IOP Conf. Series: Materials Science and Engineering **439** (2018) 032079 doi:10.1088/1757-899X/439/3/032079

Implementing the Distribution and Application of EMD Algorithm Based on TRIZ Theory

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Abstract. The problems of long delay and accuracy were caused by the process of developing mechanical fault diagnosis systems using different tools. This article aims to give a reasonable solution to this contradiction by introducing TRIZ theory. This program uses LabVIEW as the development environment, EMD as the algorithm core, TRIZ theory as the development basis. The EMD algorithm is implemented by embedding different methods to decompose the fault signal so as to achieve the fault diagnosis signal in the same mechanical fault diagnosis system that can be decomposed efficiently. During the test machine fault signal pre-processing phase, which takes LabVIEW secondary development of EMD as the core data analysis, the accurate measurement phase is to take LabVIEW and MATLAB mixed programming EMD data analysis. Through such a development process arrangement, a core and two arrangements can be implemented to effectively resolve technical conflicts and provide a new idea.

1. Introduction

TRIZ is the abbreviation of the Russian English Teoriya Resheniya Izobreatatelskikh Zadatch transliteration, which is "the theory of invention problem solving." In Chinese, The TRIZ theory was founded in 1946 by the Soviet inventor G.S. Altshuller. Altshuller and his team studied 2.5 million high-level patents from around the world, summed up the pattern of laws followed by the evolution of their respective technologies,established a comprehensive multidisciplinary field to solve various technical contradictions and innovative principles and rules of physical contradiction. An integrated theoretical system composed of solving various technical problems and implementing innovative development methods and algorithms [1].

EMD (Empirical Mode Decomposition) is a time-frequency analysis method for processing nonlinear and non-stationary signals. In the course of many years of development, this method has gradually revealed its unique advantages in non-stationary signal processing it has important theoretical research value and broad application prospects. At present, EMD has great application value in mechanical fault diagnosis feature extraction.

EMD has multiple implementations in the process of applying mechanical fault diagnosis. For example, based on the NASA Norden E. Huang et al.'s empirical mode decomposition method, Follow-up scholars based on MATLAB tool to improve the programming of its algorithm can be achieved on the breakdown of rotating machinery fault signal. The G language programming that has risen in recent years has been applied in the field of mechanical fault diagnosis due to its unique graphical programming features. The LabVIEW language developed by NI Corporation has been widely recognized in the industry. Therefore, some scholars have used LabVIEW to develop EMD algorithm.

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For the above-mentioned two implementations of the EMD algorithm, they exhibit different advantages and disadvantages in the on-site testing process. LabVIEW achieves the EMD algorithm through MATLAB function node and MATLAB mixed programming[2]. The performance of the EMD algorithm is high in the field, but the analysis process takes up a lot of computer resources and results in a long time. The secondary development of the EMD algorithm through LabVIEW's own module function shows that it takes up less computer resources and the test process has a lower delay, but the test accuracy is reduced. In order to solve this contradiction and improve the efficiency and accuracy of the test, this paper applies TRIZ theory as the ideological basis to achieve the intended purpose.

2. The basic principle of EMD algorithm

The EMD algorithm assumes that any signal was consists by several finite IMF (Intrinsic Modal Functions). Each IMF is obtained by the following method[3]:

Step 1. Initialization, let $r_1(t)=x(t)$,i=1,k=0;

Step 2. Obtain the nth order IMF;

(a). Initialization, let $h_1(t) = r_1(t)$;

(b). Find all the maximum and minimum points of $h_k(t)$

(c). Fit the maximum and minimum points through the cubic spline interpolation function to find the upper and lower envelopes, $e_+(t)$ and $e_-(t)$;

(d). Calculate the upper and lower envelope mean $m_k(t)$;

(e). $h_{k+1}(t) = h_k(t) - m_k(t)$;

(f). Judgment SD=$\frac{\sum[h_1^{k-1}(t)-h_1^k(t)]^2}{\sum[h_1^{k-1}(t)]^2}$ is not greater than the given threshold, where 0.3, if not, then $c_i(t) = h_k(t)$; otherwise, let k=k+1 go to (b);

Step 3. $r_{k+1}(t) = r_k(t) - c_{k+1}(t)$, whether the margin is a monotonic function or a constant, and if so,

Which decomposition ends. And the detail theory can be found[2-3].

3. EMD achieved in different scenarios

3.1Applying LabVIEW Secondary Development to Implement EMD

According to the principle and flow of EMD algorithm above, the main program of EMD algorithm written by LabVIEW is shown in Figure 2. The main program includes the following subVIs: Extreme Value Envelopes $e_+(t)$ and $e_-(t)$, Mean Envelope $m_2(t)$, IMF Criteria, Refinement, and Other subVIs. Its function is to calculate the upper and lower envelopes of the signal using the method of cubic spline; Calculate the local mean value of the signal according to the upper and lower envelopes of the signal; Determine whether the current signal is an IMF; Determine whether the current signal needs to continue to decompose until the criterion symbol requests to stop drawing the relevant signal.

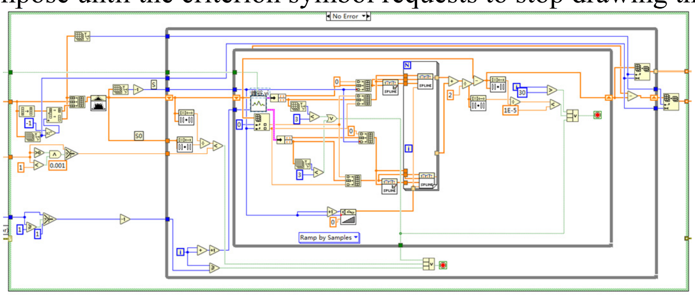

Figure 1. LabVIEW writes the EMD main program

The above main program simulates the input sine signal by adding white noise to simulate the following effects as shown in Figure 2.

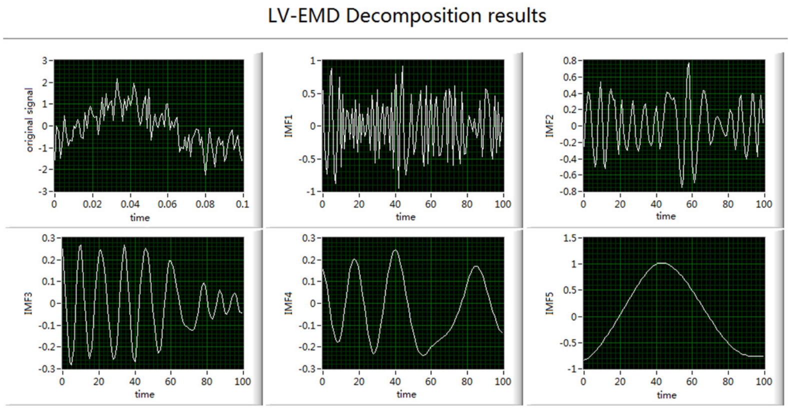

Figure 2. LabVIEW secondary development to achieve EMD algorithm renderings

3.2Application of LabVIEW and MATLAB Mixed Programming to Implement EMD

LabVIEW uses ActiveX technology to implement MATLAB script nodes. ActiveX is an object connection and embedding technology defined by Microsoft Corporation for the Internet. It satisfies the need for exchanging information between different applications on the network. LabVIEW provides various methods for calling with other applications, such as ActiveX.DDE and other standard interface methods. Although you can use these methods to call MATLAB in LabVIEW, the process is relatively cumbersome. NI Corporation proposed a relatively easy method for this purpose, namely MATLAB Script node mode. In this way, users can use MATLAB's powerful numerical functions in LabVIEW. Therefore, the second EMD implementation method in this paper is to directly call the off-the-shelf improved EMD algorithm through the mixed programming of LabVIEW and MATLAB. The effect is as shown in Figure 3.

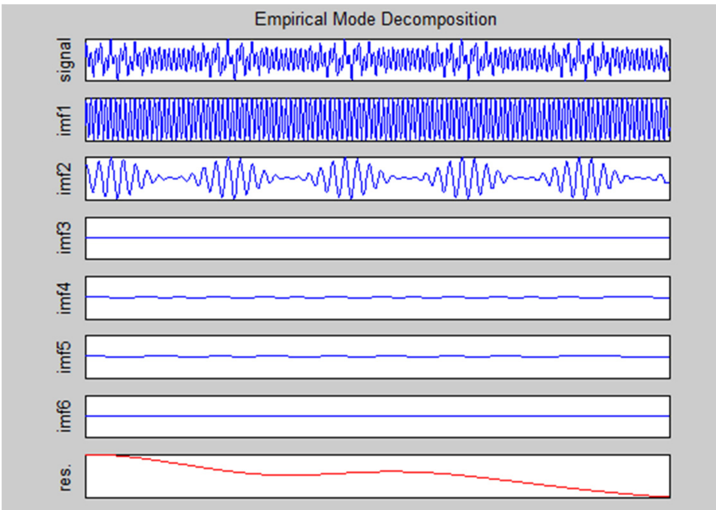

Figure 3. The effect of EMD algorithm with LabVIEW and MATLAB mixed programming

4. The application of TRIZ theory

For the above-mentioned mechanical fault diagnosis system developed by LabVIEW, it embeds different ways to implement the problems caused by the EMD core algorithm. There is a very effective analysis method in the TRIZ theory that is the "nine screen" method[5]. The application of the "nine-screen" method can give a reasonable analysis of the contradictions brought about by the above problems, as shown in Figure 4 below.

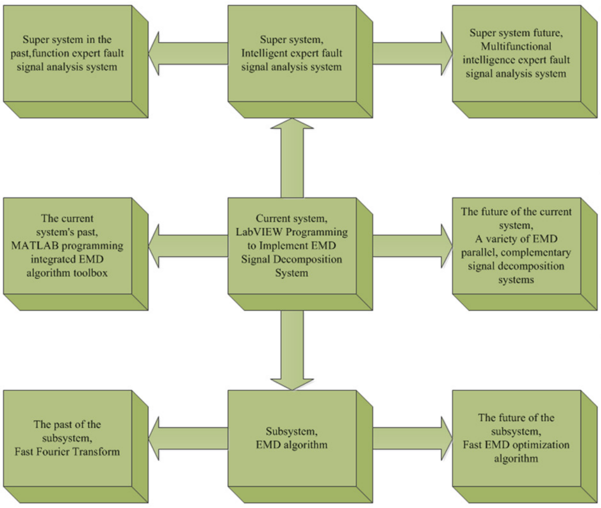

Figure 4. Nine-screen method

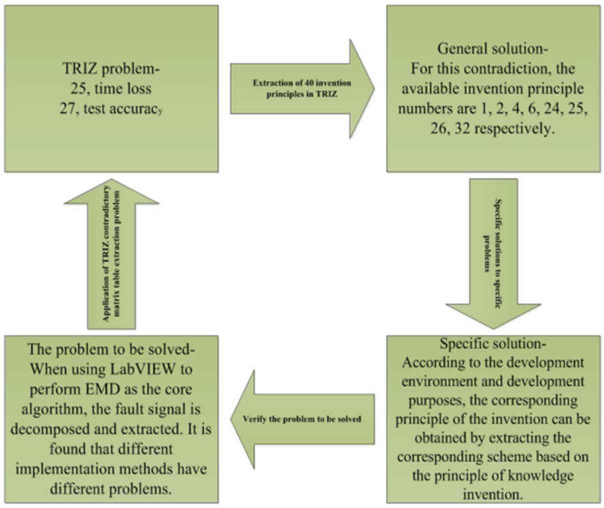

Figure 5. The application of TRIZ theory

Through the above diagram, the reader can make an accurate positioning of the core technology conflicts currently facing the system. At the same time, readers can see at a glance the major tasks and extensions to be completed in this article. The "nine-screen" diagram clearly states that the application of LabVIEW to develop a high-performance mechanical fault diagnosis system, the core subsystem is the key issue. For this reason, this paper quotes TRIZ theory contradictory matrix to give a solution to this core problem. The use of contradiction matrix for TRIZ theory is shown in Figure 5.

As shown in Figure 5 above:

(a). Name of technical system, mechanical fault diagnosis system.

(b). The main function of the technical system, the mechanical fault diagnosis system developed by LabVIEW can efficiently decompose the fault signal.

(c). A detailed breakdown of the technical system, as figure.4, clearly indicates the links between subsystems, systems, and super systems.

(d). The development system framework is built on the LabVIEW development environment. The EMD core algorithm is implemented through the LabVIEW graphical language. The EMD core algorithm is embedded in the development system through LabVIEW.

(e). Positioning problems, The above figure b-c shows two results of the EMD core algorithm achieved through LabVIEW. The conclusion reached through a large number of experiments is that the method two accuracy is higher than the method one, but the delay is longer.

(f). Determine the characteristics that the technical system should improve, According to the 39 general parameters given by the TRIZ contradictory matrix, the characteristics to be improved can be selected abstractly as time loss and test accuracy.

(g). Apply a contradiction matrix based on the above selected general parameters to give a solution (see the next section for details).

5.Application of contradictory matrix of TRIZ theory

The technical contradiction [6] is the conflict between the two parameters. One of the parameters of the system is improved and the other is deteriorated. The symbol is denoted as "A+, B-" or "B+, A-".

In TRIZ theory, an effective solution to technical contradictions is to use the Altshuller contradiction matrix. Altshuller summed up 39 common parameters for the performance of expression systems commonly used in the engineering field by studying a large number of invention patents. Common parameters are generally parameters of physical, geometric, and technical performance. The contradiction matrix is formed by 39*39 general engineering parameters and 40 innovation principles. In the contradictory matrix table, as long as the parameters to be improved and the degraded parameters are clear, a set of corresponding innovation principle numbers can be found in the contradiction matrix.

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This article mainly refers to the 25th and 27th generic parameters namely time loss and test accuracy where time loss [6], refers to the time interval of an activity. Loss of improvement time is the time it takes to reduce an activity. Test accuracy, refers to the error between the measured value and the actual value of the system characteristics. Reducing the error will improve the test accuracy.

During the application of the above two parameters, the time loss parameter is defined as the technical negative parameter. The test accuracy parameter is defined as the technical forward parameter. The technical negative parameter means that when these parameters increase, the performance of the system or subsystem is changed. Technical forward parameters: When these parameters become larger, the performance of the system or subsystem is improved.

According to the change of the parameters when the system is improved, the parameters to be improved can be divided into two categories: The parameter to be improved and the parameter to be deteriorated, The engineering parameters that will be promoted and enhanced in the system improvement. The parameters to be deteriorated: According to the theory of contradiction, when a certain engineering parameter is improved, it will inevitably lead to the deterioration of one or more other engineering parameters. These deteriorated parameters are called deterioration parameters.

Altshuller's contradictory matrix enables the problem solver to analyze the parameters to be improved and the deterioration parameters based on the two engineering parameters that produce contradictions in the system, accurately define a pair of contradictions, and then find a set of corresponding in the contradiction matrix. Principle of Invention(The TRIZ classic theory has a total of 40 inventive principles and can provide guidance on solutions to different problems). The following table lists only some of the contradictory matrix contents according to the requirements of this article [6].

Table 1. Partial Contradictory Matrix Table (only needed for the article)

Deterioration parameters / Improve parameters		1 Sports weight	... .	25 Time loss	... .	27 Test accuracy	... .
1	Sports weight	2、3、10，35	....	2、3、10、16	....	28、5、36、32	....
...	......	....	....		....		....
25	Time loss	5、10、8、20	....	4、12、13、17	....	25、4、36、26	....
...	......	....	....	....	....		....
27	Test accuracy	1、12、8、28	....	2、24、6、32	....	3、32、10、28	....
...	......	....	....	....	....	....	....

The parameters that this article needs to improve are time loss and test accuracy. As shown in Table 1, according to the contradictory matrix of the TRIZ theory, we can guide us to choose from 1 (segmentation: dividing an object into mutually independent parts) and 6 (multiple use: enabling an object to perform multiple functions, which can reduce the original design The number of items that completed these functions).

According to the guidance plan, in order to effectively solve the problems raised in this article. The solution given in this article is that in the same LabVIEW development application, Simultaneously embed the secondary development EMD algorithm of LabVIEW and LabVIEW realize EMD algorithm through calling MATLAB, That is, the 1st division method in the TRIZ theory is applied. The further use of the six, multi-use principle is to be able to reflect the sensitivity of the development process when performing mechanical fault diagnosis on site. We can use the EMD algorithm developed by LabVIEW twice. If abnormal mechanical operations are found in this process, take measures immediately. Use LabVIEW to implement EMD algorithm by calling MATLAB for further diagnosis to give a problem report. If no abnormality occurs in the first process, the second step is not required. The flow chart is as shown in Figure 6.

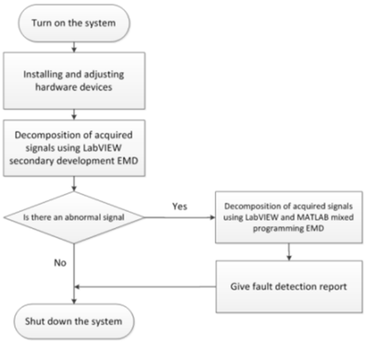

Figure 6. Development flowchart

Through the above development process ideas, you can achieve "a two core arrangement" in LabVIEW. Its purpose is to effectively solve the technical contradiction of time loss and measurement accuracy. After such a development process, the development system test accuracy can be improved without high delays. That is the use of high-sensitivity and low-precision methods in the ordinary measurement process is no different from the use of the EMD method in other high-precision measurement processes. This will increase daily measurement efficiency.

6.Conclusion

Through the above analysis, when LabVIEW is used to develop application programs for mechanical fault diagnosis, which can combine TRIZ theory to analyze and solve contradictions. Aim at the technical contradiction of the time loss and measurement accuracy, as follows;

(a). For the problem of long delay in the initial measurement process, this paper proposes to use LabVIEW secondary development EMD algorithm to decompose and display the fault signal.

(b). For the high-precision and high-delay parts that need to further determine the reason of the fault and the type of fault in the later period, which applies the EMD algorithm of LabVIEW and MATLAB mixed programming to decompose and display the fault signal.

(c). According to the conclusions of (a) and (b), for the mechanical fault diagnosis application program developed, after implementing the EMD algorithm arrangement in different ways, the problem of long delay and poor accuracy can be resolved step by step.

Acknowledge

The project is supported by the Inner Mongolia natural science foundation (Study on Time frequency Characteristics and Detection Method of Micro Leakage of Flange and coupling in Complex Pipeline,2018MS05007).

References

[1] Hsu Sheng-Yuan. A New Problem-Solving Procedure Based on TRIZ Methodology and QC Story[M].Atlantis Press:2015-06-15.
[2] Wang Ju. The Design of Facial expression recognition system based on the LabVIEW and MATLAB mixed programming[A].Proceedings of 2015 International Conference on Automation,Mechanical Control and Computational Engineering(AMCCE 2015)[C]. 2015:6.
[3] HUANG N E,Shen Z,Long SR,et al The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Nonstationary Time Series Analysis [J] Proceedings of the Royal Society of London A,1998.
[4] Rilling G,Flandrin P,Goncalves P.On Empirical Mode Decomposition and Its Algorithms. [C]//IEEE-EURASIP Workshop on Nonlinear Signal and Image Processing,2003(6):9-11.
[5] Kuo-Yi Li. Application of TRIZ in the Innovation Design of the Dry-Powdered Fire Extinguisher Training Device[M].Springer International Publishing:2014-06-15.
[6] Jack Hipple. Using TRIZ with Other Tools[M].Springer New York:2012-06-15.