

Computer Simulation Algorithm of Gymnastics Formation Change Path Based on Wireless Sensor

Bingxin Chen (✉ chenbingxin15@163.com)

College of Physical Education Hunan Normal University

Lifei Kuang

College of Physical Education Hunan Normal University

Wei He

College of Physical Education Hunan Normal University

Research

Keywords: Wireless Sensor, Gymnastics Formation Change Path, Path Computer Simulation, Improved Leader-Follower method, Host Computer Tracking

Posted Date: May 19th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-470899/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at EURASIP Journal on Advances in Signal Processing on July 30th, 2021. See the published version at <https://doi.org/10.1186/s13634-021-00766-y>.

Computer Simulation Algorithm of Gymnastics Formation Change Path Based on Wireless Sensor

Bingxin Chen^{1,a*}, Lifei Kuang^{1,b*} and Wei He^{2,c}

¹College of Physical Education Hunan Normal University, Changsha 410000, Hunan, China

²Department of Physical Education Changsha Normal University, Changsha 410000, Hunan, China

^aE-mail: chenbingxin15@163.com

^bE-mail: lifekuang1@163.com

^cE-mail: ccsbb@163.com

*Corresponding author

Abstract: Today, with the rapid development of information age, the communication of science and technology is getting closer to each other, and our country has begun to conduct in-depth research on WSN. This study mainly discusses the computer simulation algorithm of gymnastics formation transformation path based on wireless sensor. In this study, an improved leader follower method is designed. In the research of gymnastics formation transformation of mobile nodes in wireless sensor network environment, the traditional three types of nodes are divided into four categories according to different formation responsibilities, namely coordinator, beacon node, leader and follower. When it makes accurate positioning with the help of beacon node information, it will send the information in the form of broadcast, and then the coordinator will send the information to the host computer through the serial port for tracking display. In order to make the mobile nodes in the network keep the current gymnastics formation moving towards the target point after completing the gymnastics formation transformation, this paper uses the L - φ closed-loop control method to modify the gymnastics formation in real time. The method based on the received signal strength is used to locate the mobile node. Combined with the positioning engine in the core processor CC2431 of the mobile node, the efficient and low-energy wireless positioning can be realized. Multiple mobile nodes coordinate and control each other, and each node communicates with each other through wireless mode, and senses its own heading angle information through geomagnetic sensor, so as to judge and adjust the maintenance and transformation of the current gymnastics formation. In the process of formation transformation, the analysis shows that the maximum offset of follower2 relative to the ideal path is + 0.28M in the process of marching to the desired position in the triangle queue. This research effectively realizes the computer simulation of autonomous formation.

Keywords: Wireless Sensor, Gymnastics Formation Change Path, Path Computer Simulation, Improved Leader-Follower method, Host Computer Tracking

1.Introduction

Wireless sensor network has the advantages of low cost and simple node arrangement, and mobile gymnastics has strong initiative. The research on formation control of multi mobile gymnastics under wireless sensor network is to combine the advantages of wireless sensor network and multi mobile gymnastics group, so that the multi mobile gymnastics formation control is more effective and reliable, and the efficiency of completing tasks is also higher. Therefore, the research on formation control of multi mobile gymnastics based on WSN is worth further study.

Whether in the research and research of colleges and universities or the increase of investment in

military field, it shows that the research upsurge of wireless sensor network has entered a new height. At present, WSN technology has been widely used in warehouse monitoring, exploration and relief, and can be applied to a wider range according to the different environment and tasks, leading researchers to explore in-depth, and make the research enter a new stage.

Behera SK proposed a method to analyze 3D signatures captured using Leap motion sensors. He extended the original 2D function from the original signature to 3D, and applied a well-known classifier for identification and verification. Although he used the Leap motion interface to create a large data set containing more than 2,000 signatures registered by 100 volunteers, his research method is still not new enough [1]. Motion sensor technology and automatic fall detection systems have become reliable and low-cost solutions for falls. Yu S has developed a fall detection system based on Hidden Markov Model (HMM), which can use a single motion sensor to automatically detect falls for actual home monitoring scenarios. He proposed a new representation for the acceleration signal in HMM to avoid feature engineering, and developed a sensor orientation calibration algorithm to solve the problem of sensor misalignment in actual scenes. The HMM classifier is trained to detect falls based on the acceleration signal data collected from the motion sensor. Although he collects data sets from experiments that simulate falls and normal activities, the research process lacks theoretical foundation [2]. Shen C studied the reliability and applicability of active and continuous smart phone authentication using motion sensor behavior in various operating scenarios, and systematically evaluated the uniqueness and durability of the behavior. Although he provides accurate and fine-grained representations of user touch actions, his research process lacks data [3]. Yurtman A proposed a novel non-iterative direction estimation method based on the physical and geometric characteristics of acceleration, angular velocity and magnetic field vector to estimate the direction of the motion sensor unit. He obtains the orientation of the sensor unit according to the rotation quaternion transformation between the sensor unit frames. He evaluates the proposed method by incorporating it into the activity identification scheme for daily and sports activities. Although his scheme needs to accurately estimate the direction of the sensor unit to achieve the invariance of the direction the unit is worn on the body, the research process lacks experimental data [3]. Signature recognition is to identify the owner of the signature, and verification is the process of finding the authenticity of the signature. Although both are important in the field of forensic science, verification is even more important for banks and credit card companies [4].

Today, with the rapid development of information age, the communication of science and technology is getting closer to each other, and our country has begun to conduct in-depth research on WSN. This study mainly discusses the computer simulation algorithm of gymnastics formation transformation path based on wireless sensor. In this study, an improved leader follower method is designed. In the research of gymnastics formation transformation of mobile nodes in wireless sensor network environment, the traditional three types of nodes are divided into four categories according to different formation responsibilities, namely coordinator, beacon node, leader and follower. When it makes accurate positioning with the help of beacon node information, it will send the information in the form of broadcast, and then the coordinator will send the information to the host computer through the serial port for tracking display. In order to make the mobile nodes in the network keep the current gymnastics formation moving towards the target point after completing the gymnastics formation transformation, this paper uses the $L - \varphi$ closed-loop control method to modify the gymnastics formation in real time. The method based on the received signal strength is used to locate the mobile node. Combined with the positioning engine in the core processor CC2431 of the mobile node, the

efficient and low-energy wireless positioning can be realized. Multiple mobile nodes coordinate and control each other, and each node communicates with each other through wireless mode, and senses its own heading angle information through geomagnetic sensor, so as to judge and adjust the maintenance and transformation of the current gymnastics formation.

2. Method

2.1 Wireless Sensor

Generally, when researchers choose sensor positions, they often only consider the importance of different sensor positions to the action category. When a position is selected, the subsequent position selection will be selected according to the importance of the remaining position to the action category[5-6] . If each position is not related to each other, then there is no problem with this method. However, in practice, the positions are related to each other, and they may contain the same information. If only the correlation between the sensor position and the action category is considered, the result will be positions that cause serious overlap are selected at the same time, the importance is relatively small but the position and the selected position do not have any overlap are often ignored, so that some action categories that can only be distinguished by the ignored position cannot be well recognized [7]. When a single-turn optical fiber coil with a diameter of D rotates, two light waves are emitted clockwise (CW) and counterclockwise (CCW) from point P of the circular optical path, then:

$$T_{CW} = \frac{\pi D}{V_{CW}} = \frac{\pi D}{V_f - \Omega D} = \frac{\pi D}{\frac{c}{n} - \Omega D} \quad (1)$$

Among them, c is the speed in vacuum [8]. Assuming that the node has unlimited energy storage capacity, the energy collected by the node in the time period $[t_0, t_0 + \Delta T]$ is:

$$N_h(T_0, T_0 + \Delta T) = \int_{T_0}^{T_0 + \Delta T} \eta_e f_e(T) dT \quad (2)$$

Among them, t_0 is the starting point of energy harvesting time [9]. Suppose the maximum stored energy of the node is N_{\max} , then the remaining energy after the energy is collected is:

$$N_H(T_0, T_0 + \Delta T) = \min(N_{left} + N_h(T_0, T_0 + \Delta T), N_{\max}) \quad (3)$$

In most cases, the motion state of the target in a short period of time will not change much, so the following approximate constant velocity model can be used to describe the target motion[10]:

$$X(c) = A(\Delta \tau_c) X(c) + L(c) \quad (4)$$

Among them,

$$A(\Delta \tau_k) = \begin{bmatrix} 1 & \Delta \tau_k & 0 & 0 \\ \Delta \tau_k & 1 & \Delta \tau_k & 0 \\ 0 & \Delta \tau_k & 1 & \Delta \tau_k \\ 0 & 0 & \Delta \tau_k & 1 \end{bmatrix} \quad (5)$$

$$Q(\Delta \tau_k) = \frac{\Delta \tau_k^3 + \Delta \tau_k^2}{3} \quad (6)$$

The prediction of the target by the extended Kalman filter is [11]:

$$\hat{X}(c+1|c) = A(\Delta\tau_c)\hat{X}(k|c) \quad (7)$$

$$P(k) = A(\Delta\beta_k)P(k|k)A(\Delta\beta_k)^T \quad (8)$$

The predicted value of the target state at time step $k+j$ is [12]:

$$\hat{X}(k+j|k) = [A(\Delta\tau_k)]^j \hat{X}(k|k) \quad (9)$$

The predicted value of the corresponding error covariance is [13]:

$$M^-(k+j|k) = A(\Delta\tau_k)M^+(k+j-1|k)A(\Delta\tau_k)^T + Q(\Delta\tau_k) \quad (10)$$

The Kalman gain is:

$$R(k) = \frac{P^-(c+m|c)H^T(c+m|c)}{[H(c+m|c)P^-(c+m|c)H^T(c+m|c) + R(c+m)]} \quad (11)$$

Among them, $R(k)$ is the Jacobian function of the measurement function at time T [14].

2.2 Mobile Node Positioning

Ranging methods mainly include TOA method, TDOA method, AOA method and RSSI algorithm [15-16]. The AOA method is based on the principle of the angle of arrival of the signal, and the antenna array on the node realizes the angle acquisition. This method has high accuracy, but the node energy consumption is high, the cost is high, and the practical value is low [17]; the RSSI method is based on receiving positioning based on the principle of signal strength indicator converts the loss caused by the signal in the transmission process into the corresponding distance, which requires low hardware, but in the wireless transmission process, the acquisition of the RSSI value is relatively simple and low in cost. A more commonly used method in wireless sensor network positioning [18-19]. The mobile node identification is shown in Figure 1.

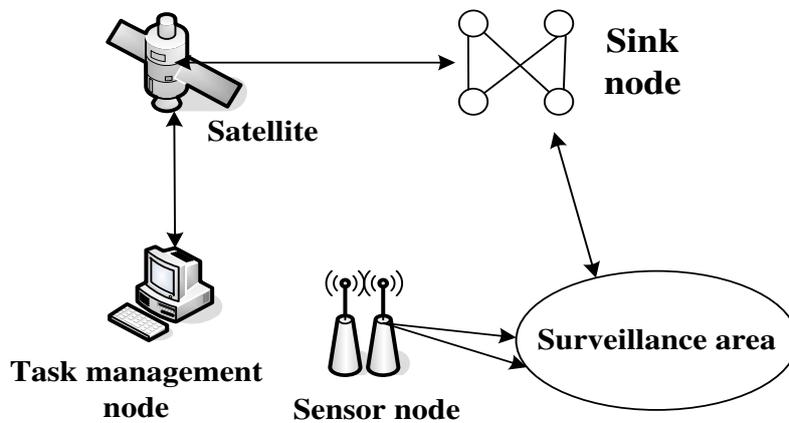


Figure 1. Mobile node identification

Feature extraction is often based on a certain decision rule used in classification as a criterion to extract features to minimize the classification error under a certain criterion [20].

$$E(r_x) = \frac{\sum_{j=1}^{|\bar{X}|} \prod_{j=1}^{N_f} K_{B_i^k \in B_j} \mu A_j^k(x_i, j)}{\sum_{i=1}^{|\bar{X}|} \prod_{j=1}^{N_f} K_{B_j^k \in B_j} \mu A_j^k(x_i, j)} \quad (12)$$

Take x_i as a sample of training data set $E(r_x)$ [21-22].

$$P(f_i, f_j) = \iint T(f_i, f_j) \log \frac{T(f_i, f_j)}{T(f_i)T(f_j)} df_i df_j \quad (13)$$

Here, $p(f_i)$ and $p(f_j)$ are the probability distributions of features f_i or f_j [23].

$$L_m(U, V) = \sum_{i=1}^c \sum_{j=1}^n \mu_{ij}^m \|x_j - v_i\|^2 \quad (14)$$

Here, $L(U, V)$ is the Euclidean distance of the cluster center [24-25]. μ is called a weighted index, which may affect the clustering effect of FCM. Generally speaking, time series multi-step (long-term) forecasting refers to the forecast of multiple data points in the future [26].

$$Y_m = \sum_{i=1}^c \sum_{j=1}^N u_{ij}^m \|T - v_i\|^2 + \sum_{i=1}^c \sum_{j=1}^N O_{ij}^m T \quad (15)$$

3. Computer Simulation Algorithm Experiment of Gymnastics Formation Change Path

3.1 Positioning Realization of the Mobile Node

(1) RSSI positioning

The method based on the received signal strength is selected to realize the positioning of the beacon node to the mobile node. Combined with the positioning engine in the mobile node core processor CC2431, it can achieve efficient and low-energy wireless positioning. The formation algorithm between each mobile node can be processed. Keep a certain formation moving towards the target point, and at the same time, if a command to change the formation is received, the current formation will be adjusted according to its own position until it is adjusted to the desired formation.

In the positioning experiment, it is necessary to select an appropriate value of N to achieve accurate positioning. However, since the value of N is very susceptible to interference from environmental factors, it is relatively difficult to obtain its value. The most common method is to test all networks at the test site. The nodes inside are tested in turn. Although this method is cumbersome, it can select an accurate N value for positioning. Since the value of the propagation coefficient N is greatly affected by the environment, in actual positioning, the parameter N_index is often used instead of the N value to perform positioning calculations to reduce errors caused by environmental interference. For the CC2431 positioning engine, the expected value of parameter A is between 30 and 50, and the value of N_index is between 15 and 25. Finally, the current position is displayed on the host computer, and each packet of data transmitted wirelessly contains the short address of the node itself, so that the node information will not be confused.

(2) Realization of mobile node positioning based on RSSI

In wireless sensor networks, beacon nodes provide blind nodes with position coordinates and

RSSI values, and the received signal strength is easily affected by environmental factors. Therefore, a reasonable layout of beacon nodes is required to ensure that blind nodes can use the beacon The information provided by the target node calculates its accurate position. In this subject, 16 beacon nodes are selected in a 20×20m experimental site to locate the mobile nodes, and the distance between adjacent beacon nodes is 5m. The beacon nodes are all distributed at the outer contour of the area, and no beacon nodes are placed in the movement area of the mobile node. This layout makes it unnecessary for the mobile node to consider obstacle avoidance during the travel process, which simplifies the overall complexity of the system.

After the core processor CC2431 of the mobile node receives the data packet sent by each beacon node, it arranges the RSSI value in it in descending order, and selects the top 8 data. If it is not due to external interference or other reasons, If the data information of more than 8 beacon nodes can be obtained, all current beacon nodes will be sorted and processed. At the same time, the program is designed such that the mobile node receives 6 data packets within 300ms, and then uses the average filtering method to smooth the RSSI value to ensure positioning accuracy.

3.2 Z-Location Positioning Monitoring

When the preliminary work of positioning is ready, the system can be started for wireless positioning, and the monitoring of the upper computer and analysis of positioning errors can be performed with the help of Z-Location Engine software. You can change the position coordinates of the beacon node in the coordinate system in Reference Node Setup on this interface. After the setting is completed, the beacon node will remember its position, which can be used directly in future experiments. After the software is turned on, you can observe the coordinates (X, Y) of the current mobile node at BlindNodeSetup, compare this coordinate with the actual position coordinate, calculate the error between the true value, and change these two parameters through the A and N input fields the value of will get the new coordinates of the mobile node. Repeat this operation until the values of A and N are changed to valuessuitable for the current experimental site. This not only finds the appropriate A and N values, but also improves the accuracy of positioning.

3.3 Coordinated Control of Multiple Mobile Nodes

The mobile node obtains its own pose information from the beacon node through the communication mechanism, and at the same time, each mobile node exchanges information to realize information sharing. When a node in the system receives the status information of other members in the system, it calculates and processes it, and combines its own perception of the environment to make corresponding behavior plans, so that each member in the system can achieve expectations through collaboration the goal of. Multiple mobile nodes coordinate with each other to control communication between each node in a wireless manner, and sense their own heading angle information through the geomagnetic sensor, so as to make judgments and adjustments on the current formation and transformation conditions.

The cooperative control of multiple mobile nodes is mainly embodied in that when the mobile node perceives the external environment information and receives the pose information of other nodes, it influences the behavior of other mobile nodes through its own decision-making and planning. The coordinated control of multiple mobile nodes mainly studies the two-party recognition results

- 1) In the process of collaborating to complete a certain task, how to make each node maintain a consistent goal;
- 2) How to avoid conflicts and deadlocks in behavior planning between nodes when running to a

consistent target point, and what measures should be taken to effectively eliminate conflicts or deadlocks.

The multi-mobile node coordinated control system established with the above two aspects as the core will be able to complete the overall task of the system efficiently with good dynamics, adaptability and flexibility.

3.4 Formation Reference Points

In order for the mobile node to have a corresponding adjustment mechanism for the maintenance and transformation of the formation in the process of moving to the target point, it is necessary to select suitable reference points for these mobile nodes. In this way, each mobile node can determine its own position and the position of the reference point. After calculation and processing, reasonable adjustments can be made to maintain the formation and make corresponding changes. In general, there are three methods for selecting reference nodes: taking the navigator as the reference point, taking the adjacent node as the reference point and taking the geometric center as the reference point.

The selection method based on the navigator as a reference point can provide reference for other nodes without resorting to a large amount of communication. The communication is simple and the control is convenient. This method is used to realize the formation maintenance and formation transformation of the mobile nodes in the wireless sensor network. Taking the navigator as a reference, each mobile node adjusts its position autonomously to achieve the purpose of maintaining and changing the formation.

3.5 Improved Leader-Follower Method Design

This paper chooses the Leader-Follower method to study the formation transformation and formation maintenance of mobile nodes. This paper designs an improved Leader-Follower method. In this research, the traditional three types of nodes are divided into four types according to the different formation responsibilities in the research work of the formation transformation of mobile nodes in the wireless sensor network environment, namely, the coordinator, beacon node, master mobile node (Leader), slave mobile node (Follower). These four types of nodes have a clear division of labor in the network.

Since the functions of the beacon node and the coordinator have not changed, this article focuses on the analysis of the functions of the master mobile node and the slave mobile node. First of all, for the master mobile node, as the leader of other nodes in the network, its fundamental task is to provide references for its followers.

After it accurately locates itself with the help of the information of the beacon node, the information should be sent out in the form of broadcast, and the coordinator sends the information to the host computer through the serial port for tracking display. The pose information sent by the master mobile node to the slave mobile node in real time includes three types of information, namely, the current position coordinates of the master mobile node, the current speed, and the current formation to be maintained or formed.

When the mobile node is traveling to the target point, it receives the formation change command from the coordinator. This command is a point-to-point communication between the coordinator and the master mobile node, and the slave mobile nodes in the network will not receive the command. The slave mobile node can obtain the related transformation of the formation from the pose information sent to it in real time by the master mobile node. Because the slave mobile node needs to make real-time adjustments to the path during the formation transformation. After a series of positioning

calculations, the mobile node transmits its position information to the coordinator in a point-to-point manner. At the same time, it needs to receive the leader's pose information in real time, calculate its distance and angle, and extract the information transmitted by the main mobile node. Determine whether the current formation information is consistent with the formation at the previous moment. If it is inconsistent, the formation needs to be changed. According to the formation information, the corresponding expectation matrix is selected as the target to adjust its position.

3.6 Formation Maintenance of Mobile Nodes

In order to enable the mobile nodes in the network to maintain the current formation and move toward the target point after completing the formation change, but in the process of travel, due to the interference of various factors in the road conditions and the environment, one or the other will inevitably appear. Thousands of mobile nodes are left behind. Therefore, this paper adopts the $l-\phi$ closed-loop control method to correct the formation in real time, and maintain the formation of the mobile node group during the walking process, so that the current follower will be between the current leader and the leader. Adjust the distance and included angle to the desired value l and ϕ . As long as the follower successfully receives the pose information sent by the leader, the $l-\phi$ controller can maintain a certain distance and angle with the leader, so that the formation can be maintained. The slave mobile node compares its own pose with the expected value, and realizes the correction of the formation through the feedback of the current position and angle error, which ensures the stability of the formation. Closed loop control is shown in Figure 2.

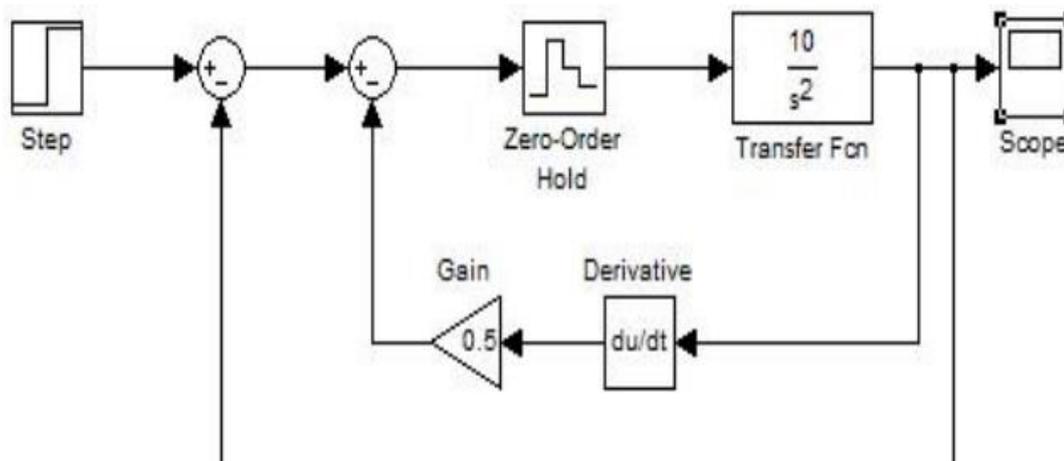


Figure 2. Closed loop control(<http://alturl.com/59r27>)

4. Results and Discussion

4.1 Positioning Analysis Based on RSSI

N is the signal propagation index. As the distance increases, the signal strength will decrease; A is the RSSI value when the beacon node is 1 meter away from the mobile node. The value is often fixed, and the unit is dBm. In the host computer monitoring software used in the positioning experiment, the N value and A value can be filled in by the user. Therefore, appropriate parameters should be selected according to the environmental characteristics of the test area to achieve the purpose of minimizing the positioning error. Table 1 shows the data of the correspondence relationship between N and N_index .

Table 1. Correspondence between N and N_index

N_index	N value	N index	N value	N_index	N value
12	2.875	18	3.625	24	4.375

13	3.000	19	3.750	25	4.500
14	3.125	20	3.875	26	4.625
15	3.250	21	4.000	27	5.000
16	3.375	22	4.125	28	5.500

In the multi-mobile formation software and hardware positioning platform designed in this paper, the mobile formation with the CC2341 chip as the blind node needs to use the beacon node closest to itself for positioning. Generally, when 3-8 beacon nodes are received positioning signal can minimize the error of the positioning result, which not only avoids channel redundancy caused by too many signals, but also prevents too few beacon nodes from receiving positioning information as reference information for mobile nodes. The sensor node control is shown in Figure 3.

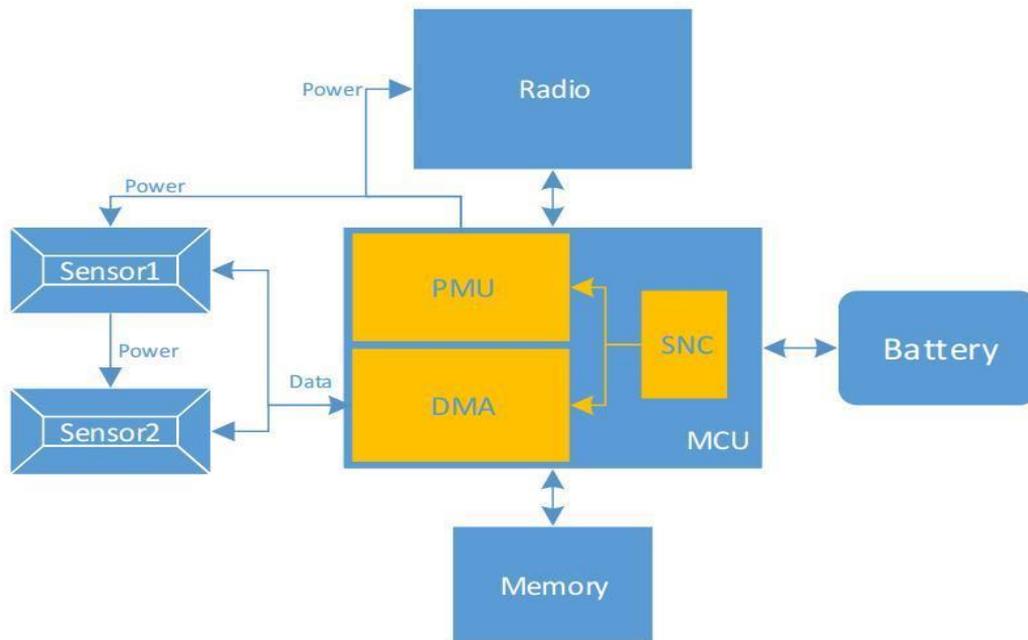


Figure 3. Sensor node control(<http://alturl.com/cfbzi>)

4.2 Simulation and Analysis of Formation Transformation under Ideal Conditions

Assuming that the gymnastics formation is 5 gymnastics forming a regular triangle, the coordinates of each gymnastics are $R_1(0, 0)$, $R_2(-2.6, 1.5)$, $R_3(-2.6, -1.5)$, $R_4(-5.2, 3)$, $R_5(-5.2, -3)$, the specific transformation rules for the upper half of the formation are shown in Table 2, and the transformation rules for the lower half are the same as the upper half.

Table 2. Specific transformation rules for the upper half of the formation

L (m)	Transformation method	Pass
$L \geq 3.5$	Keep the original formation	Can pass
$2 \leq L < 3.5$	Change R4	Can pass
$0.5 \leq L < 2$	Change R4 and R2 at the same time (combined with the lower half of consideration)	Can pass
$L < 0.5$	-	Can't pass

The simulation of transforming the column into a triangular queue is shown in Figure 4. In the simulation, a fixed pattern is set for each formation, and angles and distances are used to describe the formation, that is, the angle formed by the first column of the follower and the leader relative to the forward direction in the matrix expression and the second column of the follower and distance between the pilots, these parameters can be changed in the program to adjust the formation. Before the

simulation, the parameters should be set, and the number of mobile nodes should be set to 3. At the beginning of the operation, the mobile nodes will keep the column forward to the target point.

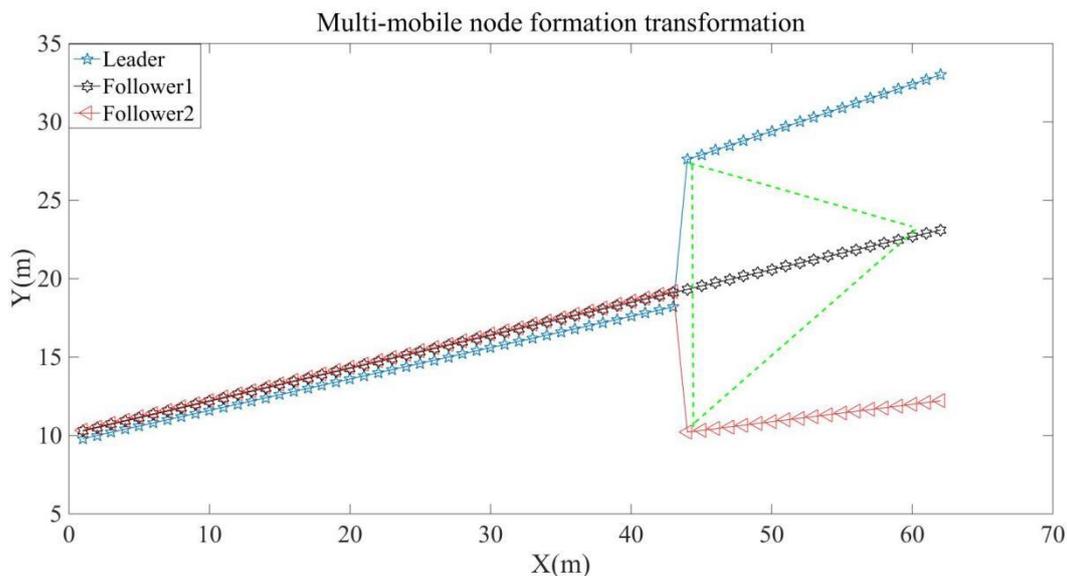


Figure 4. Simulation of transforming a column into a triangular queue

The error of each mobile node's trajectory relative to the ideal path is shown in Figure 5. After the mobile node receives the command to transform into a triangular queue, it immediately adjusts its position. Leader makes a corresponding deceleration operation, reducing the 0.3 step length to 0.1 step length to advance, Follower1 and Follower2 start to accelerate, and finally adjust to a triangular team. In the simulation, the triangular queue is set as follows: Follower1 and Follower2 are both 6m away from Leader, the angle between Follower1 and Leader relative to the forward direction is 45° , and the angle between Follower1 and Leader relative to the forward direction is -45° . During the formation change process, the analysis shows that the maximum offset of Follower2 relative to the ideal path in the process of traveling to the desired position in the triangular queue is +0.28m, the maximum offset of Follower1 is +0.15m, and the leader's offset is within +0.26m. It can be seen that the offset error of Follower2 is the largest relative to other nodes.

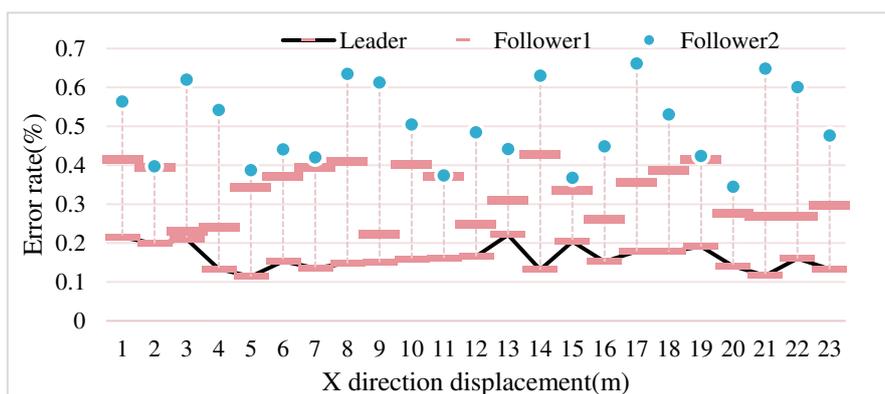


Figure 5. The error of each mobile node's trajectory relative to the ideal path

By analyzing the factors that affect the positioning effect, optimizing the corresponding parameters can reduce the positioning error and improve the positioning accuracy. The positioning test is carried out in different environments, and the positioning effect will be different. Therefore, in the experimental test, you can flexibly modify the A value and N value in the RSSI positioning principle formula in the host computer monitoring interface according to the changes in the environment, so as to

achieve more good positioning effect. The results of the ranging error are shown in Table 3.

Table3. Comparison of Ranging Error Results

Parameter	scene one	Scene two	Scene three
A value	30	38	40
N value	15	twenty two	22
Actual distance/m	(10,20)	(10,20)	(10,20)
Measuring distance/m	(17 ,25)	(12 ,23)	(5,22)

The simulation of transforming a triangle to a horizontal team is shown in Figure 6. The triangle queue in this simulation is set as follows: Follower1 and Follower2 are both 6m away from the Leader, and the angle between Follower1 and Leader with respect to the forward direction is 30° , and the angle between Follower1 and Leader is 30° . The angle of the advancing direction is -30° . After receiving the formation transformation command, each mobile node adjusts the position of the distance and angle in the horizontal expectation matrix. This article sets the parameters in the horizontal expectation matrix as: Follower1 and Follower2 are both 5m away from the Leader, and the distance between Follower1 and Leader relative to the forward direction The included angle is 90° , and the included angle between Follower1 and Leader relative to the forward direction is -90° .

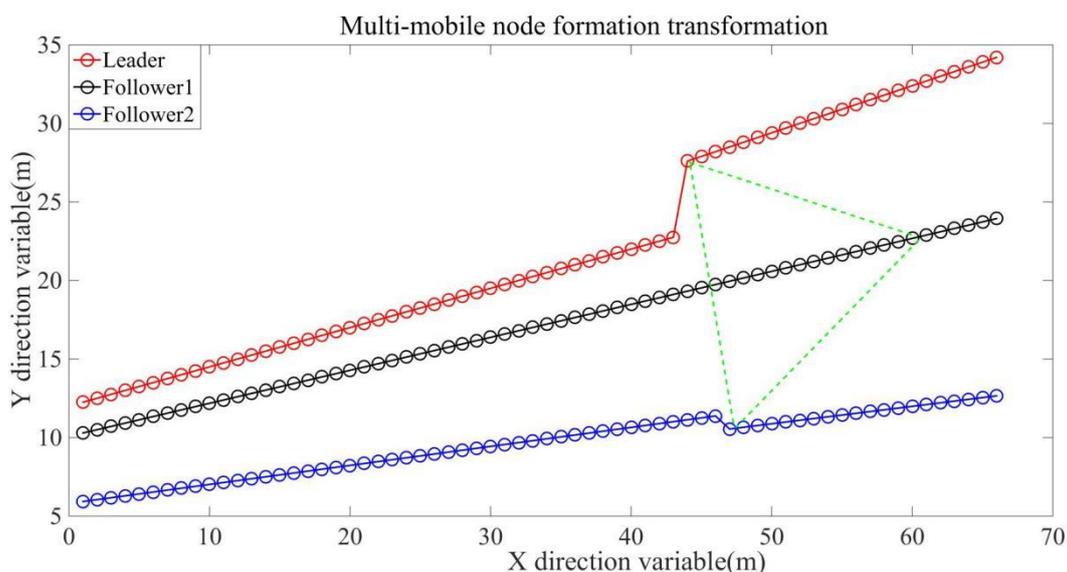


Figure 6. Simulation of transforming from triangle to horizontal team

4.3 Leader-Follower Analysis

The error comparison between the improved Leader-Follower and the traditional Leader-Follower is shown in Table 4. The data in Table 4 shows that the average error rate of the improved Leader-Follower method (1%) is 0.094, the average error rate of the improved Leader-Follower method (0.1%) is 0.007%, and the average error rate of the traditional Leader-Follower method is 3.520 %. It can be seen that the traditional Leader-Follower method can greatly reduce the average error after improving the accuracy, and because the Leader-Follower error is uncontrollable, there is still a large error after increasing the number of iterations, which is not suitable for low-error situations, so in terms of capacity limiting efficiency It is significantly higher than the traditional Leader-Follower method.

Table 4. Error comparison between the improved Leader-Follower and the traditional Leader-Follower

Method	Individual	Limit capacity	Maximum error rate (%)	Average error rate (%)
Traditional Leader-Follower	40	247.734	17.219	3.520
Improved Leader-Follower(0.1%)	40	247.734	0.999	0.094
Improved Leader-Follower(0.01%)	40	247.734	0.099	0.007

In this comparative study, in terms of formation transformation, the convergence time of formation transformation using the algorithm of this paper is 5s, the convergence time ratio of formation transformation is 5.4%, and the formation expansion transformation is performed, so the formation structure difference before and after the transformation is 0.67. All gymnastics have advanced a total of 32.6 meters during the formation change process; the used algorithm formation change convergence time is 7.55s, and the formation change convergence time ratio is 8.1%. The formation change changes the original formation structure. The team before and after the change The degree of difference in form structure is 2.51, and all gymnastics formations have advanced 46.2 meters in total during the transformation process. The formation change time is shown in Table 5.

Table 5. Formation time

Method	Team structure difference	Convergence time of formation change (seconds)	Formation change path cost
Traditional Leader-Follower	0.67	5	32.6
Improved Leader-Follower	2.51	7.5	46.2

The result of accumulating the total utility cost of the whole simulation process is shown in Table 6. It can be verified that the task modeling method proposed in this research is less effective than traditional methods.

Table 6. The result of adding up the total utility cost

Method	Simulation cost	Cost of consistency	Total utility cost
Traditional Leader-Follower	72	944	1016
Improved Leader-Follower	274	262	536

When the number of mobile nodes is set to 4, the simulation of transforming from a wedge queue to a square queue is shown in Figure 7. The initial formation is a wedge, and its parameter setting is: the distance between Follower1 and Leader is 4m. After receiving the formation change command, adjust the position. The parameters of the square queue are set as: the distance between Follower1 and Leader is 5m, the angle relative to the forward direction is 90°, the distance between Follower2 and Leader is 7.07m, and the angle is 45°. The distance between Follower3 and Leader is 5m, and the included angle is 0°.

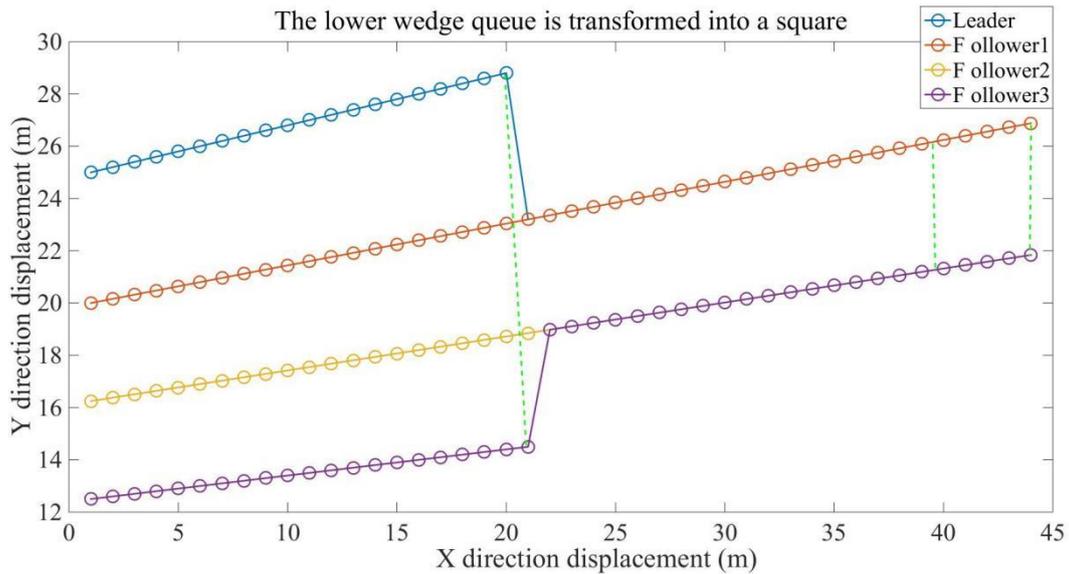


Figure 7. When the number of mobile nodes is 4, the wedge queue is transformed into a square queue

The distance to the Leader is 5m, and the error in the transformation process is shown in Figure 8. The maximum deviation between the formation change trajectory of Follower1 and the ideal path is +0.14m, the maximum deviation of Follower2 is +0.19m, the maximum deviation of Follower3 is +0.25m, and the maximum deviation of Leader is +0.21m. Compared with the transformation from the column to the triangular queue, the average deviation is also reduced. This is because the adjustment rate of each node is significantly smaller than that of the column to the triangular queue from the wedge to the square, so the adjustment of the position of each mobile node is very small, which reduces the deviation.

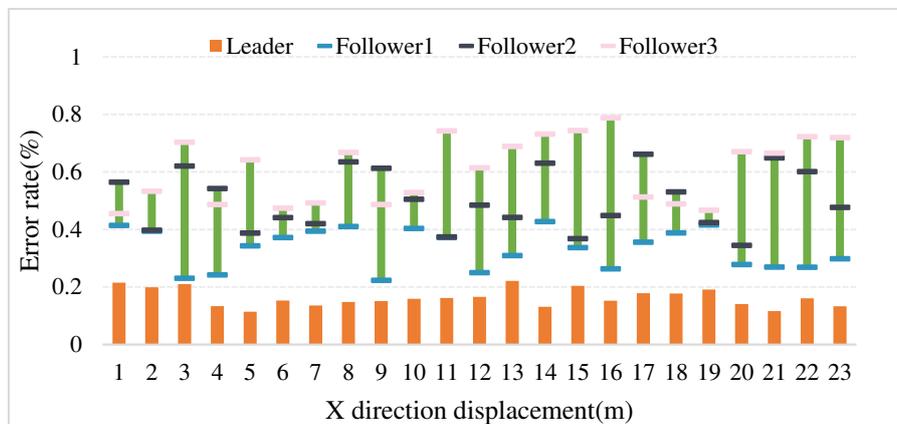


Figure 8. The distance between the leader and the leader is 5m, and the error in the transformation process

5. Conclusion

Today, with the rapid development of information age, the communication of science and technology is getting closer to each other, and our country has begun to conduct in-depth research on WSN. This study mainly discusses the computer simulation algorithm of gymnastics formation transformation path based on wireless sensor. In this study, an improved leader follower method is designed. In the research of gymnastics formation transformation of mobile nodes in wireless sensor network environment, the traditional three types of nodes are divided into four categories according to different formation responsibilities, namely coordinator, beacon node, leader and follower. When it

makes accurate positioning with the help of beacon node information, it will send the information in the form of broadcast, and then the coordinator will send the information to the host computer through the serial port for tracking display. In order to make the mobile nodes in the network keep the current gymnastics formation moving towards the target point after completing the gymnastics formation transformation, this paper uses the $L - \varphi$ closed-loop control method to modify the gymnastics formation in real time. The method based on the received signal strength is used to locate the mobile node. Combined with the positioning engine in the core processor CC2431 of the mobile node, the efficient and low-energy wireless positioning can be realized. Multiple mobile nodes coordinate and control each other, and each node communicates with each other through wireless mode, and senses its own heading angle information through geomagnetic sensor, so as to judge and adjust the maintenance and transformation of the current gymnastics formation. This research effectively realizes the computer simulation of autonomous formation.

DECLARATIONS

Ethics Approval and Consent to Participate

This article is ethical, and this research has been agreed.

Consent for Publication

The picture materials quoted in this article have no copyright requirements, and the source has been indicated.

Availability of Data and Material

Data sharing does not apply to this article because no data set was generated or analyzed during the current research period

Competing Interests

The authors declare that they have no competing interests

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Authors' Contributions

Bingxin Chen: Writing – editing

Lifei Kuang: data analysis

Wei He: sampling method

ABBREVIATIONS

wireless sensor network (WSN)

three-dimensional(3D)

Hidden Markov Model (HMM)

angle of arrival(AOA)

Received Signal Strength Indicator (RSSI)

References

- [1]Behera S K , Dogra D P , Roy P P . Analysis of 3D signatures recorded using leap motion sensor. *Multimedia Tools and Applications*, 2018, 77(11):14029-14054.
- [2]Yu S , Chen H , Brown R A . Hidden Markov Model-Based Fall Detection With Motion Sensor Orientation Calibration: A Case for Real-Life Home Monitoring. *IEEE Journal of Biomedical and Health Informatics*, 2018, 22(6):1847-1853.
- [3]Shen C , Li Y , Chen Y , et al. Performance Analysis of Multi-Motion Sensor Behavior for Active Smartphone Authentication. *IEEE Transactions on Information Forensics & Security*, 2018, 13(1):48-62.
- [4]Yurtman A , Barshan B . Novel Noniterative Orientation Estimation for Wearable Motion Sensor Units Acquiring Accelerometer, Gyroscope, and Magnetometer Measurements.*IEEE Transactions on Instrumentation and Measurement*, 2020, 69(6):3206-3215.
- [5]Hirata M , Watanabe R , Koyano Y , et al. Using a Motion Sensor-Equipped Smartphone to Facilitate CT-Guided Puncture. *Cardiovascular & Interventional Radiology*, 2017, 40(4):1-7.
- [6]Min J K , Cheon E J , Kim J M , et al. Comparison of the 6-DOF Motion Sensor and Stain Gauge Data for Ice Load Estimation on IBRV ARAON. *Journal of the Society of Naval Architects of Korea*, 2016, 53(6):529-535.
- [7]Duma I I , Giurgiu S . Circadian activity and nest use of *Dryomys nitedula* as revealed by infrared motion sensor cameras. *Folia Zoologica*, 2018, 61(1):49-53.
- [8]Multifunctional Water Drop Energy Harvesting and Human Motion Sensor Based on Flexible Dual-Mode Nanogenerator Incorporated with Polymer Nanotubes. *ACS Applied Materials And Interfaces*, 2020, 12(21):24030-24038.
- [9]Thomas Alan Donaldson. Inline calibration of motion sensor. *Journal of Chinese Pharmaceutical ences*, 2016, 48(23):2022-2025.
- [10]Marin G , Dominio F , Zanuttigh P . Hand gesture recognition with jointly calibrated Leap Motion and depth sensor. *Multimedia Tools and Applications*, 2016, 75(22):14991-15015.
- [11]Jin H , Chen Q , Chen Z , et al. Multi-LeapMotion sensor based demonstration for robotic refine tabletop object manipulation task. *Caai Transactions on Intelligence Technology*, 2016, 1(1):104-113.
- [12]Wei Z , Zhang W , Liu W , et al. Attitude Theory and Experimental Research of Micro-aircraft Based on MEMS Sensor. *Piezoelectrics & Acoustooptics*, 2018, 40(4):516-520.
- [13]Laurijssen D , Truijten S , Saeys W , et al. An Ultrasonic Six Degrees-of-Freedom Pose Estimation Sensor. *IEEE Sensors Journal*, 2016, 17(1):151-159.
- [14]Korpi D , Tamminen J , Turunen M , et al. Full-Duplex Mobile Device - Pushing The Limits. *IEEE Communications Magazine*, 2016, 54(9):80-87.
- [15]Zhou L . Mobile Device-to-Device Video Distribution: Theory and Application. *ACM Transactions on Multimedia Computing Communications and Applications*, 2016, 12(3):1-23.
- [16]Noei E , Syer M D , Zou Y , et al. A study of the relation of mobile device attributes with the user-perceived quality of Android apps. *Empirical Software Engineering*, 2017, 22(6):3088-3116.
- [17]Chiang K F , Wang H H . Nurses' experiences of using a smart mobile device application to assist home care for patients with chronic disease: a qualitative study. *Journal of Clinical Nursing*, 2016, 25(13-14):2008-2017.
- [18]Jiang J , Han G , Guo H , et al. Geographic multipath routing based on geospatial division in duty-cycled underwater wireless sensor networks. *Journal of Network & Computer Applications*, 2016, 59(1):4-13.

- [19]Xu Z , Chen L , Chen C , et al. Joint Clustering and Routing Design for Reliable and Efficient Data Collection in Large-scale Wireless Sensor Networks. *IEEE Internet of Things Journal*, 2016, 3(4):520-532.
- [20]Kumari S , Li X , Wu F , et al. A user friendly mutual authentication and key agreement scheme for wireless sensor networks using chaotic maps. *Future Generation Computer Systems*, 2016, 63(10):56-75.
- [21]Zou Y , Wang G . Intercept Behavior Analysis of Industrial Wireless Sensor Networks in the Presence of Eavesdropping Attack. *IEEE Transactions on Industrial Informatics*, 2016, 12(2):780-787.
- [22]Ebrahimi D , Assi C . On the Interaction between Scheduling and Compressive Data Gathering in Wireless Sensor Networks. *IEEE Transactions on Wireless Communications*, 2016, 15(4):2845-2858.
- [23]Hong Z , Wang R , Li X . A Clustering-tree Topology Control Based on the Energy Forecast for Heterogeneous Wireless Sensor Networks. *IEEE/CAA Journal of Automatica Sinica*, 2016, 3(01):70-79.
- [24]Pak J M , Ahn C K , Shi P , et al. Distributed hybrid particle/FIR filtering for mitigating NLOS effects in TOA-based localization using wireless sensor networks. *IEEE Transactions on Industrial Electronics*, 2017, 64(6):5182-5191.
- [25]Deniz F , Bagci H , Korpeoglu I , et al. An adaptive, energy-aware and distributed fault-tolerant topology-control algorithm for heterogeneous wireless sensor networks. *Ad Hoc Networks*, 2016, 44(7):104-117.
- [26]Liu W , Zhou X , Durrani S , et al. Energy Harvesting Wireless Sensor Networks: Delay Analysis Considering Energy Costs of Sensing and Transmission. *IEEE Transactions on Wireless Communications*, 2016, 15(7):4635-4650.



Bingxin Chen was born in Kaifeng, Henan Province, China, 1988. She received a master's degree from the School of physical Education of Hunan normal University and worked at Hunan normal University. her research interests include physical education, sports management, sports training, and sports medicine.

E-mail: chenbingxin15@163.com



Lifei Kuang, born in 1979, graduated from Hunan normal University School of physical Education, Master's degree, Lecturer, Gymnastics International referee, research field: physical Education and training

E-mail: lifekuang1@163.com



Wei He, born in Ningxiang, Hunan Province, 1986, China, obtained a master's degree in physical Education College of Hunan normal University, and now works in physical Education College of Changsha normal University.

E-mail: ccsbb@163.com

Figures

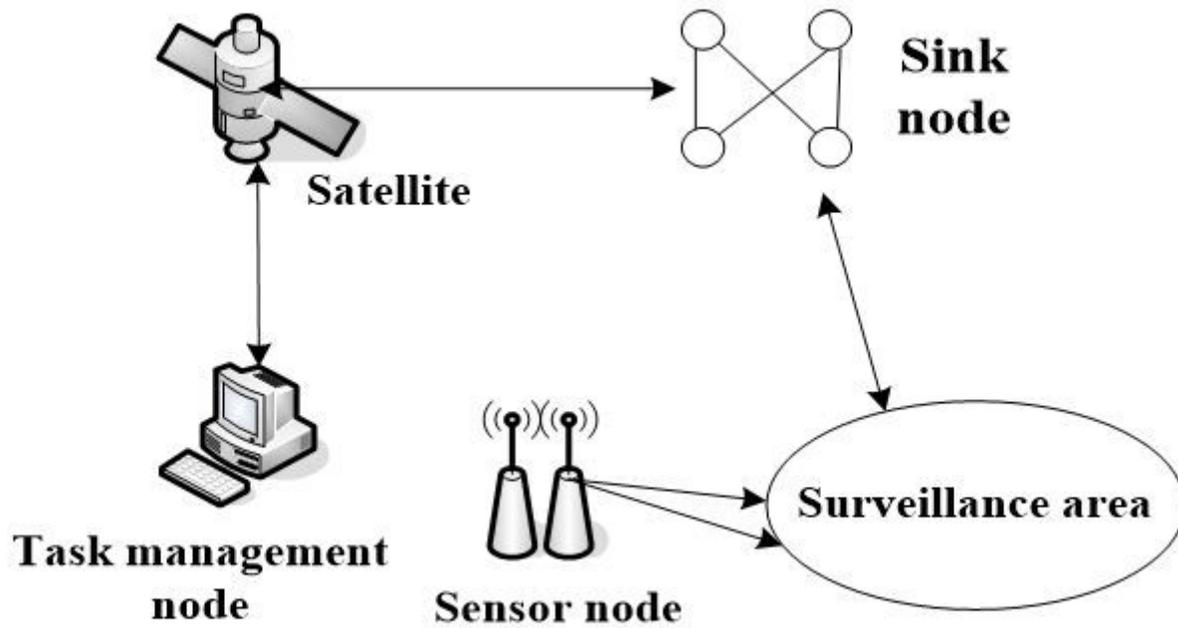


Figure 1

Mobile node identification

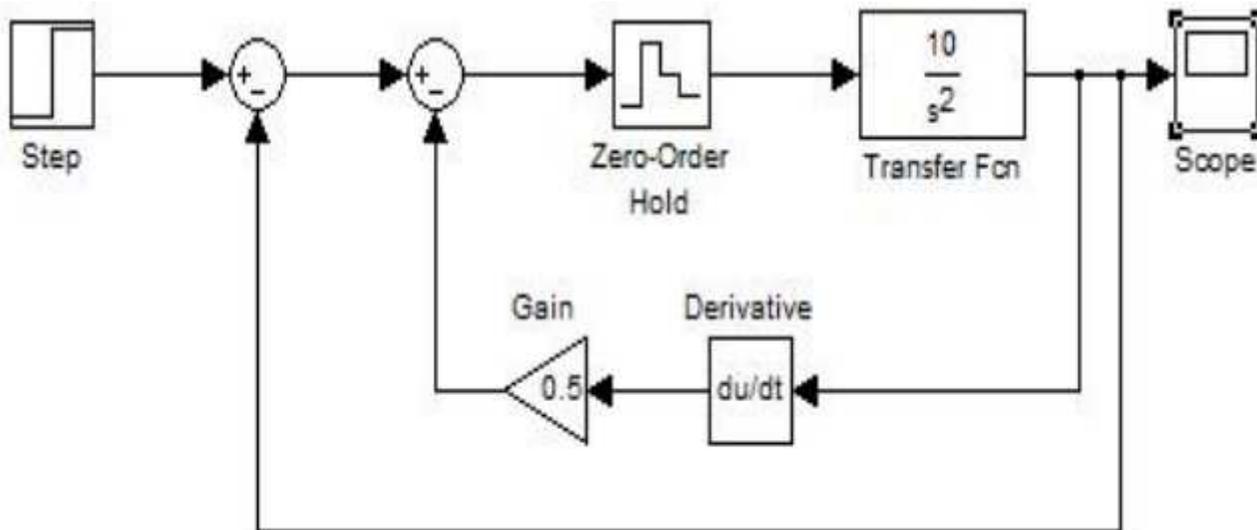


Figure 2

Closed loop control(<http://alturl.com/59r27>)

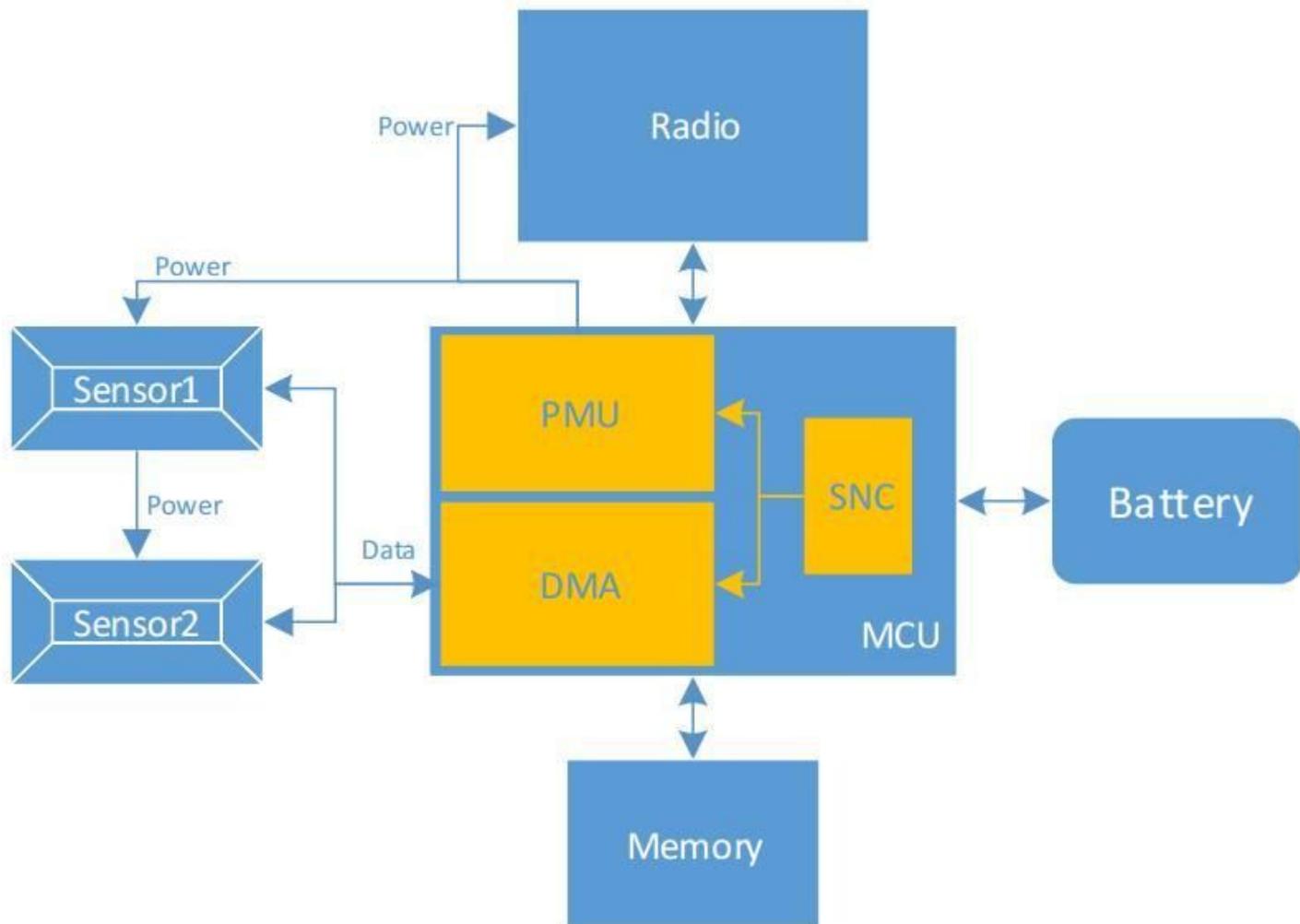


Figure 3

Sensor node control(<http://alturl.com/cfbzi>)

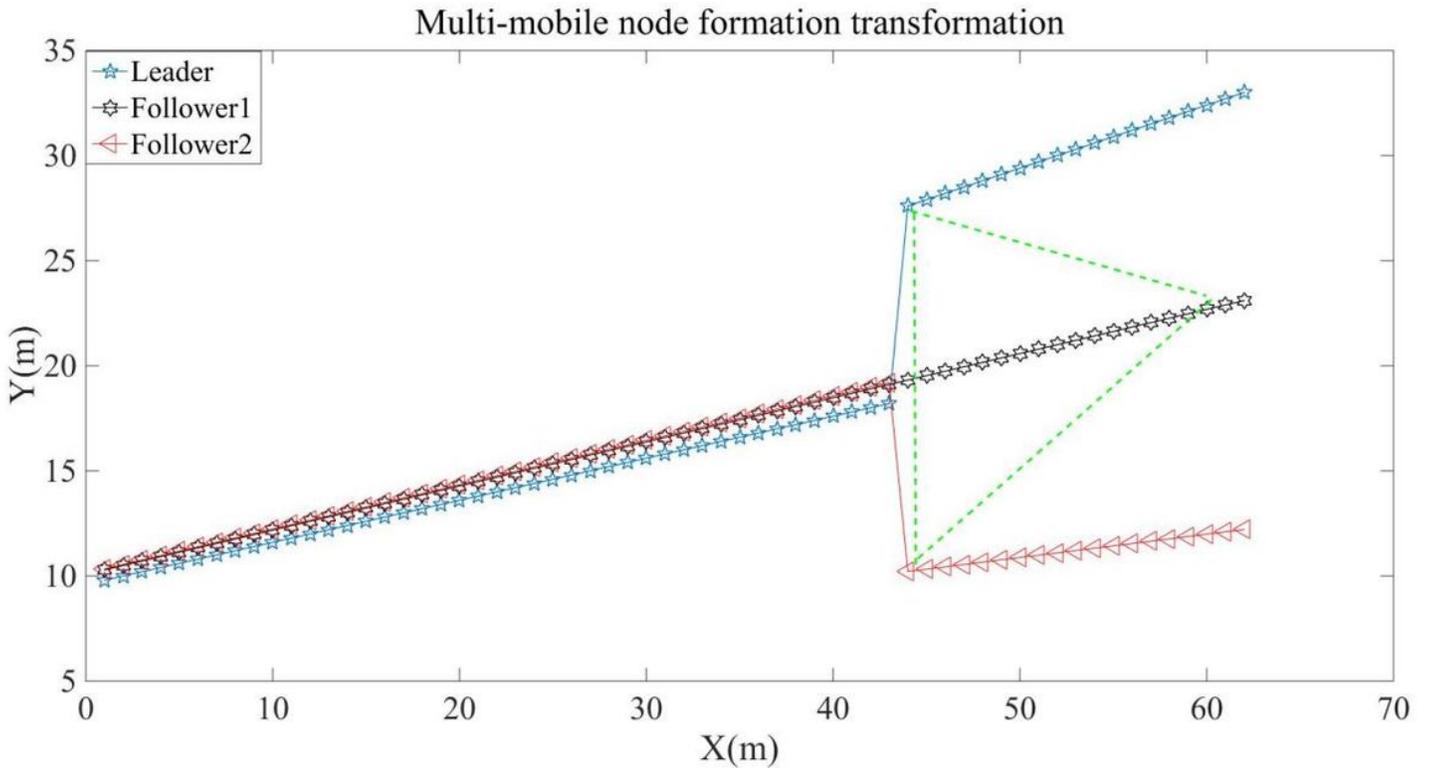


Figure 4

Simulation of transforming a column into a triangular queue

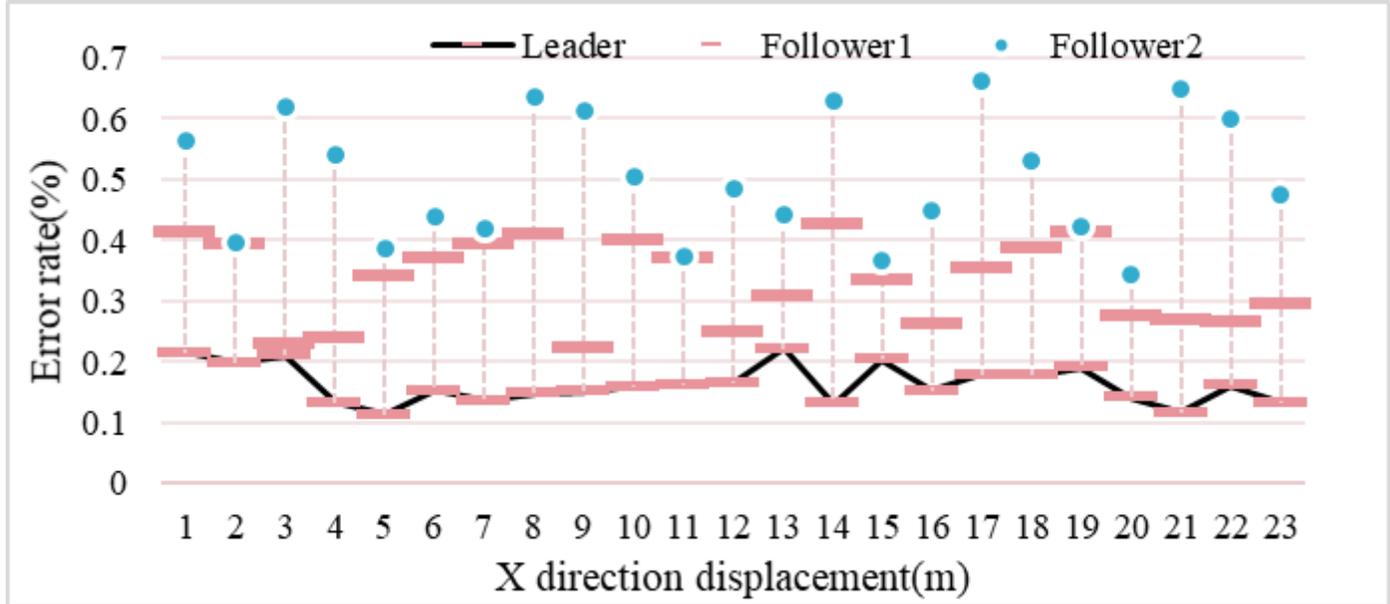


Figure 5

The error of each mobile node's trajectory relative to the ideal path

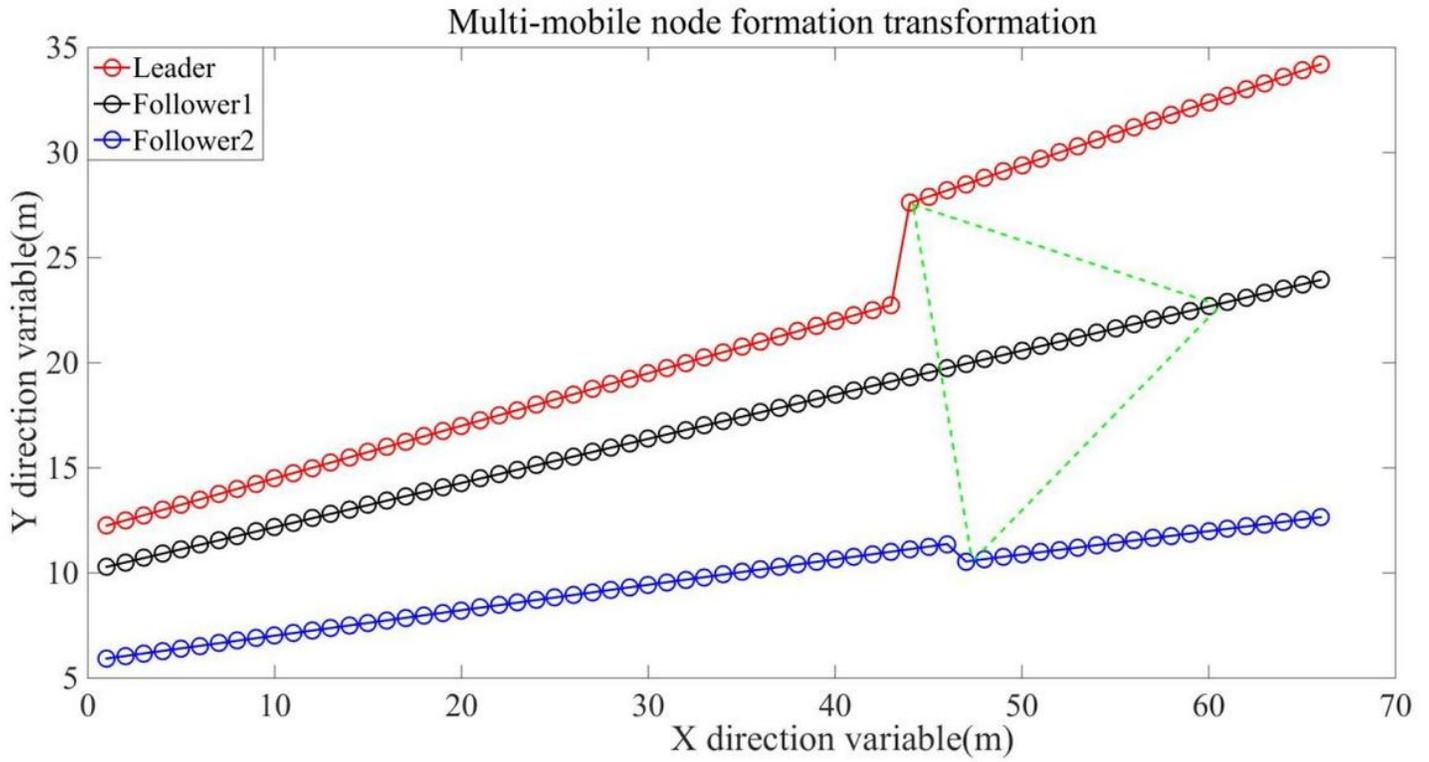


Figure 6

Simulation of transforming from triangle to horizontal team

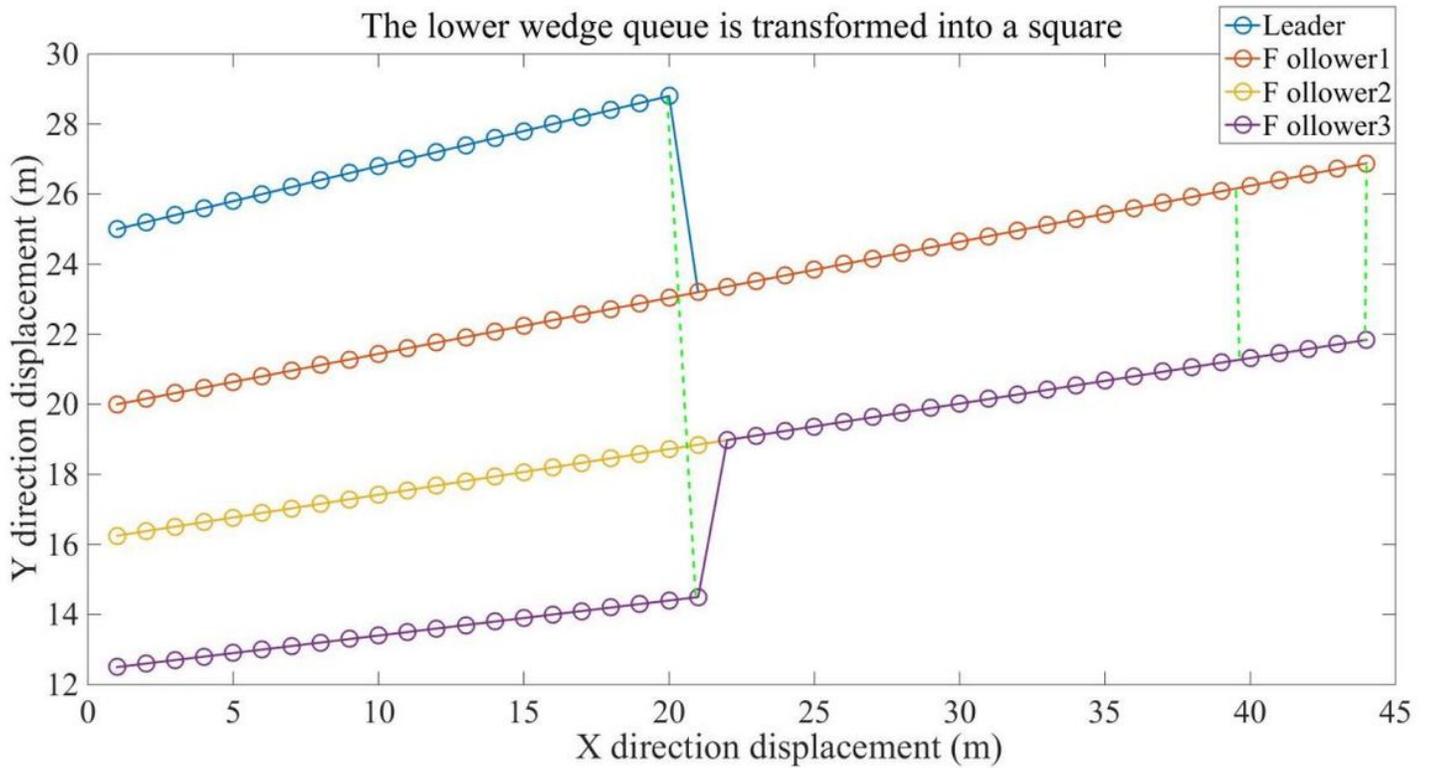


Figure 7

When the number of mobile nodes is 4, the wedge queue is transformed into a square queue

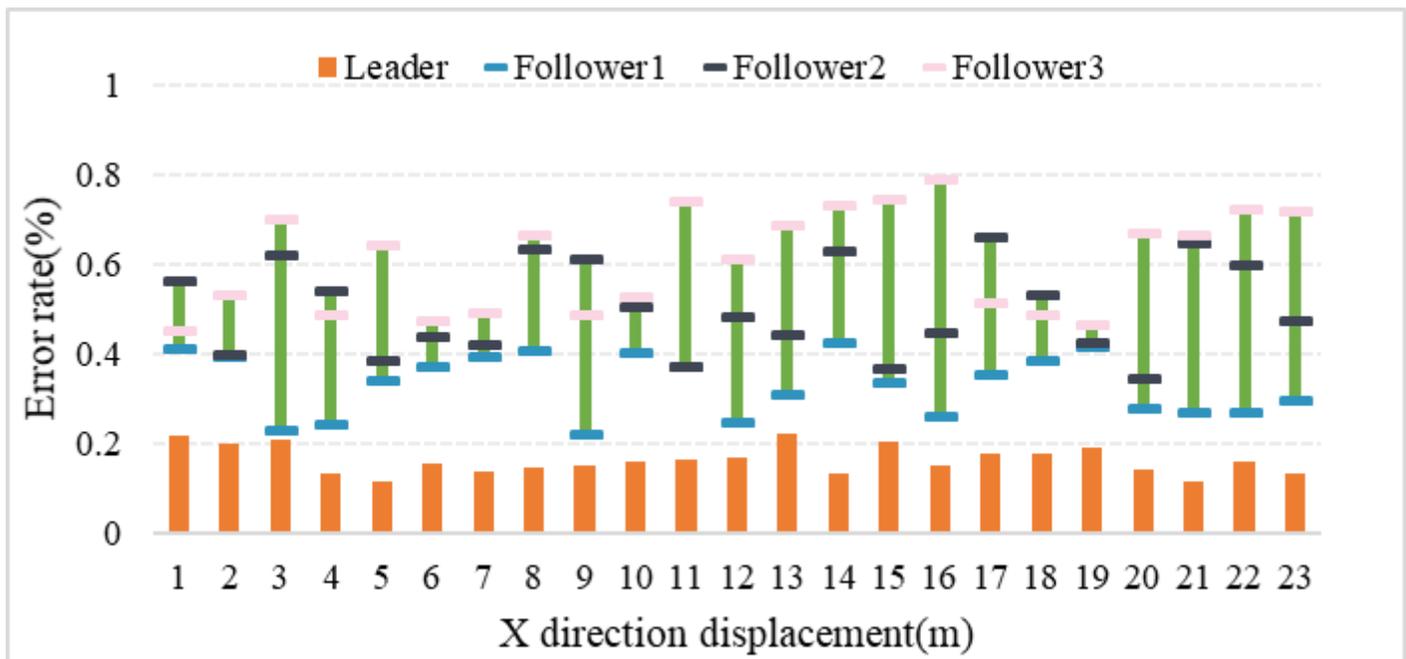


Figure 8

The distance between the leader and the leader is 5m, and the error in the transformation process