Spatial Navigation Path Analysis of Indoor Geomagnetic Digital Map and Vitby Algorithm

Wen Zhiyong
School of Fine Arts, Sichuan University of Arts and Sciences
Dazhou City, Sichuan, 635000
China
mu6116172fangqian@163.com

ABSTRACT: *With the rapid development of technologies such as the Internet of Things and artificial intelligence, indoor spatial navigation has gradually become a research hotspot. In the field of indoor navigation, geomagnetic navigation, as an emerging technology with high positioning accuracy and stability, is widely used in fields such as smart homes and robots. In order to better leverage the advantages of geomagnetic navigation, this article studies the application of indoor geomagnetic digital maps and Vitby algorithm in spatial navigation path analysis. This article studies the application of indoor geomagnetic digital maps and Vitby algorithm in spatial navigation path analysis. By constructing an indoor geomagnetic digital map and utilizing the Vitby algorithm for path planning, precise navigation of indoor spaces has been achieved. This method can provide important technical support for indoor navigation, smart home, robotics and other fields.*

Keywords: Viterbi Algorithm, Indoor Environment, Humanized Design, Humanistic Care

Received: 18 April 2023, Revised 10 June 2023, Accepted 28 June 2023

DOI: 10.6025/dspaial/2023/2/3/61-69

1. Introduction

With the development of the socialist market economy, the interior design of China has entered the "fast lane" of historical development. The great abundance of material makes people drown in the inner world of matter [1]. In the design of space, we must adhere to the people-oriented. Space is the core of interior environment art; its essence is human [2]. With the progress of science and technology in our country, the real estate industry of our country has been developing rapidly in recent years. However in the process of the development of real estate, it has great blindness, and there are many deficiencies in many aspects, especially the technology and resources. In constructing many cities, we always pursue the increase in quantity, thus neglecting the accumulation of quality. In the design and construction of an indoor environment, the problems are prominent, and it is difficult to meet the spiritual pursuit of residents. The interior design of our country is still in a backward position in the world. How to make the interior design of our country out of a road with Chinese characteristics and design a "humanized" living space is a subject to face in the future[3]. Therefore, changing the environment of people's life and improving the quality of life through the humanized design concept is the design concept that the interior environment art and design must follow[4]. This paper makes a comprehensive analysis and Research on interior design by using the concept of humanized design. By constructing the geomagnetic digital map of the navigation region, combined with the Viterbi algorithm, By building the geomagnetic digital map on the navigation area, combined with Vitby algorithm, we use the metric of Vitby algorithm to calculate the possibility of path estimation and discard the way of invalid path to avoid the path generation across the wall effectively, sum the current domestic interior design and decoration problems and point out the humanized interior design will become a developing trend in the field of future interior design[5].

2. State of the Art

The probability Decoding of Convolutional codes can be traced back to 1961. In that year, Wozencraft proposed sequence decoding, this laid a foundation for the development of probabilistic decoding of convolutional codes. After two years, Fano improved the sequence decoding and proposed the algorithm. This algorithm makes the sequence decode greatly popularized in practical application [6]. In 1967, for traditional algorithms Viterbi proposed a new algorithm which is Viterbi algorithm. It is the maximum likelihood decoding algorithm, and its algorithm is based on the grid graph of the code [7]. This algorithm belongs to *HMM* (*Hidden Markov Model*) , implicates the Markov Model. In Viterbi algorithm, it is necessary to find the optimal state sequence in a given way under a given model. So it is an optimal dynamic programming algorithm and it can find the optimal path among the many paths and be able to trace the entire path back [8]. The Vitby algorithm mainly divided the hard judgment between Vitby and the soft decision Vitby. In decoding, the method of Hamming distance accumulation is called hard decision, and the Euclidean distance is called soft decision decoding. This algorithm has been widely used in digital cellular networks, satellites, deep space communications and other deconvolution codes. Nowadays, it is also used in speech recognition, keyword recognition and computational linguistics. When the constraint degree is small, the Viterbi algorithm is more efficient, faster and simpler than the sequence decoding algorithm. Therefore, since the Viterbi algorithm is proposed, it has been greatly developed both in theory and in practice [9].

3. Methodology

3.1. Vitby Decoding Criterion

The Vitby decoding algorithm is the most commonly used convolutional code decoding method, which is the maximum likelihood decoding, and is widely used in all kinds of digital transmission systems. The Vitby algorithm is mainly hard to judge Vitby and the soft decision Vitby. In the process of decoding, the method of Hamming distance accumulation is called hard decision, and the Euclidean distance is called soft decision decoding. In comparison, the performance of the soft decision is better, but it is more complex, and it is mainly used in the decoding of TURBO code[10].

In digital and data communication, the reliability of communication is generally used as an average bit error rate P_e, It is known from the probability theory that the minimum mean error rate is equivalent to the maximum a posteriori probability, that is:

$$minP_e = min \sum_Y P(Y)P(e/Y) = min \sum_Y P(Y)P(\hat{C} \neq C/Y) \tag{1}$$

In this formula, $P(Y)$ is the probability of receiving signal sequence, It has nothing to do with the specific decoding method. e is a sequence of errors, $\hat{C}$ is the Code block for receiver recovery, and C is the sent code group. By the Bayesian formula, the maximum posterior probability criterion and the maximum likelihood criterion are equivalent under the condition of the prior probability such as the source, that is:

$$\mathrm{P}(e/Y) = \frac{P(C)P(Y/e)}{P(Y)} \tag{2}$$

When $P(C)$ is equal probability distribution, there is:

$$maxP\ (\hat{C} \neq C/Y\ ) = maxP\ (Y/C = \hat{C}\ ) \quad (3)$$

For *BSC*, a memory less binary symmetric channel. The maximum likelihood criterion can also be equivalent to the minimum hamming distance criterion, that is:

$$maxlgP\ (Y/\hat{C} = C\ ) = min\ d\ (Y,C) = min \sum_{l=0}^{L-1} d\ (Y_l, C_l) \quad (4)$$

In Viterbi decoding, the minimum Hamming distance criterion is often used in the hard decision, and the maximum likelihood criterion is often used in the soft decision.

3.2. Viterbi Algorithm

It can be seen from the coding process of convolutional codes that the number of the code sequences is very large. For instance, when code sequence length $L = 50$, $n = 3$, $k = 2$, it has $2^{KL} = 2^{100} > 10^{30}$ code sequence in total. If $m = 5$, $L+m = 55$. If the message element is sent out $KL=100$ in the middle of 1 second, the rate of information transmission is only 100*bps*. Even at such a low rate of information, the decoder is required to be calculated in a second and comparative 10^{30} likelihood function (or Hamming distance, Euclidean distance). This is equivalent to requiring the decoder to calculate each likelihood function in less than 10^{-30} a second. This can't be realized at all. What's more, in general, *L* is hundreds of thousands of things. Therefore, it is necessary to find a new maximum likelihood decoding algorithm. Based on the above difficulties, a decoding algorithm based on maximum likelihood decoding algorithm Viterbi emerges as the times require. The algorithm is to receive a comparison of a section. In all the decode branches, choose one of the most likely, to find out the sequence of the maximum likelihood function in the whole code sequence. The specific implementation process is referred to as follows:

The first step. From a unit of time, calculated the measure of a partial path and picked a partial path with the largest measure from all possible paths. This partial path is the possible path.

The second step. Addition calculation. Take all the branches of each state as an object, find a measure of the survival path at the previous moment and add the two together. The added value at this time is the possible path measure for each state. In these path metrics, select a path with the maximum path measure and delete the other paths. On this basis, we get a new survival path. Thus, the surviving path has extended a branch.

The third step. If $l < L + m$, Then you need to repeat the above two steps, or else stop running. Time unit in the process which from *m* to *L*. Convolutional codes have 2^{KL} state. Each state has a survival path corresponding to each state, with 2^{KM} common thread. After the unit node of the *L* time, the selection path is positively related to the number of states on the grid graph. If the number of states on the grid is reduced, the selection path will also be reduced, until the $L + m$ unit time. The grid graph will come back, that is, back to the state of all 0. In the final state, there is only one survival path left. This path is exactly the path to be used by the algorithm, which is the path of the maximum likelihood function. At this point, the decoder will output the estimation code sequence according to the path of the maximum likelihood function $\hat{C}$.

Through the above discussion, it is known that in the grid, if you want to find a maximum likelihood path, you need to use the Viterbi decoding algorithm. It is precisely because the Viterbi decoding algorithm has such a feature that this algorithm is the best one. Normally, in the whole process of decoding, the more complex the decoding algorithm is, the higher the gain will be and the better the decoding performance. Despite this, there are some disadvantages. If the more complex the algorithm is, the more accurate the data, but the more waste of hardware resources will be wasted. Because the hardware resource is too much, the decoding speed will become slower. So it can be seen that for a Viterbi decoder, in the process of decoding, the complexity of the algorithm can not be ignored, and the performance of the code can not be ignored, too. And we should be sure to find the best balance between the two.

In the Viterbi algorithm, its most central part is take the path metrics for each code state as subject and calculate by *ACS* (*Add - Compare - Select*). We can describe it with a butterfly figure in the specific operation process of ACS. The details are shown in Figure 1, which lists the decoded butterfly diagram of Base-2.

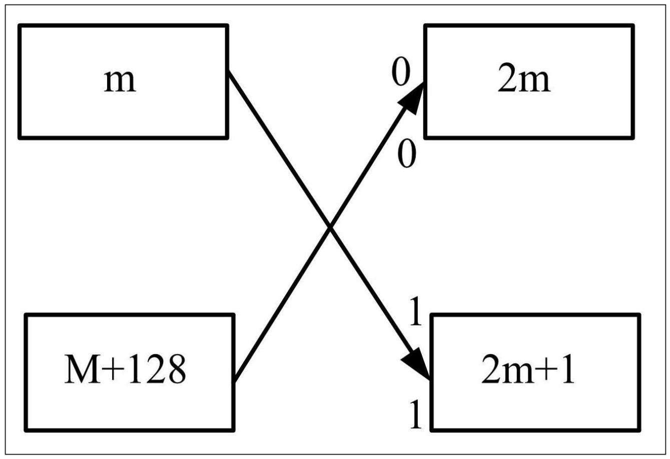

Figure 1. Butterfly graph of base -2

As shown in Figure 1, in the base - 2 sphenoid diagrams, each current state may be transformed into 1 of the 2 new states. In the process of concrete operation of *ACS*. It is necessary to accurately calculate the measured values of the current path. In this state, then the ACS operation, so as to obtain the optimal state transition path.

3.3. Constrained Viterbi Decoding Algorithm

The Vitby algorithm can be represented by a grid graph, which is a state diagram of a time series. A simple state transfer grid diagram representing 2 states is shown in Figure 2. In the n-1 moment in this graph, 2 possible states may be transferred to the 2 state of the n moment according to the input information. In Viterbi's algorithm, a decision on the maximum likelihood state sequence is required. The decision method is to find the minimum weight path in the grid. In the surviving path, the method used in the organization of its memory is similar to that of the pointer. The whole process needs to be divided into two parts, the first one is the surviving path of the preorder state and the second part is the pointer to the preorder state. When the surviving path memory is filled, it needs to be truncated and decode. In the process of truncated decoding, all the states of n at the current moment are needed as the object of study. Find the state S_n of the smallest path measure in the object. This state corresponds to a path, which is the maximum likelihood path we're looking for. Then it is based on the pointer of the storage, search for preorder state S_{n-1}, but It has to be n-1 moment. In the search process, the pointer stored in the state at that moment is the object of study by searching for the preorder state of the next moment n-2. Always follow this process until you find the starting state; we can stop when you find the starting state. The information stored at this time is the decoding output. In this method, the information stored in the surviving path is mainly two. One is the information of the path, and the other is a pointer to the preorder state. So the amount of information is larger. Therefore, we need a larger storage space, and any output bit decoding requires the depth of the whole decoding to be retrieved.

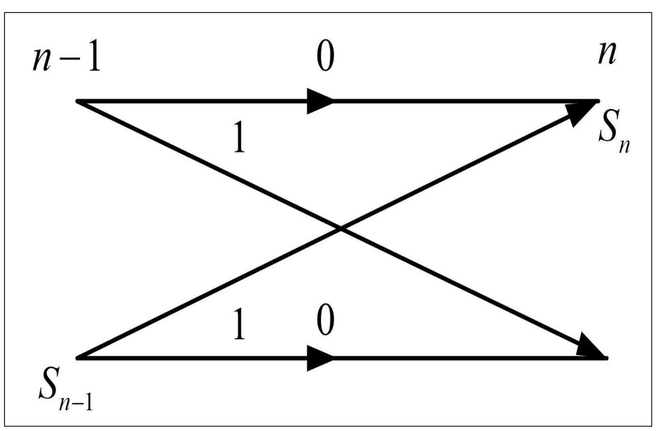

Figure 2. Transfer grid diagram of 2 states

We suppose the encoder contains n States. It starts from the 0 state, and returns to the 0 state after M time. The data received at the J moment, and from the J-1 moment, the i state, to the J moment. The hamming distance of the data output from the k^{th} state is recorded as $C_j\,(i,k)$ (if there is no connection between the I state and the K state, $C_j\,(i,k) = \infty$). From the 0 time, the 0 state, to the J moment, in all the paths of the K state, one of the paths has a minimum hamming distance $\phi_j\,(K)$. The state of the path passing through at each moment is recorded in the $\varepsilon_j\,(K)$, then at the end $\varepsilon_M(0)$ is the best path for decoding.

Using the constrained Viterbi algorithm, we suppose the input of the known J moment is correct, so make the path that conforms to the input.

$$C_j(i,k) = 0 \quad 0 \leq i \leq N-1,\ 0 \leq k \leq N-1 \tag{5}$$

It does not conform to the path of the input.

$$C_j(i,k) = \infty \quad 0 \leq i \leq N-1,\ 0 \leq k \leq N-1 \tag{6}$$

Only the path that meets the known correct input at the time will be added to the minimum and is retained.

When decoding need initialization

$$\phi_1(i) = c_1(0,i)\ \varepsilon_1\,(i) = 0 \quad 0 \leq i < N-1 \tag{7}$$

After that, added and selected the minimum value.

$$\phi_j(k) = \min_{0 \leq i \leq N-1} [\phi_{j\text{-}1}(i) + c_{j\text{-}1}(i,k)] \tag{8}$$

$$\varepsilon_j(k) = \arg\min_{0 \leq i \leq N-1} [\phi_{j\text{-}1}(i) + c_{j\text{-}1}(i,k)] \quad 0 \leq k \leq N-1 \tag{9}$$

Because at j-1, it conforms to constrained $c_{j\text{-}1}(i,k) = 0$, but $c_{j\text{-}1}(i,k) = \infty$. $\phi_j(k)$, $\varepsilon_j(k)$ is only to keep the path that conforms to the constraint.

Finally,

$$\phi_M(1) = \min_{0 \leq i \leq N-1} [\phi_{M\text{-}1}(i) + c_{j\text{-}1}(M,1)] \tag{10}$$

$$\varepsilon_M(1) = \arg\min_{0 \leq i \leq N-1} [\phi_{M\text{-}1}(i) + c_{M\text{-}1}(i,1)] \tag{11}$$

Get the state of every moment by backtracking. The iterative calculation process of the dynamic programming by the Vitby algorithm is as follows.

$$\delta_t(j) = \max_{0 \leq i \leq N-1} P\,\{\delta_{t\text{-}1}\,(i)\ a_{ij}\} b_j\,(O_t) \tag{12}$$

$$\psi_t(j) = \arg\max_{0 \leq i \leq N-1} P\,\{\delta_{t\text{-}1}\,(i)\ a_{ij}\} \tag{13}$$

$\delta_t(j)$ representing the maximum probability of the path generated by the state j in the state of observation at the time of observation is the measure. $\psi_t(j)$ represents a state value which generated from the previous state calculation.

At the same time, we can backtrack the optimal path, the backtracking formula is:

$$q_t^* = \psi_{t+1}(q_{t-1}^*) \quad (14)$$

4. Result Analysis and Discussion

4.1. Experimental Results and Analysis

In the traditional inertial navigation system, the trajectory of people walking in the human body depends on the course value, step length and step number data. The basic principle of its algorithm is figure 3. (x_o , y_o) is starting point of walking, (x_i , y_i) is the position of the *i* step on a walk. H is the heading value of the human body. The value of the course is the angle of rotation around the *Z* axis, the initial angle is the default value in the device and *S* is a step. This information can be used to calculate the walking path of the human body.

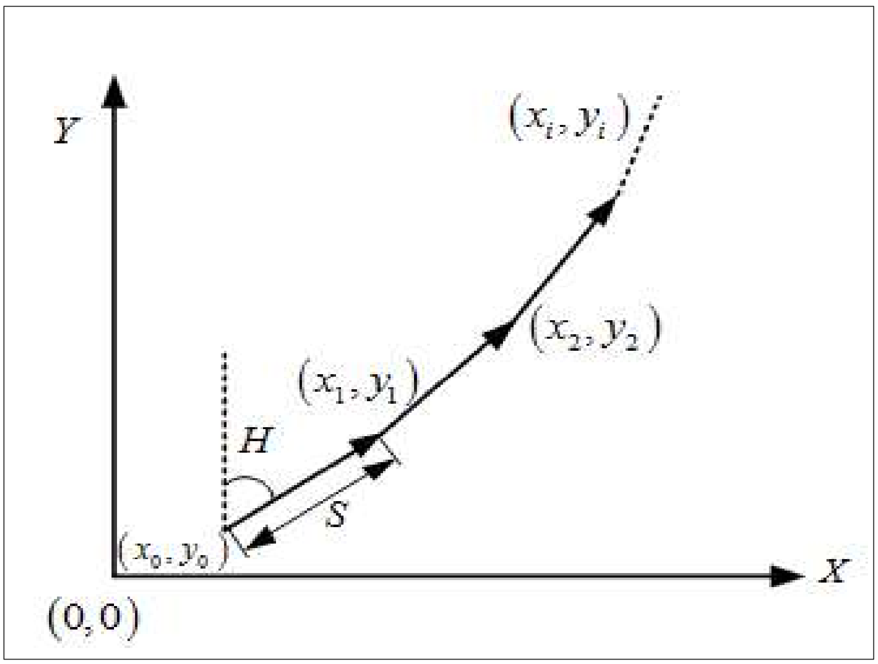

Figure 3. Traditional track estimate of inertial navigation

On this basis, the possible path calculation method is mainly:

Judge the direction of human walking according to the range of the value of the course of the human body. Because the default direction of the equipment used in the simulation test is just north, in Inertial Navigation system preinstall 45^o to 135^o is eastbound, 135^o to 225^o is southbound, 225^o to 315^o is westbound, 315^o to 360^o and 0^o to 45^o is northbound.

Judge the current position according to the orientation of the front path and the direction of the system determined by the system. The method of judgment is shown in Figure 4. $A_1(x_1, y_1)$ is location information in front of the path. *F* is the actual direction of walking. We judge the possible direction of walking is eastward. Select $A_1(x_1, y_1)$, an upward grid point to the East $A_2(x_2, y_1)$ and two points $A_1(x_2, y_2)$, $A_3(x_2, y_0)$ which perpendicular to $A'_2(x_2, y_1)$ and adjacent to the east as the current possible position. If $A_1(x_1, y_1)$ is initial position, *F'* is the second step direction. According to the threshold, the current direction of travel is eastward. When $A_1(x_2, y_2)$ is front path, $A_1(x_3, y_3)$, and $A_3(x_1, y_3)$ is current possible position. In $A^n m$, *m* represents the possible path of the current location *m*, *n* represents the *n* step that is currently walking.

Calculate the possible location in turn, output the path. Therefore, it is possible to calculate all possible paths during walking in real time.

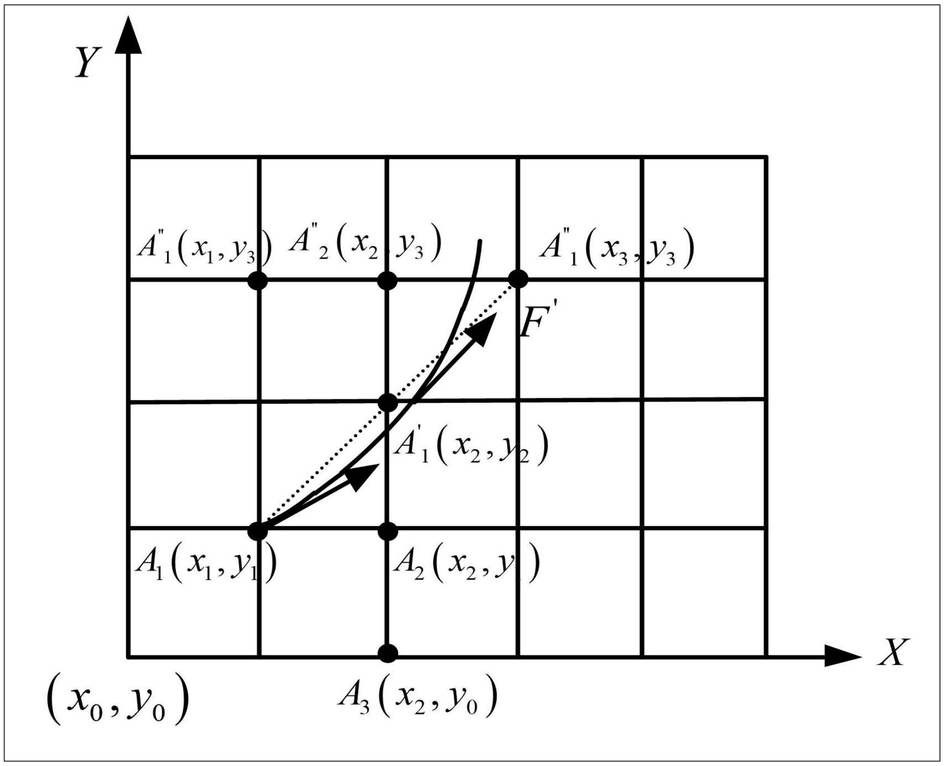

Figure 4. Inertial navigation track estimate base on Viterbi algorithm

This method records the coordinates of the current position $A^n_m(x, y)$, at the same time, record the message in front of the road path $A^{n\text{-}1}_m(x, y)$. $A^n_m(x, y)$ represents location information which is remained in the n-1 calculation during walking process by m road. This path information can be traced back to the entire path. This method sorts all paths in small to large order in each calculation, At the same time, set up the number of surviving path bars and improve the computing performance. The path with the smallest measure value is obtained after the calculation, and the path is backtracked and output as the optimal path.

In order to verify the performance of this method, the walking route of the testers should be as complex as possible during the test. Therefore, in the test, the tester is required to follow the *Z*-type walk. At the same time, it is required to walk into two adjacent classrooms that are very confusing there is only one wall between the two classrooms. A total of 200 groups of experiments were carried out, and two kinds of walking routes were divided, 100 groups of walking routes are (10,4), (20,1), (30,6), (40,1), (41,6), (41,12), (50,12). The other 100 groups of walking routes are, (10,4), (20,6), (30,1), (40,6) (41,6), (41,12), (50,12). Walk in a straight line between points. According to the characteristics described above, in the course of walking, the original path of the inertial navigation system output will not correct itself if it occurs through the wall. But in this method, if the wall behavior occurs, the final algorithm will automatically abandon the wrong surviving path and verify the error correction ability of this method. As the testers walk, the number of possible paths will increase rapidly, we need to set a reasonable surviving path number to exclude the rest of the path. The performance of the surviving path of the 32, 64, 128, 256, 512 bar is set in the experiment.

Through the above 200 groups of experiments, the traditional inertial navigation algorithm has successfully entered 131 times, and the success rate is 65.5%. The Vitby algorithm has successfully entered 177 navigation methods, with a success rate of 88.5%. The final correct rate of different surviving paths was 51.5%, 71%, 88.5%, 89.5%, 90.5%. The improvement of the final accuracy is not obvious because of the 256 and 512 surviving paths. In order to improve the computational performance, the test results of 128 surviving paths were selected as the final test results. Compared to the traditional inertial navigation algorithm, we find that the accuracy of the Vitby algorithm based navigation method to enter the correct room in a complex indoor environment is improved by 23%.

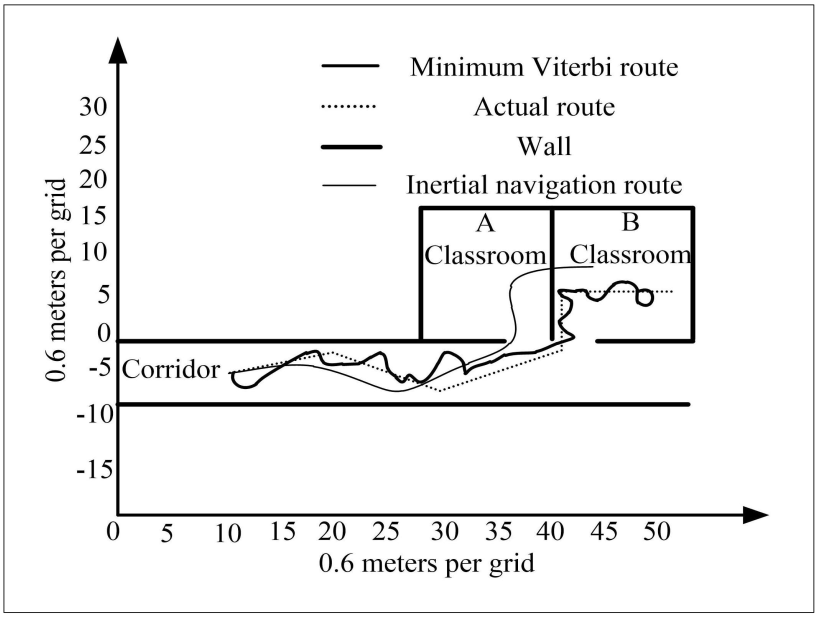

Figure 5. Simulation results

Figure 5 is a set of experimental simulation results, as can be seen from figure 5, The output path of the inertial navigation system shows the entry of the corridor into the A classroom and through the wall into the *B* classroom is an error path that does not correspond to the actual walking route in the map. There is still confusion in two adjacent classrooms. Two classrooms were separated from the possible path area of the largest measure. In the surviving path of the simulation output, there are also the *A* classrooms. However, due to the deviation from the actual path, it is gradually abandoned in the following walking process, and the walking track is basically in line with the actual walking route. Based on Vitby algorithm, it can effectively overcome the effect of error factors in the traditional navigation system to enter the wrong room and get through the wall, solves the shortcomings of the traditional inertial navigation system, which only rely on the precise step and the course value to carry on the indoor navigation at the same time and improve the ability of indoor navigation and error correction.

5. Conclusion

The development of human society and the rapid development of production and life have made the concept of humanization more and more widely used in interior design. Under the background of this era, the interior art design should take into account the material needs of people and the spiritual and cultural needs. The application of various design methods and design techniques to create an indoor space environment that meets the principles of safety, practicality and ecology. In this paper, we build the geomagnetic digital map based on the navigation area; use the measure value in the Viterbi algorithm to calculate the possibility of judging the path and discarding invalid path to avoid path generation through the wall effectively. This method combines the inertial navigation system to improve the error correction ability of the navigation system. As the results of the simulation test show, compared with relying on high precision data to complete navigation in traditional inertial navigation technology, the proposed algorithm based on Vitby algorithm can effectively avoid the occurrence of erroneous path and take full account of human uncertainties and provides a research direction for the research of humanized design in environmental art design.

References

[1] Han, S. H., Jung, E. S., Jung, M. Y., et al. (2014). A psychophysical evaluation of interior design alternatives for a high-speed train. *Computers & Industrial Engineering*, vol. 27, no. 1–4, 2014, p. 397-400.

[2] Fernandes, S. C. F., Esteves, J. L., Simoes, R., et al. (2017). Characteristics and human factors of older drivers: improvement opportunities in automotive interior design. *International Journal of Vehicle Design*, vol. 74, no. 3, p. 167.

[3] Poldma, T. (2011). The interior spatial environment: dynamic 0g environments and human places. *Personal and Ubiquitous Computing*, vol. 15, no. 5, 2011, p. 539-550.

[4] Bellomi, M., Rampinelli, C., Veronesi, G., et al. (2010). The Applications of Daylighting Illumination Technology into Interior Design of Office Building. *European Radiology*, vol. 20, no. 2, p. 286-292.

[5] Siebein, G. W., Paek, H., Lilkendey, R. M., et al. (2010)*. Architectural acoustic design concepts for drama theaters. Journal of the Acoustical Society of America*, vol. 128, no. 128, p. 2275.

[6] Gluesing-Luerssen, H., Tsang, F. L. (2017). A Matrix Ring Description for Cyclic Convolutional Codes. *Advances in Mathematics of Communications*, vol. 2, no. 1, p. 55-81.

[7] Tseng, Yi-Hong, Lee, Hsi-Jian. (2012). Recognition-based handwritten Chinese character segmentation using a probabilistic Viterbi algorithm. *Pattern Recognition Letters*, vol. 20, no. 8, 2012, p 791-806.

[8] Kim, J., Lee, J. (2011). Two-dimensional soft output Viterbi algorithm with noise filter for patterned media storage. *Journal of Applied Physics*, vol. 109, no. 7, 2011, p 4230-6254.

[9] Soltanpur, C., Cruz, J. R. (2016). Near Optimal Viterbi Algorithm for Storage Channels With Linear Regressive Noise. *IEEE Journal on Selected Areas in Communications*, vol. 34, no. 9, p 2518-2524.

[10] Gao, B., Xiao, Z., Chen, Z., et al. , (2013). Multigigabit balanced add-select-register-compare Viterbi decoders architecture in 60 GHz WPAN. *IEEE*, p 531-535.