Development of Data Acquisition Algorithm for Spectrometer for Fluorescence Applications

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Abstract
Emission and reflection of light from the objects depends on their internal energy levels and composition present in the environment. The hot objects emit light while cold objects reflect or absorb light on some specific wavelengths. Spectrometer is equipment which is used to measure the spectra of light emitted. This project aims to use Ocean Optics USB 4000 spectrometer to measure the intensity spectra of light incident on its input port. The control and data acquisition of spectrometer will be developed under EPICS (Experimental Physics and Industrial Control System). The signals acquired from spectrometer will be then decomposed into small functions by using EMD (Empirical Mode Decomposition). The conspired solution for removing noise from the signals which are non-stationary and non-linear in nature is done by using EMD. Available processing techniques are either linear and stationary or nonlinear and stationary so they are unsuitable for the random signals received from the sample object. The objective of the processing technique is to bring out the useful data from the signal received after reconstruction and accurately measuring the position with the help of time of flight. This spectrometer finds several applications in Agricultural Measurements and Monitoring, Polymer Analysis, Medical Diagnostics etc. Enabling it with EPICS allows it to easily communicate and control along with other device like laser, imaging system, time synchronization etc. involved in experiment.

Keywords: Spectrometer, EMD, IMF, HHT

1. INTRODUCTION
A spectrometer is normally used to quantify wavelengths of electromagnetic radiation (light) that is associated with a sample. The characteristics of a sample can be recognized by the changes in the incident light which can be reflected off, absorbed by, or transmitted through a sample at different wavelengths. The changes in the incident wavelengths of a light will be measured by a spectrometer. The fluorescence spectrometers are perfect for use in low light fluorescence applications where the capacity to distinguish weak signals is pivotal for proper measurements. Moreover, fluorescence spectrometers highlight broadband spectral response ranges for distinguishing wide wavelength bands alongside a wide opening width for expanded throughput. There are many types of spectrometer available for different types of works. They are used in laboratories, processes, field and some other applications like OEM etc.

Flame series Spectrometer provide us benefits of modular spectroscopy. It doesn’t compromise with the features of spectroscopy.

USB series spectrometers are general purpose spectrometers, they are UV-Vis-NIR spectrometers and are versatile in nature.

The JAZ spectrometer presents a divergent level of adaptability. This spectrometer is used for many applications like quality assurance, life sciences, remote sensing, greenhouse lighting and monitoring because of its uncommon features and extended platform initiate, it is a satisfactory choice for this type of applications.

2. LITERATURE REVIEW

Soldatov et al [1] present an automatic control system for an auger spectrometer. The main principle of designing of the script and implementation of the system is shown. The system includes multiple bit digital code which helps in controlling the Auger Spectrometer. the specialized acknowledgement of the yield information procurement and post-handling arrangement of Auger spectrometer giving signal processing in a wide unique range is depicted.

Han-Kuei Fu in his paper performs a comparison between the spectral correction algorithms and integrate them to process the correction of spectrum measurement to find the best optimal algorithm [2]. The spectral correction algorithms plays very important role in the field of research and industrial applications.

Piotr and Roman in their paper present techniques for calibrating a spectrometer using Genetic Algorithm. The paper describes the data acquisition by using spectrometer of lower resolution, and is based on the digital processing [3].

The digital spectrometer includes some amplitude extracted algorithms which is responsible for calculating peak to peak value, curve fitting and statistics algorithm. The LabVIEW is used for controlling the digital spectrometer [4].

Oumar in his paper, proposed a substitute for the sifting process used in the original Huang’s empirical mode decomposition (EMD) method [6]. Data acquisition, sequential control, supervisory control, closed-loop control and operational optimization are performed by using an open source software named Experimental Physics and Industrial Control System (EPICS). The present EPICS coordinated effort comprises of five U.S. research centers: Los Alamos National Laboratory, Argonne National Laboratory, Lawrence Berkeley Laboratory, the Superconducting Super Collider Laboratory, and the Continuous Electron Beam Accelerator Facility [5]. Harshal Chaudhari presents the review for enhancement of speech signals using Empirical Mode Decomposition (EMD) with its Intrinsic Mode Function’s (IMF’s) processing and inherited problem occurs during generation of IMF has been detected [7].

3. OCEAN OPTICS USB 4000 SPECTROMETER

The USB 4000 spectrometer is the advanced version of the USB 2000+ spectrometer. It incorporates advanced features for highly spectral response and optical resolution. The leading features of this spectrometer include advance detector and high speed powerful electronics.

The USB 4000 interfaces to computer through USB 2.0 or RS-232. Information unique to every spectrometer is customized into a memory chip on the USB4000; the spectroscopy working programming peruses these qualities for simple setup and hot swapping among PCs, regardless of whether they keep running on Linux, Mac or Windows working frameworks. The USB4000 works from +5V control, given through the USB, or from a different power supply and a RS-232 interface.

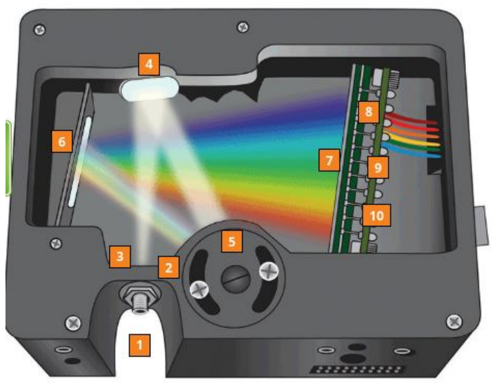


Figure 1: Ocean Optics USB 4000 Fiber Optic Spectrometer Optical Bench

4. PROBLEM DEFINITION

In a spectrometer, the light is made to fall on a grating which separates different wavelengths into spectrum. These wavelengths are incident at different positions of linear CCD, which is then sent to the computer via USB interface for further processing. In our proposed work, the signal acquired is further analyzed by using signal decomposition technique known as EMD. EMD is used for de-noising, signal enhancement and economic data analysis. We have many advantages of using EMD i.e. they are adequate for both non-linear and non-stationary data and it gives sharp spectrum.

5. SOFTWARE USED

Oceanview Software

OceanView software is Java based spectroscopy software. To work out with spectrometer, the software impart good stability, settings for the ingenuity of the users, various features for devices and other features like saving and loading data.

The communication between computer and spectrometer is done by using USB cable. OceanView has the capability to communicate with multiple spectrometers with different acquisition parameters. The spectra of the light from each and every spectrometer is represented graphically and numerically is given by the software. We can collect and combine data from more than one sources for various measurements like monitoring of processes, dual beam referencing.

6. TAKING INPUT FROM SPECTROMETER

The first step in the process of taking input from the spectrometer is, the light is incident on the narrow aperture called as entrance slit of the spectrometer through optical fiber cable which will get reflected through the collimator and directed on to the grating. The light after directed on to grating, gets dispersed into spectral components.

The fundamental working of the spectrometer is to take light through a light source, break light into its spectral components, digitization of the signals using various function of wavelengths and at last read these signals and display it through computer.

7. TECHNIQUE USED TO PROCESS SIGNALS

Empirical Mode Decomposition

EMD is a key feature of HHT, which provides analytical basis functions for the decomposition of the original back-echo flaw signal into a set of some functions (IMF). The basic idea of the Empirical Mode Decomposition is a simple assumption that any data consists of different simple intrinsic modes of oscillation. At any given time, the data may have many different coexisting modes of oscillations, one superimposing on the others. The result is the final complicated data. Each of these oscillatory modes is represented by an intrinsic mode function (IMF) with the following definition:

- In the whole dataset, the number of extrema and the number of zero-crossings must either equal or differ at most by one, and
- At any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero.

Mathematically, the original signal ***f(t)*** is decomposed through EMD as follows:

$$f(t) = \sum_{i=0}^{n} \mathrm{h_i(t)} + \mathrm{r_i(t)} \quad \dots (1)$$

Where $h_n(t)$ denotes the n^{th} IMF and $r_n(t)$ denotes the residue function.

To decompose the signal f(t), first, identify the local extrema (peaks). Connect the local maxima points with cubic spline interpolation, to get the upper envelope. Repeat the previous step for local minima points to get the lower envelope. The mean of both of the envelopes is calculated as $m_n(t)$. The mean is subtracted from the original data ***f(t)*** to get the first IMF.

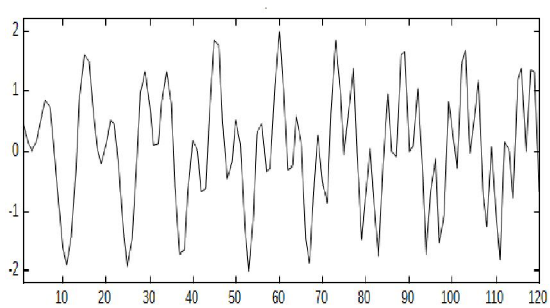
$$h_i(t) = f(t) - m_i(t) \quad \dots (2)$$

If the above function $h_i(t)$ does not satisfy the above stated definition of IMF, such function is known as protoIMF and this is considered as new data and same process is simply executed to $h_i(t)$ until it reaches the definition of IMF.

When such a $h_i(t)$ satisfies the IMF definition, it is considered as the 1^{st} IMF. This IMF is separated from the original signal to get the residue $r_i(t)$.

$$r_i(t) = f(t) - h_i(t) \quad \dots (3)$$

Since the residue $r_i(t)$ still contains the longer frequency variations in the data, it is treated as new data and subjected to the same sifting process as above. The process is repeated until $r_i(t)$ becomes monotonic function from which no more IMFs can be extracted.



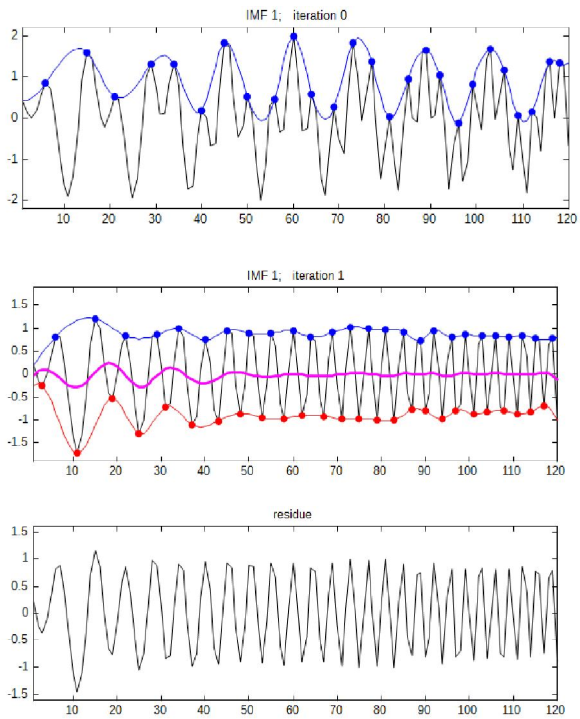


Figure 2:1^{st} IMF generation

8. CONCLUSION

In signal processing, decreasing noise and expanding signal-to-noise are fundamental steps expected to recognize the smallest focus levels of an analyte of intrigue. The Boxcar Width of the signal should be kept low because it does not smooth out the spectral features and the averages are set to high. The signal to noise ratio, signal and noise of spectrometer vary from one spectrometer to another, the system design of the spectrometer and software settings can help in maximizing the signal to noise ratio.

Empirical Mode decomposition is the technique used for the decomposition of signals acquired as the inputs. EMD is useful for highly non linear and non-stationary signals so the technique should be justifiable with the signal.

References

[1] A.I. Soldatov,E.L. Loginov,M.A. Kostina,P.V. Sorokin,N.V. Kopysova, and S.I. Bortalevich, “AN AUGER SPECTROMETER CONTROL SYSTEM,” International Siberian Conference on Control and Communications (SIBCON), 2016.

[2] Han-Kuei Fu, Yen-Liang Liu, Tzung-Te Chen, Chien-Ping Wang, And Pei-Ting Chou, “The Study Of Spectral Correction Algorithm Of Charge-Coupled Device Array Spectrometer,” IEEE Transactions On Electron Devices, VOL. 61, NO. 11, NOVEMBER 2014.

[3] Czak And Roman Z. Morawski, “Calibration Of A Spectrometer Using A Genetic Algorithm,” IEEE Transactions On Instrumentation And Measurement, VOL. 49, NO. 2, APRIL 2000.

[4] Yonggang Huo, Peng Xu, Feng Yang, Xiaolin Qiu, "Effect Of Amplitude Extracted Algorithm To The Sampling Energy Resolution On Digital Spectrometer," The Ninth International Conference On Electronic Measurement & Instruments Icemi'2009.

[5] M. Knott, M. Thuot, D. Gurd, And S. Lewis, These Proceedings (ICALEPCS '93, Berlin, Germany, 1993), Nucl. Instr. and Meth A 352 (1994) 486.

[6] Oumar Niang, Éric Deléchelle, And Jacques Lemoine, "A Spectral Approach For Sifting Process In Empirical Mode Decomposition", IEEE Transactions On Signal Processing, VOL. 58, NO. 11, NOVEMBER 2010.

[7] Harshal Chaudhari , S. L. Nalbalwar , Rashmee Sheth, " A Review On Intrinsic Mode Function Of Emd", International Conference On Electrical, Electronics, And Optimization Techniques (ICEEOT) – 2016.

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