Intelligent Building Data Fusion Algorithm by Using the Internet of Things Technology

Duo Peng¹, Jingqiang Zhao¹*, Tongtong Xu¹

¹School of Computer and Communication, Lanzhou University of Technology, China, 730050

*Corresponding author e-mail: zhaojing@lut.cn

Abstract. Analyzed in this paper based on the Internet of things technology for intelligent building data, redundancy of data fusion are pointed out, based on the dynamic Kalman filter algorithm of multi-sensor fusion, first using the theory of fuzzy and covariance matching technique to adjust the noise covariance of traditional algorithm, combined with weighted minimum variance matrix under the optimal information fusion algorithm of data fusion, Finally, the simulation results show that this algorithm can effectively reduce the redundancy of intelligent data and make the estimated value of data fusion more close to the actual value.

Keywords: Intelligent Building, Internet of Things, Data Fusion, Sensor

1. Introduction

In recent years, with the continuous development of information technology, such as the maturity of computer technology, communication technology and Internet of Things technology, it has had a significant impact on the traditional construction industry. The progress of science and technology has brought about the development of society. At present, one of the important urban development strategies in China is the smart city represented by digitalization, networking and intelligentization.

Intelligent building can be defined as the optimal combination of building structure, system, service and management according to the needs of users, so as to create an intelligent, efficient and convenient humanized building environment for the society [1]. Its technical basis mainly includes modern building technology, modern computer technology, modern communication technology and modern control technology. At present our country is accelerating to the intelligent transformation of public buildings, the rise of intelligent buildings have a further request for technology, from different channels, and belong to different types of intelligent building data in the process of acquisition, transmission and utilization, need to study a new data fusion algorithm, speed up the data simulation precision, meet the needs of the people production and living.

The Internet of Things is the result of the third industrial revolution after the computer and the Internet, and it is applied to all walks of life. The intelligent building big data dominated by the Internet of Things technology is conducive to the construction of a safe, efficient and intelligent comprehensive management system, to the promotion of the combination of information technology and the construction industry, and to the acceleration of the construction of smart cities, which has a...
certain guiding significance and theoretical value [2]. This paper analyzes the characteristics of intelligent building data, discusses how to reduce the redundancy of intelligent building data acquired based on Internet of Things technology, and selects appropriate algorithms for data fusion.

2. Intelligent building data based on Internet of things technology
The Internet of Things technology obtains the data of intelligent buildings mainly through the perception layer, which is the foundation of the Internet of Things technology. The perception layer is composed of common physical components and is used to perceive and identify various kinds of building information. Common sensors include temperature sensors, air detectors, structural detectors, surveillance cameras, electronic tags, and ground subsidence detectors. And GPS, GIS and other technologies [3]. The network layer refers to the intelligent building data fusion network composed of various communication networks, which mainly transmits the intelligent building data between the perception layer and the application layer, mainly including the Internet, Intranet, local area network, mobile Internet and industrial communication private network, etc. The application layer is to store, mine and process the intelligent building data based on certain functions, and to save all kinds of building data collected by the sensing layer in real time or on a regular basis.

2.1. Data acquisition
The acquisition of intelligent building data is mainly based on the Internet of Things technology and the existing building information database on the Internet. The data is characterized by diverse sources and various types. The data types are structured, semi-structured and unstructured. The accuracy of data collection mainly depends on the hardware and software conditions of the intelligent building system.

2.2. Data integration
Data integration refers to the filtering, sorting and storage of the collected data based on the acquisition of intelligent building data by the sensing layer. The biggest characteristic of data collection is diversity. In order to realize the unified utilization of intelligent data, firstly, the data of different forms should be transformed into a unified structure, and secondly, the data should be filtered and processed to remove data noise and interference.

2.3. Data fusion issues
The data of intelligent building is mainly obtained by using a variety of different types of sensors. It is difficult to fuse the data of different structures and types. The performance of multi-sensor data fusion results is a long-term problem [4-5]. The traditional solution is the classical Kalman filter algorithm, which uses the variance upper bound to eliminate the correlation and uniform information allocation principle. But the traditional Kalman filter has some problems such as strong coupling degree with the system model, poor robustness and some divergence problems which are difficult to overcome. After referring to a lot of literature related to fusion algorithm, it is considered that dynamic Kalman wave combining matrix weighting can improve the adaptability of the model and make the filtering precision higher.

3. Research on fusion algorithm
In order to make the process of system noise and observation noise conforms to the actual situation, and therefore cannot be fixed system noise and observation noise covariance matrix of process, so can use dynamic method to estimate the above two kinds of covariance, so as to improve the accuracy of filtering, avoid filtering divergence, makes the system state correction is worth to correct, so as to estimate is close to the actual value in the system, Data fusion algorithms for smart buildings are improved [6-8].

3.1. Covariance matching
Covariance matching technique is an important part of dynamic Kalman filter algorithm. It is realized by enhancing the consistency between theoretical covariance and actual covariance of residual. Residual $U(j)$, can be expressed as:

$$u(j) = Y(j) - Z(j)X(j / j - 1)$$  \hspace{1cm} (1)

The theoretical covariance of the residual, $S(j+1)$, can be calculated by the following expression:

$$S(j+1) = H(j+1)P(j+1/j)H^T(j + 1) + R(j + 1)$$  \hspace{1cm} (2)

The actual covariance of the residual $R(j)$ can be calculated by the following formula:

$$R(j) = \frac{1}{j} \sum_{i=0}^{j} u(i)u^T(i)$$  \hspace{1cm} (3)

Where, $j$ is an empirical parameter, representing the window size used to calculate the actual covariance matrix, and it is generally appropriate to take a value of 20. By comparing the deviation between the theoretical covariance value and the actual covariance value, the fuzzy system theory is adopted to adjust $R(j)$ to eliminate the difference between them. The data fusion algorithm can be improved by improving the accuracy of intelligent building data and reducing the data redundancy.

3.2. Fuzzy logic system

Fuzzy Logic System (FLS) consists of three parts: fuzzification, generation of Fuzzy control rules and anti-fuzzification. Fuzzification is to transform the input precise quantity into the output fuzzy quantity, generation of fuzzy control rules is to generate the input fuzzy quantity through reasoning to generate the output fuzzy quantity, and the final anti-fuzzification process is to transform the output fuzzy quantity into the output of precise quantity [9]. The main methods of anti-fuzzification are maximum membership degree method and center of gravity method [10]. Among them, the barycenter method is the most commonly used anti-fuzzification method. The barycenter method is adopted in this paper, and its calculation formula is as follows:

$$a = \frac{\sum_{i=1}^{n} u(a_i) \cdot a_i}{\sum_{i=1}^{n} u(a_i)}$$  \hspace{1cm} (4)

4. Experimental verification

Suppose there are two sensors that satisfy the following linear relationship:

$$\begin{bmatrix} x_1(k + 1) \\ x_2(k + 2) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} u_1(k) \\ u_2(k) \end{bmatrix}$$  \hspace{1cm} (5)

$$\begin{bmatrix} y_{j1}(k) \\ y_{j2}(k) \end{bmatrix} = H_j \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} v_{j1}(k) \\ v_{j2}(k) \end{bmatrix} j = 1, 2$$  \hspace{1cm} (6)

Where: $X_1(k)$ and $X_2(k)$ are the state values of the input signal at time $k$ respectively, and $U_1(k)$ and $U_2(k)$ are Gaussian white noise sequences. [10] The linear relationship between them is uncorrelated, and the mathematical expectation is zero (i.e. $E(Uk)$ is 0). Its covariance matrix is $Q = 0.0212$; $Y_{j1}(k)$ and $Y_{j2}(k)$ are respectively the observation of the system state value of the JTH sensor at time $k$, $V_{j1}(k)$ and $V_{j2}(k)$ are respectively the noise sequence of the JTH sensor, and
\[
\begin{bmatrix}
1 & 0 \\
0 & 1
\end{bmatrix}
\]

H1=H2= is the observation matrix of the two sensors. For the convenience of demonstration, the following formula is used as the performance index of the data fusion algorithm:

\[
d_i = \sqrt{\frac{1}{n} \sum_{k=1}^{n} (x_i(k) - \bar{x}_i(k/k))^2}
\]

(7)

In the above formula, Xi(k) and Xi(k/k) respectively represent the true value and estimated value of the positioning object at time k.

The following table shows the comparison of the mean square error between traditional Kalman filter and dynamic Kalman simulation experiment (as shown in Table 1):

| Mean square error (mse)(di) | d1       | d2       |
|---------------------------|----------|----------|
| Classical Kalman filtering| 0.9231   | 0.9316   |
| Dynamic Kalman filtering  | 0.7148   | 0.7253   |

5. Conclusion

This paper introduces the acquisition method of intelligent building data based on the Internet of Things technology and the accuracy and redundancy problems existing in data fusion. It is learned that the Internet of Things mainly obtains data through sensors and other induction layers, and based on the original traditional Kalman filter fusion algorithm, It is found that the covariance of process noise and observation noise can not be determined in advance, and then the covariance matching fuzzy logic system are introduced to estimate the covariance of the two kinds of noises in real time by increasing the consistency of the theoretical covariance and the actual covariance of the residual. Dynamic Kalman filter is used as a new data fusion algorithm, and the feasibility of this algorithm is verified by simulation experiments, which plays a promoting role in the research of intelligent building data fusion algorithm.

References

[1] Pang Weiqing, He Ning, Li Xiumei, et al. Research on Data Fusion and Adaptive Regulation Methods of Indoor Environment [J]. Control Theory and Application, 2020, 037 (003): 610-619.
[2] Fu Lifang. Construction Quality Monitoring Method of Intelligent Building Measurement Instrument on BIM and GIS [J]. Automation and Instrument, 2020, No. 248 (06): 138-141.
[3] Zhao Kai. Research on Multi-Sensor Information Fusion Algorithm in Greenhouse Intelligent Control [D]. Xi ’ an University of Science and Technology, 2020.
[4] Cheng Mo. Research on Indoor Positioning and Data Fusion Algorithms Based on Machine Learning [D]. University of Electronic Technology, 2019.
[5] Gan Xingwang, Wei Handi, Xiao Longfei, Zhang Binghua. Research on Marine Environmental aware Data Fusion Algorithm Based on Vision [J]. China Shipbuilding, 2021, 62 (02): 201-210.
[6] Zou Dan, Wang Zhe, Ma Xiaoning, Sun Siqi, Wang Peiran. Research on Multi-source Data Fusion Architecture Based on Railway Data Service Platform [J]. Railway Computer Application, 2021,30 (04): 26-30.
[7] Wang Meiyiing. Data Fusion Algorithm for Multi-wireless Sensor Based [J]. Electronic test, 2021 (08): 73-74.
[8] Ge Yu, Du Chunhui, Li Yajie, Zhang Lian. Research on multi-dimensional sensor data fusion algorithm in big data environment [J]. Modern Electronics, 2021, 44 (07): 28-31.
[9] Wang Yan, Lu Hai, Yang Yang, Zhang Xudong, Su Shi. Data Analysis Method of Power Grid
Based on Data Fusion algorithm [J]. Energy-saving technology, 2021, 39 (02): 153-158.

[10] Yin Zihong, Lan Fuan, Jiang Liangwei, Ran Guangjiong, Wang Xueling. Research on multi-data integration and fusion method based on BIM+GIS [J]. Science and Technology Innovation, 2021 (04): 70-72.