True Value Estimation of Centrifugal Fan Vibration Data Based on Fusion Method

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***Abstract*—Poor information means incomplete and insufficient information, such as unknown probability distributions and trends. In this case, many statistical methods may become ineffective. So a fusion method based on the information poor theory is proposed. The fusion method contains five methods, three concepts, and one rule. The five methods include the rolling mean method, the membership function method, the maximum membership grade method, the moving bootstrap method, and the arithmetic mean method. The three concepts comprise the solution set on the estimated true value, the fusion series, and the terminal estimated true value. The rule is the range rule. The centrifugal fan vibration data is evaluated using the above methods and theory. The experimental investigation shows that the fusion method is effective in evaluating true value with small sample sizes without any prior information of the probability distribution.**

***Index Terms*—Information Fusion; Point Estimation; Data Series; Small Sample; Information Poor System**

I. Introduction

Point estimation method is a vital issue in data processing. Classical statistics can only assess the true value of data under the condition of large sizes and known probability distributions [1-3]. Commonly, the poor information technique expectation or the arithmetic mean in statistics can be employed to evaluate the true value in the condition of small sample sizes or unknown probability distributions [4-6].

As one of universal machines, centrifugal fans have been broadly used in lots of departments of the national economy, such as cement stove ventilating system, mile ventilating system and so on. Centrifugal fan is important auxiliary equipment in many companies. The research of vibration problem is very important for the centrifugal fan with high rotating speed. To warrant their safe and reliable operation for the centrifugal fan, their state of vibration has to be monitored and analyzed. Li [7] introduced one method to monitor the vibration data processing based on wireless sensor networks. Zhou [8] used numerical optimization technique to reduce the vibration and noise of centrifugal fan volute. The article is to evaluate the true value of centrifugal fan vibration data series using point estimation method based on poor information.

Nevertheless, in areas of science and technology research process, much problems are characterized by small sizes data or unknown probability distributions because of high cost in trail or other difficulties. For example, we can't get much centrifugal fan vibration data because of high cost. Accordingly, in this condition, point estimation is reckoned as a difficult research task. Luckily, with the development of the poor information theory such as grey system theory, it is possible to evaluate the true value with the help of fusion technique [9-16].

At present, parameter estimation and analysis for poor information system is one of the hot research program in the area of information technique science [1, 9]. Most published article focus on the research areas. For instance, Ah-Pine Julien [11] researched the fusion technique for information retrieval on the basis of different aggregation operators, Zhi [12] made a damage effect assessment for battlefield target using the multiple neural network fusion algorithms, Wu [14] researched oil quality evaluation system using multi-information fusion method, and Xia [17] evaluated the bearing data series using fusion knowledge. Zhu [18] developed one new method to deal with data fusion based on improved D-S theory.

The available methods for information evaluation and analysis are based on the distribution characteristics of one data series. Although these techniques can be used to deal with information fusion, different methods have different results under different rules. This does not mean that one information evaluation method is better than another. It just shows that this method may be better for one certain data series, but the other information evaluation method may be better for another data series [19]. From this we can get the message that we can't receive the comprehensive information of one data series only using single information evaluation method. Because one method can only reflects single character of a data series with poor information. In this condition, we must use more than one method to evaluate the data series. In the article five methods, three concepts, and one

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rule were used to evaluate the centrifugal fan vibration data. Based on this, the character of centrifugal fan vibration data can be comprehensively analyzed and evaluated under the condition of poor information.

II. Concept of Fusion Method

In the true value analysis, so far as the data series of centrifugal fan vibration with small trail information is concerned, various methods should be utilized in order to get more varied information that can be used to describe the characteristics of centrifugal fan vibration data series from more aspects. Because different methods own different rules, so the characteristic information obtained from the data series is also different.

Suppose the centrifugal fan vibration data series, that is to say, a small sample of size N, outputted by a population, can be written by

$$X = (x(1), x(2), \cdots, x(t), \cdots, x(N)); \quad t = 1, 2, \cdots, N; N > 2 \tag{1}$$

where t is called the sequence number of centrifugal fan vibration data series, $x(t)$ is called the tth data in the centrifugal fan vibration data series X, and N is called the number of the data.

It must be indicated that based on the poor information theory, N can be a small sample series and the probability distribution of data series X can be unknown.

The two definitions are listed in the following.

Definition 1: Suppose using L methods to evaluate the true value of centrifugal fan vibration data series. It is written as

$$X_0 = (X_{01}, X_{02}, \cdots, X_{0l}, \cdots, X_{0L}); \quad l = 1, 2, \cdots, L \tag{2}$$

where X_0 is named the solution set and X_{0l} is named the lth estimated true value acquired according to the lth method in mathematics.

The solution set is not the terminal fusion solution to the centrifugal fan vibration data series. It is only a set on the varied characteristic information of the data series.

Definition 2: Fusion for the multiple estimated true value means that a new value which is closely related with the set X_0 can be obtained from a special method of mathematical treatment. This new value is the terminal solution X_{0True} according to the rule Θ, which is written by

$$X_{0True} \left|\Theta\right| Fusion X_0 \subseteq A_{True} \tag{3}$$

where X_{0True} is the terminal solution that is an estimation for the true value of the data series, that is to say, the terminal estimated true value; A_{True} is the true value set on the varied attributes of the data series; symbol |Θ in accord with the rule Θ; symbol |Fusion X_0 means that X_0 is fused according to the L methods in mathematics; and symbol $X_0 \subseteq A_{True}$ imply that X_0 is included in A_{True}.

Fusion technique for the true value, in fact, is that through the mathematical treatment of the solution set X_0 mentioned above, a finally fusion true value is acquired, which is the terminal estimation for the true value of the character of the data series.

Just as mentioned in Definition 1, L methods are used to evaluate the true value on the basis of poor information theory. The poor information theory is usually used to deal with a data series with poor information such as small sample sizes or unknown probability distributions. The theory used in processing poor information data is different from classical statistics. With the development of the poor information theory, some knowledge can be used to deal with this condition. For instance, the theories such as grey system theory, the fuzzy set theory, the bootstrap method, the Bayesian statistics, and the chaotic theory belong to the category of the poor information theory. In point estimation, many methods and theories can be employed to evaluate the true value for the poor information data series. On the basis of available knowledge, this paper brings the five methods, as listed in Table 1, which are used for fusion of the true value of the mentioned centrifugal fan vibration data series.

TABLE I. Main Method Used in Pooy Information Theory

No. l	Method	Remark
1	Rolling mean method	Variation of weighted average method
2	Membership function method	Method derived from fuzzy set theory
3	Maximum membership grade method	Method derived from fuzzy set theory
4	Moving bootstrap method	Variation of bootstrap methodology
5	Arithmetic mean method	Method derived from statistical theory

The steps to use the fusion method listed in table 1 for the multiple estimated true values are shown as follows:

1. A rule, written by Θ, is chosen, that is usually a convergence criterion.
2. A raw data series X outputted by a population such as centrifugal fan vibration data series discussed in the article is obtained (see (1)).
3. The estimated true values X_{0l}, where l=1,2,…,5, is copulated by means of the lth method listed in Table 1.
4. The solution set X_0 is formed in accord with (2).
5. The terminal solution X_{0True} according to the rule Θ is obtained with the five methods listed in Table 1.

III. Five Method for True Value Estimated

There are many theories for point estimation in statistics technology, each of which can be used to evaluate the true value of data series, but not all the methods are suitable to analyze a poor information system such as unknown probability distributions because of their requirements for prior information. For instance, the Bayesian method requires prior distribution information, the maximum-likelihood method needs known probability distribution information, and the histogram method is based on a large number of data series. On the condition, the five methods listed in Table 1 may be better to deal with the problem of poor information such as a small data size or unknown probability distribution.

Based on the theory of poor information, the number of methods used in data estimation can be from 4 to 6. In the article, five methods are used in data fusion processing.

The five data fusion methods mentioned in Table 1 is explained in detail below.

A. Rolling Mean Method Discuss

The 1st introduced method is rolling mean method. It derived from bootstrap technique. The detail calculation process is shown in formula (4)-(6).

Rearrange the data series $x(t)$ taken from the formula (1) from small to large to form a new order as shown in below:

$$x_i \le x_{i+1}; i = 1, 2, \cdots, N-1 \tag{4}$$

An estimated true value of the data series is defined in formula (5).

$$X_{01} = \sum_{j=1}^{N} \omega_j x_j = \frac{1}{N} \sum_{j=1}^{N} \xi_j \tag{5}$$

With

$$\xi_j = \frac{1}{N-j+1} \sum_{j=1}^{N-j+1} \sum_{k=i}^{i+j-1} \frac{x_k}{j}; j = 1, 2, \cdots, N \tag{6}$$

where X_{01} is called the 1st estimated true value of the data series, ω_j is the weight of the data x_j, and ξ_j is the jth factor of the rolling mean.

B. Membership Function Method Discuss

The 2nd introduced method is membership function method. It derived from membership function which belongs to fuzzy set theory.

By means of (1) and (4), define the difference sequence of centrifugal fan vibration data series as

$$d = (d_1, d_2, d_i \cdots, d_{N-1}) \tag{7}$$

with

$$d_i = x_{i+1} - x_i \ge 0; i = 1, 2, \cdots, N-1 \tag{8}$$

where d_i is named the difference between x_{i+1} and x_i, the difference value for short.

According to the possibility theory, X in the formula (1) can be reckoned as an event. The smaller the difference value d_i is, the thicker the distribution of the data x_i is, expressing that the possibility of the event in the interval $[x_i, x_{i+1}]$ is likely to be larger. The larger the difference value d_i is, the thinner the distribution of the data x_i is, expressing that the possibility of the event in the interval $[x_i, x_i+1]$ is likely to be little. From this we get the message, the difference value d_i is closely related to the distribution density. Accordingly, define the linear membership function f_i as

$$f_i = 1 - \frac{d_i - d_{\min}}{d_{\max}}; i = 1, 2, \cdots, N-1 \tag{9}$$

with

$$d_{\min} = \min_{i=1}^{N-1} d_i \tag{10}$$

and

$$d_{\max} = \max_{i=1}^{N-1} d_i \tag{11}$$

where $d_{\min}$ and $d_{\max}$ are named the minimum difference value and the maximum difference value respectively.

Set the immediate neighbor mean series as

$$Z = (z_1, z_2, \cdots, z_i, \cdots, z_{N-1}) \tag{12}$$

with

$$z_i = \frac{1}{2}(x_{i+1} + x_i); i = 1, 2, \cdots, N-1 \tag{13}$$

where z_i is called the ith immediate neighbor mean.

An estimated true value of the data series is defined as

$$X_{02} = \frac{1}{\sum_{i=1}^{N-1} f_i} \sum_{i=1}^{N-1} f_i z_i \tag{14}$$

where X_{02} is called the 2nd estimated true value.

It can be gotten the message from the formula (9)-(14) that the membership function method also belongs to the weighted average method which has the varying weight sequence formed by the membership function f_i. And the smaller the difference value d_i is, the larger the weight of the ith immediate neighbor mean z_i is.

C. Maximum Membership Grade Method Discuss

The 3rd introduced method is maximum membership grade method. It derived from maximum membership grade which belongs to fuzzy set theory.

From the formula (9), set the maximum membership grade $f_{\max}$ be

$$f_{\max} = \max_{j=1}^{N-1} f_j = 1 \tag{15}$$

Define the mean of the two data x_{v+1} and x_v according to the maximum membership grade $f_{\max}$ as an estimated true value of the data series, which is shown as follows:

$$X_{03} = \frac{1}{2}(x_{v+1} + x_v); v \in (1, 2, \cdots, N-1) \tag{16}$$

If there are T repeated maximum membership grades, set the τth mean be

$$X_{0\tau} = \frac{1}{2}(x_{v+1} + x_v)_\tau; \tau = 1, 2, \cdots, T-1 \tag{17}$$

An estimated true value of the data series is defined as bellow

$$X03 = \frac{1}{T-1} \sum_{\tau=1}^{T-1} x_{0\tau} \tag{18}$$

where τ is the position of the τth data according to the maximum membership grade principle.

The method of maximum membership grade is an unusual mean method, in which the mean of the several data, in common the two data, only according to the minimum difference value $d_{\min}$ (see (10)) are used to compute the estimated true value.

The cause for only using the several data is that they are closely related to the true value corresponding to the rule of the maximum membership grade from the fuzzy set theory. Based on the theory discussed above, the smaller the minimum difference value $d_{\min}$ is, the better the several data meet to the true value, implying that the relative error between the true value and the estimated true value is likely to be small. The larger the minimum difference value $d_{\min}$ is, the worse the several data meet to the true value, implying that the relative error between the true value and the estimated true value is likely to be large.

D. Moving Bootstrap Method Discuss

The 4th introduced method is moving bootstrap method.

For the convenience, a data series is represented as a vector, thus (1) is denoted by

$$X = \{x(t); t = 1, 2, \cdots, N\} \tag{19}$$

In the formula (19), the sequence number t can be also considered as the time t. This is not related to the result estimated for the true value.

In the process of measurement, the problem researched using moving bootstrap method is an estimation of the true value. The parameter m is a very small integer, the larger the value m is, the larger the errors estimated for the true value is. Based on the theory of bootstrap method, the value of the parameter m is less than or equal to N.

At the time t, the m data taken from the series X can build a sub-series X_m, which is shown as follows:

$$X_m = \{x_m(u)\}; u = t-m+1, t-m+2, \cdots, t; \quad t \geq m \tag{20}$$

where u in the above formula is the time.

Based on the principle of bootstrap method, B simulation samples of size m, that is to say the bootstrap resampling samples, can be acquired by an equiprobable sampling with replacement from (20), which is shown as follows:

$$Y_{Bootstrap} = (Y_1, Y_2, \cdots, Y_b, \cdots, Y_B) \tag{21}$$

with

$$Y_b = \{y_b(u)\}; b = 1, 2, \cdots, B \tag{22}$$

where Y_b is called the bth bootstrap sample, $y_b(u)$ is called the uth bootstrap resampling sample within Y_b and B is called the number of the bootstrap resampling samples.

The mean of Y_b is written by

$$y_{mb} = \frac{1}{m} \sum_{u=t-m+1}^{t} y_b(u); t = m, m+1, \cdots, N \tag{23}$$

Thus at the time w=t+1, a sample of size B can be acquired, which is shown as follows:

$$X_{mw} = \{y_{mb}(w)\}; b = 1, 2, \cdots, B; w = t+1 \tag{24}$$

From the formula (24), a probability function can be acquired, which is shown as follows:

$$F_{wB} = F_{wB}(x_m) \tag{25}$$

Based on the histogram principle derived from statistics theory, the true value at the time w can be calculated by a weighted mean, which can be shown as follows:

$$X_{04}(w) = \sum_{q=1}^{Q} F_{wBq} x_{mq} \tag{26}$$

where X_{04} (w) is called the estimated true value at the time w; Q is called the number of groups; q is called the qth group, q=1,2,…, Q; x_{mq} is called the median of the qth group; F_{wBq} is called the value of the bootstrap probability at the point x_{mq}.

The estimated true value of the data series is defined as

$$X_{04} = \frac{1}{N-m+1} \sum_{k=m}^{N} X_{04}(k) \tag{27}$$

E. Arithmetic Mean Method Discuss

The 5th introduced method is arithmetic mean method. It is also one of the most commonly used methods for point estimation. This method is characterized by the equal weight means.

An estimated true value of the data series is defined as

$$X_{05} = \frac{1}{N} \sum_{t=1}^{N} x(t) \tag{28}$$

It is easy to see that the character of the five methods discussed above is different from each other. Generally, they can be used to get five different kinds of feature information of the data series from calculating the raw data series X, setting the foundation for the fusion method for the estimated true values.

IV. Method of Fusion for True Value

In order to analyze the terminal evaluation result, the solution set X_0 acquired using the above discussed five methods can be considered as a data series. It can be defined as the 0th fusion series, just as follows:

$$\begin{aligned} X_{0Fusion0} &= (X_{01F0}, X_{02F0}, \cdots, X_{0lF0}, \cdots, X_{0LF0}) \\ &= (X_{01}, X_{02}, \cdots, X_{0l}, \cdots, X_{0L}) \end{aligned} \tag{29}$$

with

$$X_{0lF0} = X_{0l} \tag{30}$$

where X_{0lF0} is called the lth fused true value obtained using the lth method discussed above to generate the centrifugal fan vibration data series X.

The 0th fusion data series $X_{0Fusion0}$ is fused using the five methods discussed above and then a new data series, which is named the 1st fusion data series $X_{0Fusion1}$, is generated, which is shown as follows:

$$X_{0Fusion1}=(X_{01F1},X_{02F1},\cdots,X_{0lF1},\cdots,X_{0LF1}) \tag{31}$$

where X_{0lF1} is the lth fused true value with the help of the lth method to generate the 0th fusion series $X_{0Fusion0}$.

The 1st fusion series $X_{0Fusion1}$ is fused using the five methods discussed above and then a new data series, which is named the 2nd fusion data series $X_{0Fusion2}$ is generated, which is shown as follows:

$$X_{0Fusion2}=(X_{01F2},X_{02F2},\cdots,X_{0lF2},\cdots,X_{0LF2}) \tag{32}$$

where X_{0lF2} is the 2nd fused true value obtained according to the lth method to generate the 1st fusion series $X_{0Fusion1}$.

Using the same method discussed above, the jth fusion series $X_{0Fusionj}$ can be calculated, which is shown as follows:

$$X_{0Fusionj}=(X_{01Fj},X_{02Fj},\cdots,X_{0lFj},\cdots,X_{0LFj});\ j=1,2,\cdots \tag{33}$$

where X_{0lFj} is the jth fused true value obtained according to the lth method to generate the j-1th fusion series $X_{0Fusionj\text{-}1}$.

If the jth fusion series $X_{0Fusionj}$ is consistent with the given rule Θ, the terminal estimated true value X_{0True} is obtained.

Rule 1: Define the range as

$$\delta_j=\max_{l=1}^{L}X_{0lFj}-\min_{l=1}^{L}X_{0lFj} \tag{34}$$

If the range $\delta_j \leqslant \varepsilon$ where ε is an arbitrarily small plus number, the terminal estimated true value X_{0True} is acquired by

$$X_{0True}=\frac{1}{L}\sum_{l=1}^{L}X_{0lFj} \tag{35}$$

The above is the rule Θ. It is named the range rule and, in fact, is a convergence standard, in which the estimated true values tend to a point, which is the true value.

V. Experimental Investigation and Calculation Method

The experiment is done in order to ensure the reliability of the method discussed in the article. The main thoughts of the plan are shown as follows:

1. Receiving conventional true value

From the experiment, lots of centrifugal fan vibration data must be monitored in order to obtain the conventional true value. These data generate a data series, viz., a large number of sizes N_{Test}, which is named the testing data series, written by X_{Test}. With the help of the five methods listed in Table 1 to form the testing series, the five estimated true values, denoted by X_{m01}, X_{m02}, X_{m03}, X_{m04}, and X_{m05}, respectively, corresponding to the large sample size, can be acquired.

Based on the principle of large numbers of data series and the central limit theorem derived from classical statistics, each of the five true values estimated above should be equal or close to a fixed value called the mathematical expectation E_m because of the large data sizes, that is to say, the five estimated true values should be equal to each other in theory. But the difference always appears among them, this is because much interference and the additional uncertainty exist in the process of measurement or experiment. Based on the statistical theory and the error theory, suppose the difference is very small, the mean of the five true values based on the large data size can be regarded as closing to the mathematical expectation E_m and can therefore be considered as a conventional estimated true value X_{True}, viz., which is shown as follows:

$$X_m=\frac{1}{5}\sum_{l=1}^{5}X_{m0l}=X_{True}\subseteq A_{True} \tag{36}$$

where X_m is the mean of the five estimated true values based on the large data size, the mean for short, and X_{True} is the conventional true value.

2. Making small sample

Select the former N data from the testing series X_{Test} as the raw data series X (see (1)), where N is called the number of data in X and is a very small integer for the condition of the small sample size. As a rule, the range of N is from 3 to 10 corresponding to the poor information theory.

3. Obtaining the terminal estimated true value

By means of (1)-(35), the terminal estimated true value X_{0True} is acquired. It is the calculation for the true value of the testing series X_{Test}.

4. Testing estimated result

The relative error E_R of calculation can be used for testing the estimated result, which is shown as follows:

$$E_R=\left|\frac{X_{0True}-X_{True}}{X_{True}}\right|\times 100\% \tag{37}$$

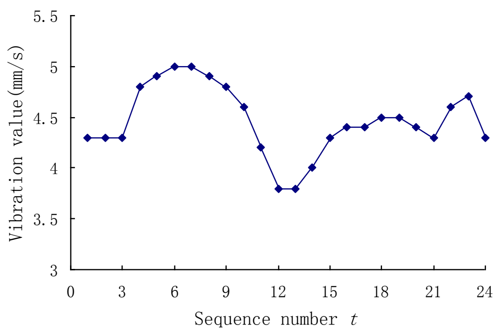

Figure 1. Centrifugal fan vibration data series acquired from experimental investigation

A. Testing Series for Centrifugal Fan Vibration Data

The experimental investigation deals with information of the vibration parameters of the centrifugal fan. As shown in Fig. 1, one testing series is obtained in the experimental investigation, which has 24 data.

B. Conventional True Value Based on Large Sample Size

As discussed above, the mean value X_{m} can be used to show the conventional true value X_{True} under the condition of the large data sizes. Based on this and regarding the 24 data as a large sample of size N_{Test}=24, the five true values can be estimated using the five methods listed in Table 1, respectively. The calculation results are shown in Tables 2.

It can be seen from Table 2 that for centrifugal fan vibration based on the large data size, the five estimated true values take values in the range from X_{m03}=4.45384mm/s to X_{m02}=4.48823mm/s, only with a very small difference between X_{m03}=4.45384mm/s and X_{m02}=4.48823mm/s (the relative error is only 0.77%). The mean of the five estimated true values in Table 2 is equal to 4.46772mm/s. It can be considered as the conventional true value X_{True} of the centrifugal fan vibration.

TABLE II. ESTIMATED TRUE VALUE OF INFORMATION OF CENTRIFUGAL FAN VIBRATIN BASED ON LARGE SAMPLE OF SIZE N_{TEST}=24

No. l	Methods	Estimated true value X_{mol}(mm/s)
1	Rolling mean method	4.46418
2	Membership function method	4.48823
3	Maximum membership grade method	4.45384
4	Moving bootstrap method	4.46986
5	Arithmetic mean method	4.46249

C. Evaluation of Information of Centrifugal Fan Vibration Based on Small Sample Size

From Fig. 1, select the former 5 data (viz., a small sample of size N=5) in the testing series X_{Test} about the centrifugal fan vibration as the raw data series X=(4.3, 4.3, 4.3, 4.8, 4.9). Using the five methods listed in Table 1 to form the centrifugal fan vibration data series X, the calculation results are shown in Table 3.

TABLE III. ESTIMATED TRUE VALUE OF INFORMATION OF CENTRIFUGAL FAN VIBRATION BASED ON SMALL SAMPLE OF SIZE N=5

No. l	Methods	Estimated true value X_{mol}(mm/s)	Relative error E_R(%)
1	Rolling mean method	4.50355	0.8
2	Membership function method	4.45714	0.24
3	Maximum membership grade method	4.3	3.75
4	Moving bootstrap method	4.51947	1.16
5	Arithmetic mean method	4.52	1.17

It is easy to find from Table 3 that the five results are different from each other. The range of estimated true value is from 4.3mm/s to 4.52mm/s. And the minimum and the maximum of the relative errors are 0.24% and 3.75% respectively.

Based on the definition 1, the solution set X_0 can be gotten from the estimated true value X_{0l} in Table 3, viz., X_0= (4.50355, 4.45714, 4.3, 4.51947, 4.52).

It is to be noted that the solution set X_0 acquired according to the five methods discussed above is not the terminal solution to the problem. It is only a set on the varied characteristic information of the data series. In order to acquire the terminal estimation result, let the 0th fusion series be $X_{0Fusion1}$= X_0. Then processing the 0th fusion series $X_{0Fusion0}$ according to the rolling mean method, the 1st fused true value 4.46822mm/s can be acquired. Processing the 0th fusion series $X_{0Fusion0}$ according to the membership function method, the 2nd fused true value 4.50604mm/s can be acquired. Processing the 0th fusion series $X_{0Fusion0}$ according to the maximum membership grade method, the 3rd fused true value 4.51973mm/s can be acquired. Processing the 0th fusion series $X_{0Fusion0}$ according to the moving bootstrap method, the 4th fused true value 4.46822mm/s can be acquired. Processing the 0th fusion series $X_{0Fusion0}$ according to the arithmetic mean method, the 5th fused true value 4.46003mm/s can be acquired.

These five fused true values above can form the 1st fusion series $X_{0Fusion1}$=(4.46822, 4.50604, 4.51973, 4.46822, 4.46003).

In the same way, many fusion series are acquired successively. Let ε=0.001, based on Rule 1, the terminal estimated true value can be gotten.

VI. DISCUSSIONS

Just as described above, the fusion method introduced in the article includes three approaches. First, for a raw data series such as centrifugal fan vibration data series outputted by a population, the solution set structured with different estimated true values is acquired from different properties with different methods. Second, a chain of the fusion series composed of the fused true values is formed with different methods to process repeatedly the fusion series. Finally, the terminal estimated true value is accepted according to the range rule, which is the appropriate estimation for the true value of the population.

It can be seen from the Tables 2, under the condition of large number of data sizes (such as the 24 centrifugal fan vibration data series), the five results calculated using the five methods listed in Table 1 are close to each other in numerical value. But it can be seen from the Tables 3, under the condition of small data sizes (only with the five data choosing from the former centrifugal fan vibration data series X), the difference among the five results is large. This means that the five methods in Table 1 are effective under the condition of large samples (for example as many as 24 data), but they are likely to be ineffective under the condition of small samples (for example as few as five data).

Besides this, when the true value is estimated under the condition of small data series and unknown probability distributions, if the fusion method is used in estimation, the maximum of the relative errors is commonly small, on contrary, if only one method is used, the maximum of the relative errors is commonly large.

Just as mentioned above, the fusion method used above is good at solving the problem on both very small data series and unknown probability distributions.

VII. CONCLUSIONS

The fusion method discussed above can be used to solve the problem such as the number of centrifugal fan vibration data to be very small or unknown probability distribution.

Generally speaking, comprehensive thinking of using various methods mentioned above to solve the poor information of centrifugal fan vibration data series can depict the true value from different sides; the fusion method mentioned above is able to calculate the terminal estimated true value which can represent the true value from different aspects for the poor information system.

The estimation method used in centrifugal fan vibration data processing is able to deal with some other poor information data series.

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