobile terminal services, mobile computing has penetrated all aspects of people's lives. With the development of the social economy, the demand for intelligent terminals is also increasing. However, due to limitations in storage, computing, energy, and other issues, mobile terminals make it difficult to complete tasks with high computing loads such as big data analysis, image recognition, and video sessions. To overcome these limitations of mobile terminals and provide high-quality information services for mobile users, cloud and mobile internet have been integrated to form a new computing method-6G edge cloud computing. By configuring efficient servers in the cloud, 6G edge clouds can provide mobile users with computing and storage capabilities. The 6G edge cloud platform moves a large amount of computing work into the UWB system and quickly completes tasks using efficient computing resources. The UWB system outputs the processed computing results to users.

3.2 UWB Indoor Positioning Algorithm

(1) Visual location technology based on 2D-3D feature point matching

Determining the appropriate camera angle is a classic problem in the field of machine vision. Currently, the most widely used method involves mapping the relationship between two-dimensional and three-dimensional points to determine the position and angle of the camera. Using the binocular vision technology of a depth camera, the depth of each feature point in the database is obtained. Combining its internal and external parameters, its three-dimensional coordinates in the 3D coordinate system are obtained; by matching the 2D image with the feature points in the database, the 3D coordinates in the 3D space corresponding to the 2D image in the image submitted by the user are determined; according to the mapping relationship between 2D-3D points in a two-dimensional image, the camera matrix submitted by the user is determined; finally, the camera matrix is split to obtain the corresponding phase information. This study used an offline modeling method based on 2D-3D images. First, a database is established offline to store the depth information of each feature point. Then, using 2D-3D feature points, the geometric constraints on the poles are used to solve the 2D-3D feature points of the pixel matrix, thereby obtaining the position of the user's camera head. The visual positioning method for 2D-3D feature point matching is shown in Figure 1.

Methods such as depth camera, total station, or binocular vision can be used to extract the 3D feature points in the database. The Kinect camera released by Microsoft is a structured light-based camera with a depth of field consisting of three cameras.

(2) Application of ultra-wideband indoor positioning algorithm in indoor design

The UWB indoor positioning algorithm has great application value in the field of indoor design due to its high precision and high-resolution characteristics. UWB technology helps designers to obtain accurate three-dimensional coordinates inside the building to achieve finer spatial planning. Using its high-precision positioning information, designers can determine the details of furniture placement, the location of decorative features, and the human flow line in the early stage of the design to ensure that the plan is both aesthetically pleasing and practical. At the same time, UWB technology

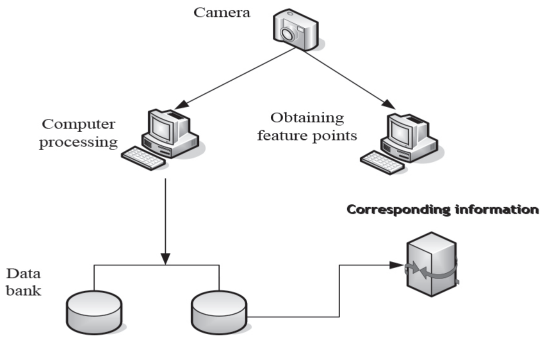


Figure 1 Visual location of 2D-3D feature point matching.

helps designers better understand the sense of spatial layering and mobility, make more reasonable decisions, and improve design quality.

During the construction phase, the value of the UWB indoor positioning algorithm is even more prominent. The construction team can monitor the location of building materials and equipment in real time to ensure the accuracy and safety of construction. In projects with complex structures and high accuracy requirements, UWB technology significantly reduces costs and construction delays caused by human error. In the construction of large-scale commercial complexes, UWB positioning technology accurately monitors the assembly position of steel structures to avoid overall structural problems caused by the accumulation of small deviations. In high-end residential projects, this technology also ensures that electrical appliances, pipelines and other equipment are installed accurately, improving residential safety and comfort.

The UWB indoor positioning algorithm brings innovative experience to interior design. Combined with a dynamic interaction system, this technology can provide users with a personalized space experience. In the field of smart home, UWB technology can accurately capture the behavior and habits of family members, and automatically adjust the status of home equipment, such as lighting, temperature, etc., to create a more comfortable living environment. At the same time, the application of this technology in the fields of virtual reality (VR) and augmented reality (AR) provides designers with intuitive design tools to make design solutions more diverse and vivid, and improve communications with customers.

(3) Solution and error analysis of the camera matrix

When designing interiors, the precise positioning of indoor spaces is the top priority, and can be achieved with the use of ultra-wideband (UWB) technology. The scheme cleverly attaches UWB tags to the object to be positioned, and sets up at least three fixed base stations as signal-receiving points. These base stations accurately calculate the distance by capturing the arrival time difference (TDoA) of the signal transmitted by the label in order to lock the exact position of the object in the three-dimensional coordinate system. This method not only improves the accuracy of positioning, but also ensures that the layout planning of interior design can be based on highly accurate spatial information, laying a solid foundation for creating a personalized and high-performance indoor environment.

After collecting sufficient location data, the next key step is to achieve accurate indoor positioning through data processing. This process covers techniques such as feature point extraction, matching, and Kalman filtering. With the help of binocular visual information captured by the depth camera, the feature points of the indoor environment are extracted. Using the 2D-3D feature point matching algorithm, these newly-extracted feature points are compared and matched with the existing feature points in the database. In the matching link, optimization algorithms such as the least squares method are used to improve the accuracy of matching. To further improve the accuracy of positioning, we applied the Federal Kalman filter. As an efficient recursive optimal estimator, Kalman filter not only predicts the state of the system; it also fine-tunes the measured values to ensure the accuracy and reliability of the positioning results. The update equation of the Kalman filter can be expressed as:

$$\hat{v}_g^{+} = \hat{v}_g^{-} + G_g \left(f_g - K \hat{v}_g^{-} \right) \tag{1}$$

Among: $\hat{v}_g^{+}$—post-update status estimation;
$\hat{v}_g^{-}$—predicted state estimation;
f_g—observed value;
K—observational matrix;
G_g—Kalman gain.

After the data collection and processing are completed, ultra-wideband indoor positioning technology can be applied to interior design. The designer relies on the precise location information obtained to design a more accurate spatial layout. The location data provided by UWB technology can be used to determine the best placement point for furniture, ensuring the efficient utilization of space. UWB technology also gives designers the ability to adjust the design plan in real time to ensure that the final result is both practical and beautiful, so as to meet all aspects of design needs. Through the use of this technology, the process of interior design has become more scientific and efficient, and the design quality has also been significantly improved.

After the database containing the depth information of image feature points is established, global image feature matching and retrieval are performed, followed by local feature point matching and error removal matching. Subsequently, multiple pairs of indoor location feature points are obtained. That is to say, in real space, each matching point is the same three points in real space, thereby obtaining multiple pairs of indoor location feature points. Therefore, after searching for images, multiple 2D-3D matching point pairs of images submitted by users can be obtained.

Hence, through the extraction of image feature points, the overall matching of image feature points is achieved, and part of the feature points are matched to eliminate erroneous matching. This allows multiple pairs of indoor location feature points to be obtained. In real space, each pair of feature points can be corresponding in real space, which allows multiple pairs of feature points to be obtained. After searching for a photo, users can obtain two- and three-dimensional point pairs point pairs of multiple photos. The two-dimensional point refers to the image pixel coordinate system where the feature points of the uploaded image are located, and the three-dimensional point refers to the three-dimensional position in the global coordinate system where the two-dimensional feature points are located.

For each pair of matching 2D-3D points, the formula is as follows:

$$Z^{J} * X = P_2 * Y \tag{2}$$

where Z^{J} is the depth of the image point, and P_2 is the camera matrix of the user uploaded image that needs to be solved. In addition, the formula is as follows:

$$J_Z = PijM^n \sum_{k=0}^{n} \binom{n}{k} x^k a^{n-k} \tag{3}$$

where Pij is the element in row i and column j.

The user's camera matrix is solved using the above method, and then the geometric error is defined. It is assumed that there are n pairs of matching 2D-3D matching points, and the resulting geometric error is defined as follows:

$$E_R = F \sum (X - Pij) \tag{4}$$

(4) Location based on camera matrix decomposition

After solving the camera matrix of the image uploaded by the user, the camera matrix is decomposed to obtain the internal and external parameter matrices of the camera, and finally the position of the user's camera is located.

The specific camera center C is a three-dimensional point, and the constraints satisfied can be solved as follows:

$$C = -T * R \tag{5}$$

(5) Function switching design of visual/UWB integrated positioning system

Due to the failure of UWB positioning and visual sensors in some cases, a mode conversion function is designed in the joint Kalman filter. Here, the conversion of the joint Kalman filter is explained. If all subsystems are normal before time k, then an optimal estimate can be obtained by fusing information from each sub filter. It is assumed that a subsystem fails at $k+1$. At this point, at time k, the main filter has allocated a global state estimation and estimation error covariance matrix to each subsystem, so this information will be lost, thus resulting in the global state estimation made by the main filter at time $k+1$ losing its global optimality. Therefore, the following design has been carried out for the isolation failure subsystem:

At the time of $k+1$, according to the information allocation principle, the global state estimation and global estimation error covariance matrix of the main filter at the time of $k+1$ are used to update the time and measurement of the subsystems that have not failed at the time of $k+1$. The global state estimation at the time of $k+1$ is obtained through federated Kalman filtering. The fault subroutine is separated and waiting for the recovery of the fault subroutine. After recovery, ordinary joint Kalman filtering is performed.

The fault conditions of each subsystem of the federated Kalman filter are analyzed, which are the special conditions necessary for the mode conversion of the federated Kalman filter. The image acquired by a 2D-3D camera may have no feature points, may be subject to extreme changes in lighting conditions and significant changes in viewing angle, which will cause the tracking failure of the 2D-3D point matching visual positioning algorithm. In this case, the algorithm will not be able to obtain camera motion information. On this basis, by calculating the number of feature points between two targets in the image, the feature points between the targets are compared. If the number of feature points is below a certain threshold, it is determined that the target cannot be achieved, and the target is transferred to an independent UWB system. Until 2D-3D point registration, by means of loop back detection and relocation, the camera's movement trajectory is retraced, and the distance between adjacent frames is changed within error tolerance, thereby restoring the Kalman filtering process.

Based on the label location information obtained by the federated Kalman filter, the distance difference J_C between different base stations is found:

$$J_C = \sqrt{(x-a)^2 + (y-b)^2} - \sqrt{(x-a)^2 - (y-b)^2} \tag{6}$$

When the UWB signal is blocked and cannot be received or detected in a non-line-of-sight environment, there is a large discrepancy in the measured distance of the UWB ranging module, which will cause the positioning accuracy of the UWB positioning module to be low. At this point, before the number of reliable signals sent from a fixed base station exceeds three, the operation mode is converted to a single operation of a visual subsystem, and then returned to the federated Kalman filter program.

Currently, 6G edge cloud is one of the most popular computer application technologies available. Transferring computing work from the local computer to a large distributed computer allows users to share hardware, software, and data resources, and allocate computing resources, storage resources, and information services based on users' needs, thereby providing users with more effective services [15]. This approach can achieve unified configuration of network resources, thereby improving the efficiency of network usage. The application of 6G edge cloud technology in UWB systems will greatly improve the operational efficiency of the system.

The timestamp difference received by each base station in an indoor non-line-of-sight environment is as follows:

$$Ti = Tli - Tsi + Tei \tag{7}$$

The error introduced in $T\ i$ will directly lead to a deviation in the final position coordinates.

Table 1 Different indoor positioning methods.

Number	Positioning technique	Farthest range(m)
1	Radio Frequency Identification	180
2	Wireless Local Area Network	150
3	Bluetooth	50
4	ZigBee	100
5	UWB	300

4. UWB INDOOR POSITIONING INVESTIGATION RESULTS

In UWB wireless positioning systems, there are many factors that affect positioning accuracy. Non-line-of-sight error is an important factor that restricts the precision positioning of indoor UWB, and line-of-sight transmission is the prerequisite for achieving indoor UWB precision positioning. If there is nonlinear transmission between two nodes, or if the signal passes through obstacles, there will be a significant delay, affecting the accuracy of positioning. In order to track a single target, unbiased and biased Kalman filtering techniques are used to effectively suppress non-line-of-sight errors, thereby achieving the accurate positioning of specific targets.

The number of base stations per unit area also affects the accuracy of the UWB indoor positioning. Although a single positioning base station can also utilize signal strength for positioning, it cannot fully exploit the advantages of UWB positioning technology. To achieve accurate positioning, it is necessary to have at least three or more positioning base stations [16]. However, the installation of excessively dense positioning base stations will inevitably increase the cost of the system. Therefore, how to select the appropriate base stations to ensure accurate positioning is also a question that researchers should address.

The multipath transmission characteristics of UWB signals can also have a certain impact on positioning results. Among them, the impact of the arrival angle of the UWB signal and the RSSI (Received Signal Strength Indicator) of the received signal on the positioning accuracy of the UWB is particularly significant, and the spatiotemporal resolution of the UWB affects the accuracy of the positioning to some extent.

The huge bandwidth allows UWB to fully utilize spectrum resources. The different indoor positioning methods are shown in Table 1. The farthest range of the UWB was 300m, while the farthest range of ZigBee was only 100m.

Bluetooth technology also has radio frequency characteristics, mainly using frequency hopping, wireless, and other technologies. Due to its high transmission efficiency, safety, and reliability, it is widely used in various fields. Currently, the main solution for indoor positioning is to use Bluetooth signal strength for ranging to achieve positioning functions.

To date, theoretical research on UWB technology has made considerable progress, and related products based on UWB technology have gradually emerged. Due to the problems of multipath interference in indoor wireless communication, how to effectively improve the anti-interference and positioning accuracy of wireless communication systems is a hot research topic at present.

The ideal scenario is the simplest and most important scenario that defines the relationship between an indoor-ranging system and a target. In an ideal state, the TOF (Time-of-Flight) error will monotonically increase as the round-trip delay error and the recovery time increase. The TOF errors under different response times are shown in Figure 2 (TOF errors for response times of 100μs and 200μs are shown in Figure 2 (a). The TOF error when the response time is 600μs is shown in Figure 2 (b). The TOF error was only $1.84 \times 10^{-3}\mu$s when the response time was 600μs.

For this study, UWB indoor positioning technology was adopted, and a UWB-based indoor positioning method was used for a small number of targets that required high-precision positioning services. In theory, using UWB technology to locate indoor targets can significantly reduce the average positioning error of the system. UWB technology was first used in military fields such as military radar, remote sensing, and ranging. At the beginning of the 21st century, this technology began to be valued and recognized by the public, and indoor positioning systems based on UWB also gained rapid development and research. UWB technology is not limited to initial pulse communication. At this stage, all means of communication can utilize UWB. Some standards also impose corresponding restrictions on the application of various UWB technologies, such as indoor UWB communication systems, outdoor UWB equipment, and medical equipment. In this information age of scarce spectrum resources, spectrum sharing is achieved by using extremely low power spectral density, which is also a major reason for the rapid development of modern UWB technology.

In indoor wireless positioning systems, a positioning model is usually constructed based on the obtained location-related variables or parameters, and then these variables or parameters are combined with the mathematical model to obtain the location information of the measured target. A positioning method based on the azimuth angle requires constructing multiple array antennas to accurately obtain the azimuth of the target under test, thereby achieving the positioning of the target under test. When there are few visual fields and obstacles, this method can achieve high positioning accuracy. Due to the large bandwidth of UWB signals, if applied indoors, it will generate UWB signals from the outside, which will have a significant effect on the angle measurement results. Therefore, it is usually applied to other positioning methods to improve the angle measurement accuracy [17].

The estimated value of 100 coordinates was selected and compared with the estimated true location. The RMS curves of different filter positioning results are shown in Figure 3 (partial and generalized Kalman filters are shown in Figure 3 (a), and federated Kalman filters are shown in Figure 3 (b)).

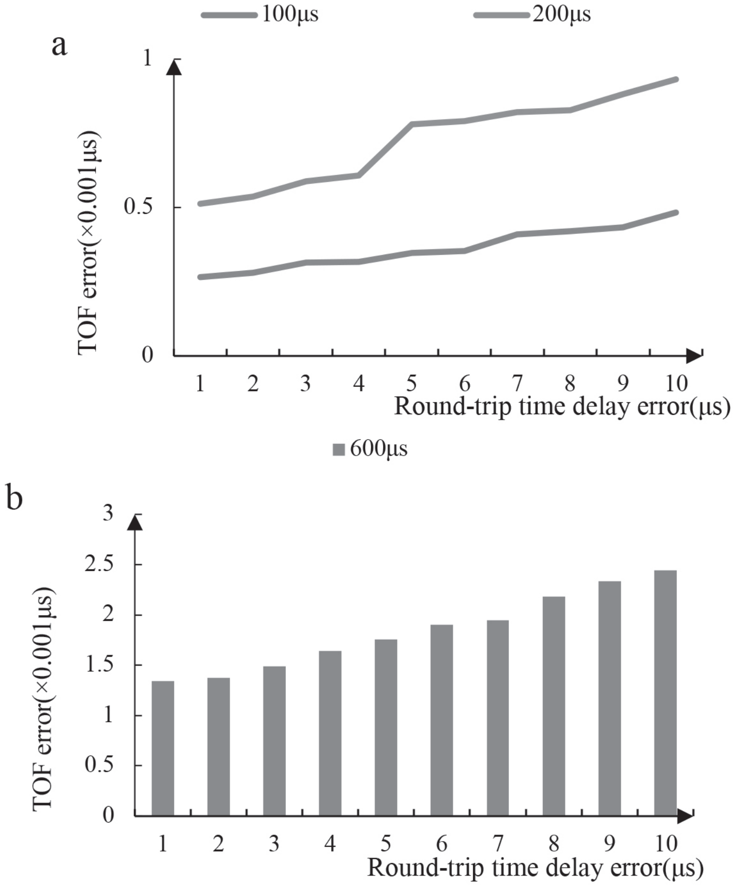


Figure 2 TOF error under different response times.

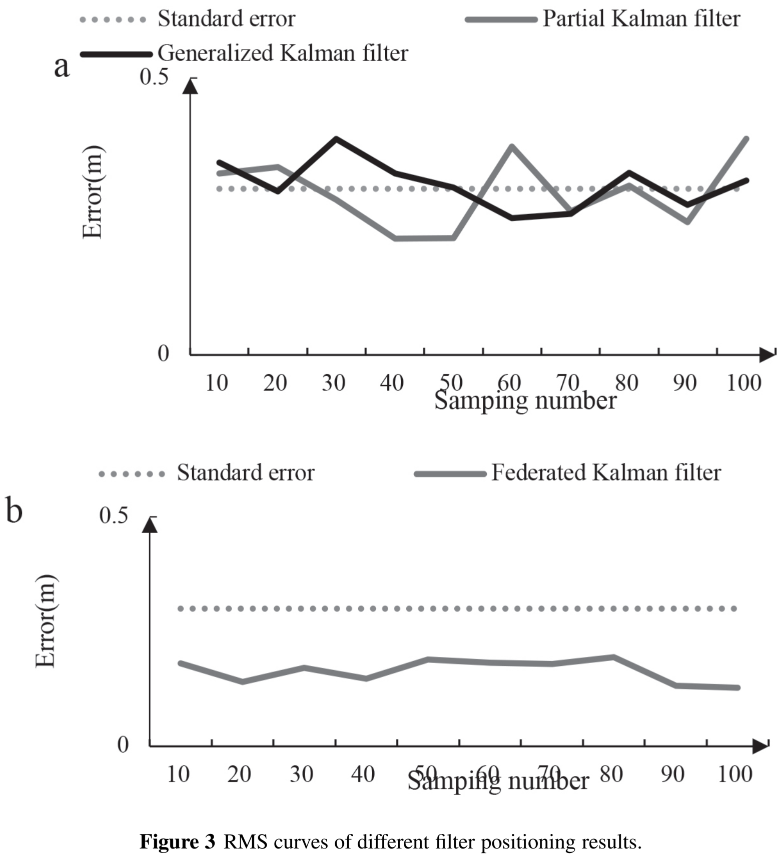


Figure 3 RMS curves of different filter positioning results.

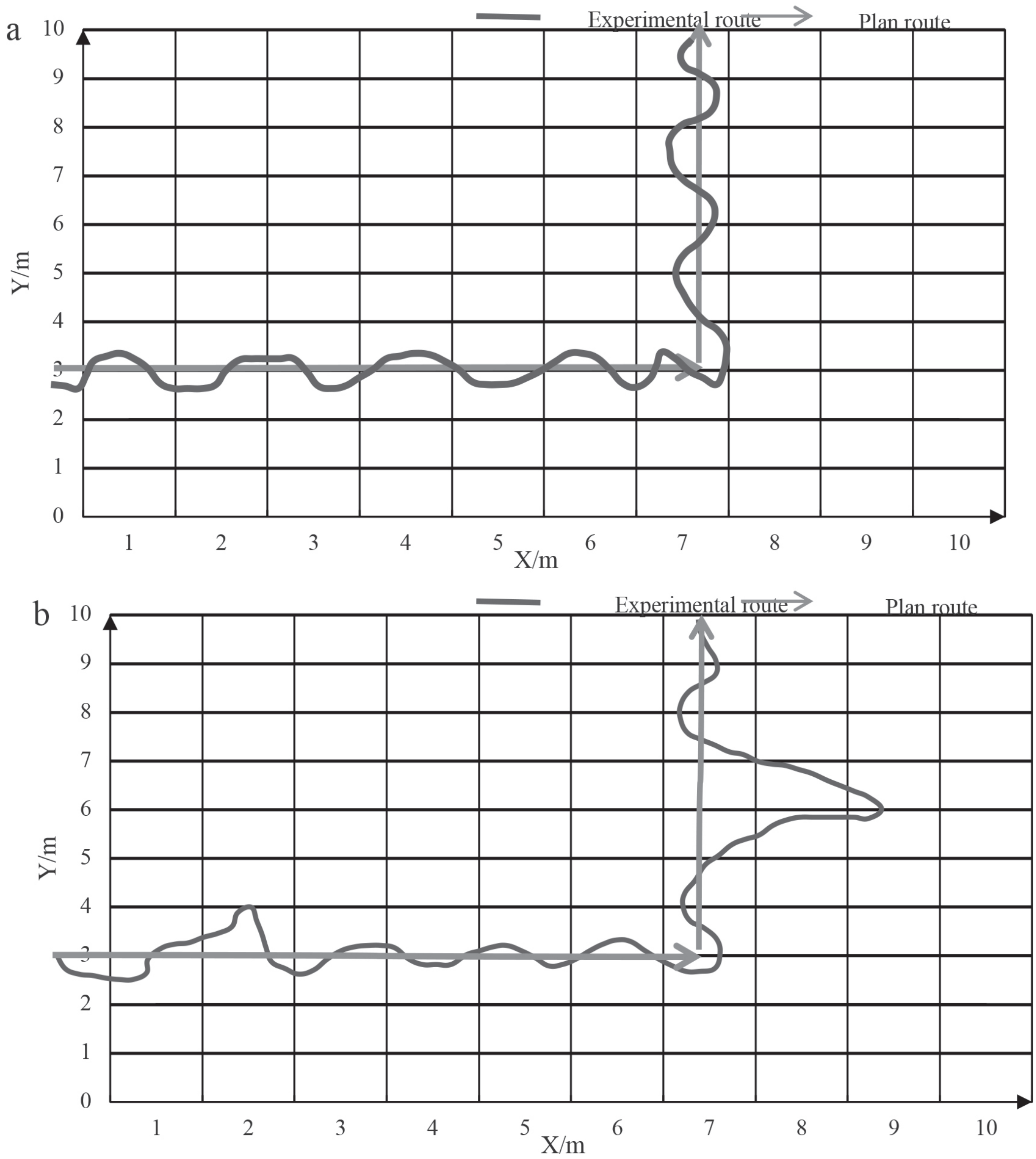


Figure 4 Test results of moving target dynamic positioning on positioning system.

The mean RMS error of the coordinates estimated by the federated Kalman filter in this study was below 0.3 meters. This indicated that although the impact of non-line-of-sight errors was relatively large, the method used in this study could effectively suppress non-line-of-sight errors and achieve indoor accurate positioning.

In recent years, UWB positioning technology has been widely used in intelligent elderly care, intelligent manufacturing, rail transit, warehousing and logistics, etc. Compared with other positioning technologies, UWB positioning technology has more advantages, especially for indoor positioning, which is currently a hot topic in the field of wireless positioning. The research on indoor accurate positioning algorithms for UWB has become very important. The key issues are how to improve the positioning accuracy, stability, and reduce the complexity of the algorithm, which are the focus of and the difficulty addressed in this research. It is hoped that this paper will contribute to the development of UWB indoor positioning technology.

The test results for the dynamic positioning of moving targets on the positioning system are shown in Figure 4. The motion planning route of the test moves from (0,3) to (7,3) along the x-axis, and then moves to (7,10). The first test result is shown in Figure 4 (a), and the error is within 1m. The second test error is shown in Figure 4 (b), which is within the 2m range. The 2m error occurs only once. It is evident that the accuracy of the proposed method is relatively high.

At present, the understanding of UWB positioning technology in China's scientific research institutions and universities is theoretical, and the industrialization of scientific research achievements has not yet been achieved. Although China's UWB positioning technology has made great progress, it still lags behind other advanced countries.

UWB indoor positioning and tracking technology is highly affected by the complex indoor channel environment, making it difficult to achieve an optimal balance between accuracy, cost, and power consumption. UWB technology has extremely narrow pulses and extremely high bandwidth,

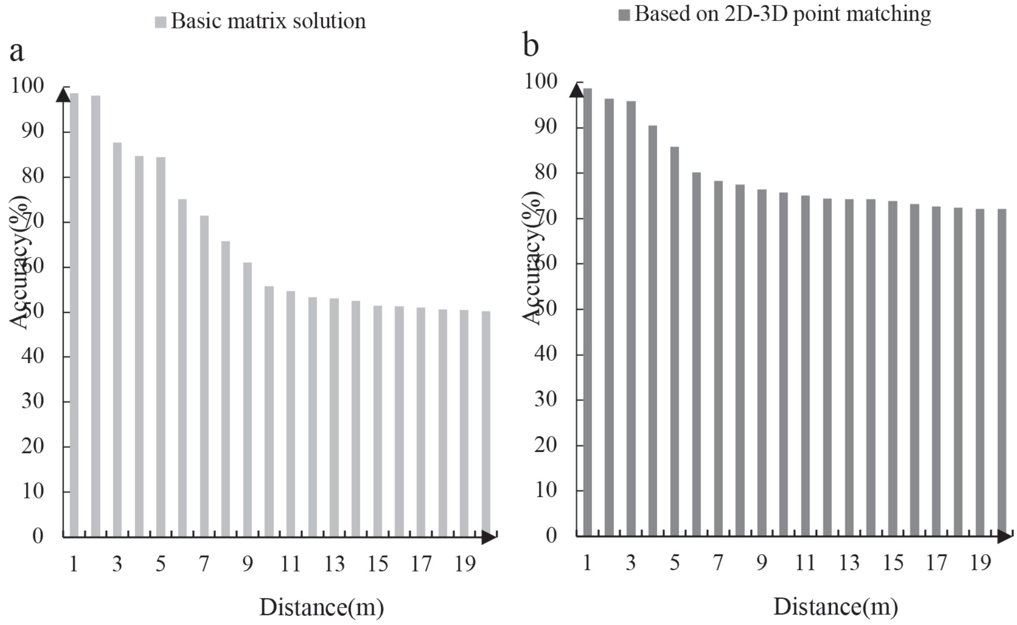


Figure 5 Comparison between fundamental matrix solution and 2D-3D point matching method.

which can better meet the requirements for positioning accuracy under indoor conditions. However, the limitation of its application lies in power consumption. The broadband characteristics of ultra bandwidth make it difficult to receive signals. In order to fully restore the waveform, it is necessary to have a sampling rate twice the signal width. Moreover, ultra bandwidth pulses are greatly distorted when transmitted in complex rooms. Even if analog methods are used, it is difficult to design a corresponding analog matching filter in the case of dense multipath and waveform distortion. UWB signals have a large bandwidth and a large band, so they are the same size or longer than many targets. These features make UWB signals easily reflected or dispersed in indoor environments.

After the signal is reflected or dispersed multiple times, the number of echoes will sharply increase, and its multipath effect will become more obvious, which is the main reason for the multipath factor. The existing UWB technology does not consider multipath effects. With the continuous development of future positioning needs, many scholars have gradually shifted from ordinary non-line-of-sight situations to environments that take into account multiple factors such as multipath, non-line-of-sight, Doppler, etc., and have conducted in-depth research on them.

A comparison between fundamental matrix solution and 2D-3D point matching method is shown in Figure 5 (fundamental matrix solution method is shown in Figure 5 (a)). The 2D-3D point-matching method is shown in Figure 5 (b). As the distance increases, the accuracy gradually decreases. For the 2D-3D point matching method, the decline is relatively stable, with an accuracy of 72% at 20m.

5. DISCUSSIONS

This article discusses the application of the ultra-wideband (UWB) indoor positioning algorithm in indoor design and focuses on its important role in improving design accuracy and efficiency. By using UWB technology, designers can obtain high-precision location information, and then obtain the precise three-dimensional coordinates of the internal space of the building prior to beginning the design. This allows designers to more accurately optimize the spatial layout and functional area division, thereby improving the accuracy and implementation of the design plan. The value that UWB technology brings to interior design is not limited to providing real-time spatial positioning data. Its greater significance is that through this technology, the design process becomes more flexible and rapid. Especially when dealing with complex environments or multi-obstacle spaces, UWB technology can ensure that the design accuracy is not affected by external factors, thereby maintaining the stability and reliability of the design scheme. In addition, the application of this technology enables interior design to be integrated with modern technology, providing designers with more innovative tools enabling the dynamic adjustment of design plans, real-time feedback on customer needs, etc., to further enrich the design possibilities and user experience.

With the continuous progress and widespread application of technology, the prospects of UWB technology in the field of interior design will be broader. It is not only expected to improve the level of specialization of design, but may also become an indispensable and important part of future interior design. For example, in the integration and application of emerging technologies such as smart home, VR and AR, UWB technology will further expand the boundaries of the design experience and make the design scheme more in line with the individual needs of users and real-use scenarios. However, it is also necessary to acknowledge the limitations of UWB technology. At present, the application of this technology is still facing challenges in terms of cost and power consumption. These problems are particularly prominent in projects that require large-scale base station coverage. At the same time, the complexity and variability of the indoor environment may also have a certain impact on the positioning accuracy. Therefore, in practical applications, we need to comprehensively consider the balance between the advantages of technology and cost investment, and continuously optimize the positioning algorithm to adapt to more diverse application scenarios and needs. Nevertheless, the application of UWB technology in interior design still has great potential and broad room for development.

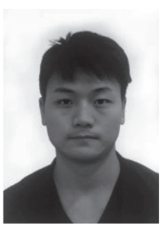
6. CONCLUSIONS

By combining UWB technology and computer vision technology, this article proposes a novel indoor positioning algorithm based on 6G edge cloud, and discusses its application potential in the field of interior design in depth. Studies have shown that this algorithm can significantly improve the accuracy and real-time achievement of indoor positioning, and provide strong support for designers to carry out accurate spatial measurement and layout in complex environments. In the early stage of design, the algorithm can help designers quickly obtain accurate three-dimensional coordinates of the interior of the building, thereby optimizing spatial planning and functional zoning, and improving the accuracy and execution of the design plan. With the help of the 2D-3D feature point matching algorithm, we have successfully solved the bottleneck associated with accuracy and speed in traditional technology in complex environments, and brought us a higher-precision positioning solution. In addition, the technology also greatly enhances the real-time interactivity and dynamic adjustment capabilities of the design, enabling designers to obtain spatial information in real-time, quickly adjust the design plan, and respond to customer needs promptly, thereby comprehensively improving design efficiency and quality. Although UWB technology still faces challenges such as cost, power consumption and environmental complexity in practical applications, we believe that with more in-depth research, the positioning algorithm will be continuously optimized, and the detection performance of the receiving end will be further improved to meet more diverse design scenarios and needs.

REFERENCES

1. Guo, Xianshen. “A survey on fusion-based indoor positioning”. IEEE Communications Surveys & Tutorials 22.1 (2019): 566–594.
2. Liu, Fen. “Survey on WiFi-based indoor positioning techniques”. IET communications 14.9 (2020): 1372–1383.
3. Kunhoth, Jayakanth. “Indoor positioning and wayfinding systems: a survey”. Human-centric Computing and Information Sciences 10.1 (2020): 1–41.
4. Maheepala, Malith, Abbas Z. Kouzani, and Matthew A. Joordens. “Light-based indoor positioning systems: A review”. IEEE Sensors Journal 20.8 (2020): 3971–3995.
5. Cengiz, Korhan. “Comprehensive analysis on least-squares lateration for indoor positioning systems”. IEEE Internet of Things Journal 8.4 (2020): 2842–2856.
6. Jang, Beakcheol, and Hyunjung Kim. “Indoor positioning technologies without offline fingerprinting map: A survey”. IEEE Communications Surveys & Tutorials 21.1 (2018): 508–525.
7. Tao, Ye, and Long Zhao. “A novel system for WiFi radio map automatic adaptation and indoor positioning”. IEEE Transactions on Vehicular Technology 67.11 (2018): 10683–10692.
8. Li, Yiwei. “A VLC smartphone camera based indoor positioning system”. IEEE Photonics Technology Letters 30.13 (2018): 1171–1174.
9. Yao, Chia-Yu, and Wei-Chun Hsia. “An indoor positioning system based on the dual-channel passive RFID technology”. IEEE Sensors Journal 18.11 (2018): 4654–4663.
10. Feng, Daquan. “Kalman-filter-based integration of IMU and UWB for high-accuracy indoor positioning and navigation”. IEEE Internet of Things Journal 7.4 (2020): 3133–3146.
11. Zhu, Xiaomin. “Adapted error map based mobile robot UWB indoor positioning”. IEEE Transactions on Instrumentation and Measurement 69.9 (2020): 6336–6350.
12. Afzalan, Milad, and Farrokh Jazizadeh. “Indoor positioning based on visible light communication: A performance-based survey of real-world prototypes”. ACM Computing Surveys (CSUR) 52.2 (2019): 1–36.
13. Xu, Z. Computational intelligence based sustainable computing with classification model for big data visualization on map reduce environment. Discov Internet Things 2, 2 (2022).
14. Lin, Zhipeng, Tiejun Lv, and P. Takis Mathiopoulos. “3-D indoor positioning for millimeter-wave massive MIMO systems”. IEEE Transactions on Communications 66.6 (2018): 2472–2486.
15. Oh, Jongtaek, and Jisu Kim. “AdaptiveK-nearest neighbour algorithm for WiFi fingerprint positioning”. ICT Express 4.2 (2018): 91–94.
16. Michael Zipperle, Marius Becherer, Yu Zhang, Elizabeth Chang, Tharam Dillon and Achim Karduck. Enabling digital transformation with sustainability criteria through resilient cybersecurity: challenges and opportunities. Engineering Intelligent Systems, 2024, Vol 32 No 1.
17. Linlin Wu. Method for constructing network intrusion detection model based on improved apriori algorithm. Engineering Intelligent Systems, 2024, Vol 32 No 2.

Wei Zhang was born in Huaying, Sichuan, P.R. China, in 1986. She received the Master degree from Sichuan Fine Arts Institute, P.R. China. Currently, she works at the School of Urban Construction Engineering, Chongqing Technology and Business Institute, Chongqing Open University. Her research interests include interior design architecture and landscape design.
E-mail: zhangw@cqtbi.edu.cn



Xiaolong He was born in Chengdu, Sichuan. P.R. China, in 1988. He graduated from Chengdu Technological University, P.R. China. Currently, he works in the MB test Laboratory Div., Alpha Networks (Chengdu) Co. His research interests include computational intelligence and communication technology.
E-mail: jackiehe1125@126.com