A Low Energy Consumption Multi-sensor Data Fusion Method for Fan Coil Unit Thermal Performance Test

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Abstract. The multi-sensor network can acquire and analyze the thermal performance data of fan coil unit and other building systems in real time by means of low energy and high precision sensing technology. It is necessary to compress the thermal data in the data transmission process. Aiming at the data fusion process applied to the thermal performance test system of fan coil unit, a new SMART-RR algorithm with low energy consumption data fusion is proposed. Considering the existence of cyclic repeatability and data redundancy, a time interval data fusion strategy of adding repeatability reduction factor is bedded in the algorithm. The simulation results show that the SMART-RR algorithm is a low energy consumption data fusion algorithm with low data communication volume and high accuracy.

Keywords: Multi-sensor network · Data fusion · Thermal performance test
Low energy consumption · Repeatability reduction

1 Introduction

The fan coil unit consists of fans, coils and filters. It is used as an end device for the air conditioning system. It is distributed in each air-conditioned room and can be treated independently for air. The hot and cold water required for air treatment by the air conditioning room focused on the preparation, through the water supply system to provide the fan coil unit. At present, most of the parameters of the fan coil system are used to cooperate with each other, and the multi-sensor data fusion is needed after acquiring the data.

Multi-sensor data fusion is a combination of data from multiple sensors, and this method could estimate the value of the measured parameters more accurately compared to the data measure method using only a single sensor, but there is still a lot of research work should be applied on the reliability of measurement data [1, 2]. The key

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technologies of data fusion are data conversion, data correlation, database and fusion computing, among which fusion computing is the core technology of multi-sensor data fusion system. The general data fusion method is based on the basic principle of data statistics according to the data collected by each sensor to determine the confidence interval of each sensor matrix, and then uses the threshold to measure the degree of correlation between the sensors, but the threshold point to determine the sensor mutual support is a big ambiguity [3–5].

The thermal performance test system of fan coil units is the basis and support for teaching, testing and engineering testing of many disciplines such as construction engineering, environment and energy engineering, and there are many universities and research institutes have built fan coil performance test platform of different scales with corresponding test and control software system. In this paper, the data processing requirements of the thermal performance test system of fan coil are studied, discusses how to extract the multi modal data collected by multi sensor network, and proposes a data fusion method of fan system based on Bayesian network model and inference algorithm.

2 Fan Coil Thermal Performance Test System

There has a number of universities and research institutes have built different scale fan coil performance test platforms with the appropriate test and control software systems. In this paper, based on the original relevant test platform, re-build a complete set of fan coil performance test platform for teaching and research work. The fan coil performance test system topology is shown in Fig. 1.

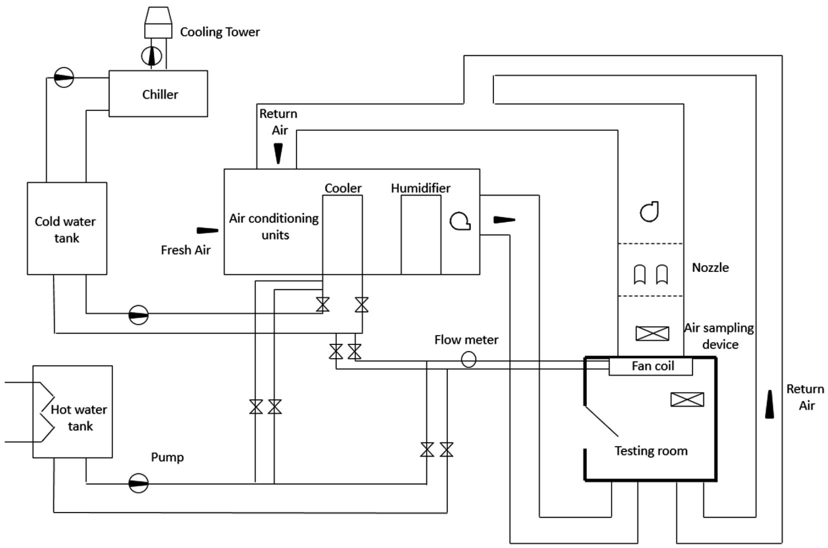

Fig. 1. Fan coil performance test system topology.

2.1 Low Energy Consumption Sensor Node

In the practical application of thermal performance test of fan coil, usually distributes and collects data with low energy and high precision sensor nodes.

First, each sensor node collects the test system thermal performance data with energy-constrained, and the energy consumption of the sensor nodes must be strictly controlled to extend the lifetime of the entire sensor network [6]. The energy of the sensor nodes in the thermal performance test system of the fan coil is mainly consumed in the network communication process, so it is necessary to minimize the data traffic and data redundancy between the sensor nodes.

Secondly, due to the external environment, such as electromagnetic interference, the sensor nodes should collect the data often accompanied by a variety of noise signals, witch reduce the accuracy of the obtained thermal performance data and integrity.

2.2 Data Acquisition Process Based on Multi-sensor Network

Fan coil performance test system is designed for independent design, build the fan coil performance test platform for research and development, and data acquisition Agilent-34970A, digital power meter Yokogawa-WT310 and other hardware work together to collect test room in the fan disk pipe, air conditioning unit inlet and outlet temperature, humidity, pressure, water flow and other technical parameters, real-time record of the node's test data, and through the software system to calculate the corresponding cooling/heating performance indicators.

The thermal data in the fan coil performance test platform is mainly collected by the Agilent 34970A data acquisition and YOKOGAWA WT310 digital power meter. The data interface is connected with the computer supporting the test platform, and the collected test platform thermal data is transmitted to Client application system, that is, the project development of the fan coil performance test system V1.0. The software system can complete the test condition parameter setting, the data record, the test platform real-time monitoring, the data computation processing and the test report generation and the printing function. A fan coil performance test system consisting of a data collector, a digital power meter, a matching computer, and a client application system.

3 Low Energy Data Fusion Method Based on Reproducibility Reduction

Fan coil performance test system in a variety of sensor nodes to obtain fan coil system thermal performance data through the tree sensor network layer by layer upload and fusion, data transmission traffic and encryption and decryption mechanism affect the thermal performance data privacy protection And sensor network energy consumption. In this paper, the sensor network is abstracted into a tree network with three layers. A data fusion algorithm based on repetitive protocol factor is proposed, and the data traffic is reduced by key distribution mechanism.

3.1 Data Fusion Model Based on Tree Structure

The sensor network may be represented by a connected directed graph $G(V, E)$, where the vertex $v(v \in V)$ represents the node in the sensor network and the directed arc $e(e \in E)$ represents the data transmission link between the nodes. A typical sensor network typically consists of three types of nodes: (1) a leaf node consisting of a variety of sensors for collecting and transmitting thermal data from the system; (2) a fusion node, the data transmission node undertaking to collect system thermal data and data fusion (3) QS (Query Server) node, the data analysis node is responsible for the final fusion analysis of the data [7].

The three types of nodes form a tree structure, where the QS node obtains the data fusion result as the root node and provides the basis for further thermal data analysis. The fusion node is responsible for receiving the data from the leaf node and converging the calculation to the root node, the leaf node acquires a variety of modal thermal data and upload to the corresponding node, based on the tree structure of the data fusion process is one-way transmission.

The data fusion function structure currently used in the sensor network can be expressed as the formula (1):

$$f(t) = \theta(d_1(t),\ \ldots, d_n(t)) \tag{1}$$

where $d_i(t),\ (i = 1, 2,\ \ldots, n)$ is the data collected by node i at time t, and operator θ represents the fusion calculation factor, such as count, average, max, min, sum function.

As a sensor network in the field of energy measurement applications, the fan coil performance test system to collect the transmission of thermal data has a certain periodicity characteristics. It can consider the characteristics of the above fields in the design of the data fragmentation and transmission strategy of the sensor network, compress the processing of a large number of periodic data, and collect the change data, thus reducing the data traffic of the sensor network. This paper proposes a data fusion function based on unequal time interval as shown in Eq. (2):

$$f'(t) = \theta(d_1(\Delta t_1),\ \ldots, d_n(\Delta t_n)) \tag{2}$$

where $d_i(\Delta t_i)$ $(i = 1, 2,\ \ldots, n)$ is the data collected by the node i in the Δt_i time interval and $t = [\Delta t_1,\ \ldots, \Delta t_n]$ is the minimum common time period for all node data acquisition time intervals. For periodically significant thermal data, the time interval can be set relatively long, and remove some of the repeated data, which can reduce the data traffic, improve data fusion efficiency.

3.2 Data Fusion Algorithm Based on Reproducibility Reduction Factor

Based on the SMART series algorithm, this paper proposes a data fusion algorithm based on the repetitive reduction factor for the sensor network application.

Data encryption and decryption uses a random key allocation strategy: a key pool containing K keys is generated, and k ($k < K$) keys are randomly selected; nodes in the sensor network send messages to determine which nodes are assigned the same key, A node with the same key thinks that a data transmission link can be established. If the parent and child nodes in the tree structure are not allocated to obtain the same key, the transmission link can be established by hop-by-hop. As can be seen from the key distribution strategy, if the listener takes the same key distribution scheme, the probability of data being eavesdropped in the sensor network is $p = k/K$. In general, the number of keys in the key pool is set relative to each other, thereby reducing the probability of data being eavesdropped in the sensor network.

The basic structure of the algorithm consists of three main steps: (1) each node divides the collected data into J slices, where $J - 1$ slices are sent to $J - 1$ nodes randomly selected from neighboring node sets; (2) the node receives the fragment data and decrypts it with the shared key; (3) uses the TAG algorithm to carry on the data fusion. Some of the modal data in the sensor network have significant periodic repeatability [8]. The SMART-RC algorithm with repetitive reduction factor is used to divide the data acquisition and transmission time interval into different time slices according to different modal data., And the time slice of the cycle of repetitive data to reduce the amount of data traffic to reduce the sensor network energy consumption.

4 Analysis of Results

In order to verify the performance of the SMART-RR algorithm based on the repetitive convention factor proposed in this paper, we compare the data traffic and accuracy from the data and compare the SMART-RR algorithm with the TAG algorithm and SMART algorithm.

4.1 Data Communication Volume

The data traffic used in the sensor network data fusion algorithm mainly includes node fragment data transmission traffic and data fusion traffic. Data fusion communication is directly related to the network size, that is, the sensor network structure and the number of nodes to determine the data fusion communication fixed. Therefore, the comparison of SMART-RR algorithm and SMART algorithm node data communication volume, which is based on data fragmentation data fusion algorithm, the main communication volume overhead. TAG, SMART, SMART-RR three methods of data traffic shown in Fig. 2, where J is 3.

It can be seen from the simulation results that the data communication volume of SMART and SMART-RR algorithm is smaller than that of TAG algorithm due to the addition of data fragmentation strategy, and because SMART-RR has a certain reduction operation on the existence of repetitive data, data communication volume is further compressed. The relationship between the number of slices and the data communication volume of SMART-RR algorithm is further analyzed. From the simulation results of Fig. 3, it can be seen that the data traffic increases first and then decreases with the increase of J.

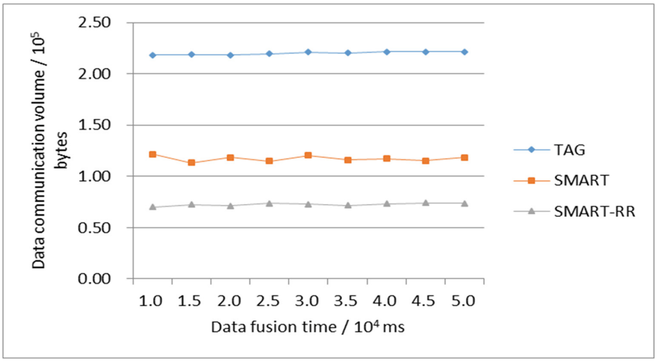

Fig. 2. Data communication volume of TAG, SMART and SMART-RR algorithm

Fig. 3. Data communication volume changes of SMART-RR with the number of slices

4.2 Measurement Accuracy

The SMART-RR algorithm and SMART algorithm proposed in this paper are based on SUM function data fusion calculation [8, 9], the definition of data accuracy is:

$$ma = |D_{QS}|/|\sum D_i| \tag{3}$$

where $|D_{QS}|$ is the amount of data for the root node after fusion, and $|\sum D_i|$ is the amount of raw data collected by all sensor nodes. As shown in Fig. 4, the data accuracy of the SMART-RR algorithm is more sensitive to the number of slices: when $J \geq 5$ the accuracy is significant improved, and the accuracy tends to be stable when $J \geq 8$.

From the simulation analysis of the algorithm data traffic and accuracy, it can be seen that the setting of data segment J in SMART-RR algorithm directly affects the performance of the algorithm, and it should be selected in the practical application according to the specific requirements such as privacy protection.

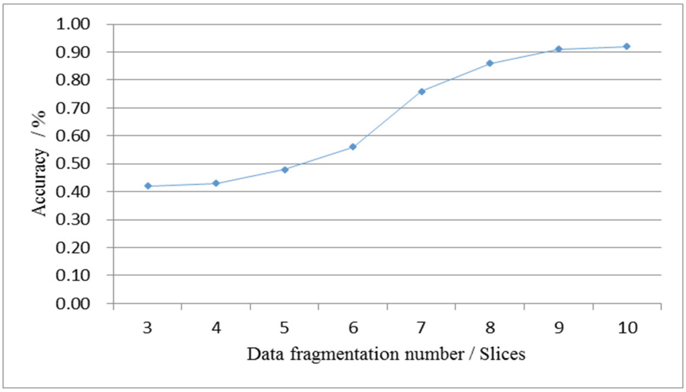

Fig. 4. The accuracy of the SMART-RR algorithm varies with the number of slices

5 Conclusions

In this paper, a data fusion algorithm based on repetitive reduction factor is proposed for the data fusion and analysis of sensor networks used in the thermal performance test system of fan coil. It is possible to carry out data for data with dynamic repetition of data cycle Compression, thereby reducing the sensor node data traffic and energy consumption, to extend the sensor network survival time. The performance of the algorithm in data traffic and accuracy is verified by simulation experiment and comparison, which has certain advantages in the field of data acquisition and application of sensor network compared with the same type of algorithm. Further work could study other data fusion strategies and algorithms to collect more practical case analysis algorithm application value.

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