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Chemical Analysis Program for the Time of Flight Mass Spectrometry System

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Abstract: In this work, we present a computer program that reads, manipulates, analyses and stores the mass spectra obtained by using Laser Time of Flight Mass Spectrometry (L-TOF-MS) system described elsewhere. This program allows users to record the characteristic parameters of experimental data such as vacuum pressure, voltages, laser power, sample name etc. both manually and automatically. Also, the obtained mass spectra can be used to investigate chemical substances (NO_x, SO_x, organic molecules etc.) or can be used to real time identification of the sample differences for given material database (metal oxides, alloys, paintings, healthy and cancerous tissues etc.) by using different mathematical and statistical procedures (PCA, LDA, kNN etc.). We have recently presented a simple chemical analysis procedure by starting from reading raw MS data from oscilloscope using TCP/IP protocol and following data processing steps. We have a great success to reduce the numbers of steps and time duration consumed for the following procedure.

Keywords: *Mass Spectrometry, Data Acquisition, Data Processing, Statistical Analysis, GUI, MATLAB.*

1. Introduction

Mass spectrometry is an analytical method and has a wide applications including; industrial quality control [1]-[3], pharmacology [4]-[7], isotope ratio determination [7]-[10] and space exploration researches [11-13]. Mass spectrometers consist of three units, which are an ionisation unit, separation unit and detector. The obtaining and interpretation of the mass spectral data have a great importance to reveal the molecular structure and laser ionisation/dissociation processes [14], [15].
Data analysis is the most time-consuming processes and manual data processing can cause the unintended human error, such as, reading or writing ion intensities, workspace (time – mass to charge ratio) conversion errors. In this work, we have presented the reducing the numbers of steps and time duration spend for the mass spectral analysis procedure.

2. Background and Theory

Recent years, multivariate data analysis methods have attracted great attention due to the large experimental data sets obtained from different experimental methods, especially in mass spectrometry, researchers obtain thousands of ion peaks (mass to charge ratio) in different intensities for multiple repetitions for each experiment. Thus, dimension reduction and selection of the data analysis methods (PCA, LDA, kNN etc.) became an important problem. In order to overcome these problems, new software tools was created similar to MCR-ALS (Multivariate Curve Resolution-Alternating Least Squares) toolbox programmed in MATLAB environment [16]. A similar program (FlavonQ) was developed to simultaneously analyse ultra-high-performance liquid chromatography (UHPLC) high-resolution accurate mass spectrometry −mass spectrometry (HRAM-MS) data and UV-VIS spectrometry data in order to profile the flavonoids [17]. Recently, a user-friendly program (SIM-XL) was developed for structural protein characterization by using peptide cross-linking analysis method for tandem mass spectrometric data [18].
In proteomics studies, a GUI program (IPeak) also presented for identification of the peptides data obtained from LC-MS/MS method [19]. To identify TLC (Thin Layer Chromatography) information from MSI (Mass Spectrometry Imaging) data sets, a program (DetectTLC) was developed [20]. Homemade software or package programs were used for biological tissue identification [21] or cancer detection [22] by using mass spectrometry data.

3. Experimental Setup

Experimental setup consists of laser systems, time of flight mass spectrometer and electronics. In our experiments, we are using high-intensity femtosecond/nanosecond lasers. In the scope of this work, we have used a femtosecond laser system (Quantronix, Integra-C-3.5, NY, USA) as an ionisation source. TOF-MS system was designed and built by our group; background pressure of the vacuum chamber can be pumped down to 10-8 mbar. Ion signals were collected by using an MCP detector (El-Mul Technologies LTD., Israel). The details of the experimental setup were presented elsewhere [23, 24].
Mass spectra were recorded remotely via TCP-IP protocol and real time by using a four-channel oscilloscope (LeCroy Corporation, WaveRunner 64 Xi, NY, USA).

4. Results and Discussion

GUI of the mass spectrometry program consists of the subpages that are Experiment, Setup, Connection, Laser Diagnostics and Database Control, as shown in fig. 1. In the experiment section, the user can write sample name, number of sampling and perform plotting mass spectra. Setup section (given as an inset in fig. 1) provides the user to recording experimental parameters such as electrode voltages, vacuum pressure and laser power. In the connection section, the user defines IP number of the oscilloscope

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to connect using TCP-IP protocol. In laser diagnostics section, the user can obtain real-time UV-VIS spectrum of the laser pulses (fig. 2.) by using UV-VIS-NIR portable fiber-optic USB spectrometer (0.1 nm FWHM optical resolution, USB 2000+, Ocean Optics). In database control section, the user can load a database file for given directory from local drivers. The user can control and plot mass spectra for desired rows and each row corresponds to a mass spectrum (fig. 3).

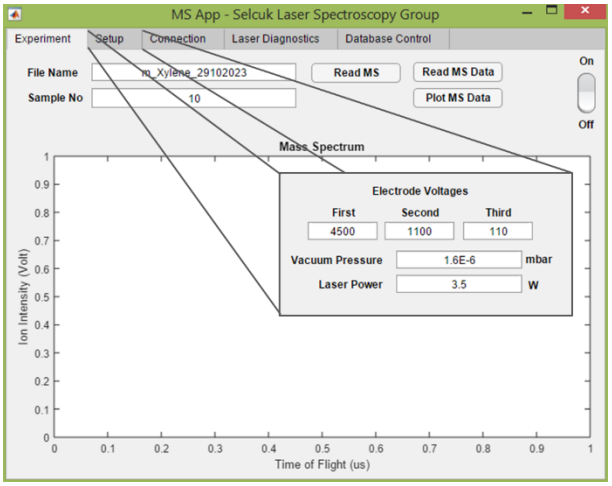

Figure 1. GUI of the MS spectrometry program and subpages; Experiment, Setup, Connection, Laser Diagnostics, Database Control. Setup section presented as an inset.

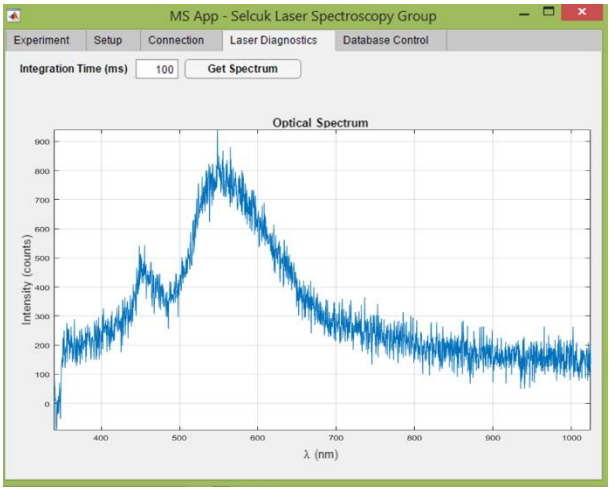

Figure 2. In laser diagnostic section the user can read UV-VIS spectrometer for desired integration time in ms time scale and spectra are plotting real time in the optical spectrum figure area.

In the database control section, the user firstly uses "Load Database" button to and then select database file stored as a MATLAB .mat file. After selecting and opening database file, the program record raw experimental data that contain mass spectra as an ion intensity (intensity corresponds to voltage value read by the oscilloscope) versus the time of flight of the corresponding ion peak. The user has to calibrate the system by using equation $(m/z) = at^2 + b$ to transform time of flight spectrum to mass spectrum to use m/z ratio for further spectral analysis [25]. For calibration, the user has to select two known peaks (H^+ and C^+ or CH_3^+ peaks) to calculate constant a and b to convert all time points to m/z ratio. The peak selection on the mass spectrum is shown in fig. 4. The user select first hydrogen ion peak and then carbon ion peak in fig. 4 by using mouse cursor (appearing crosshair).

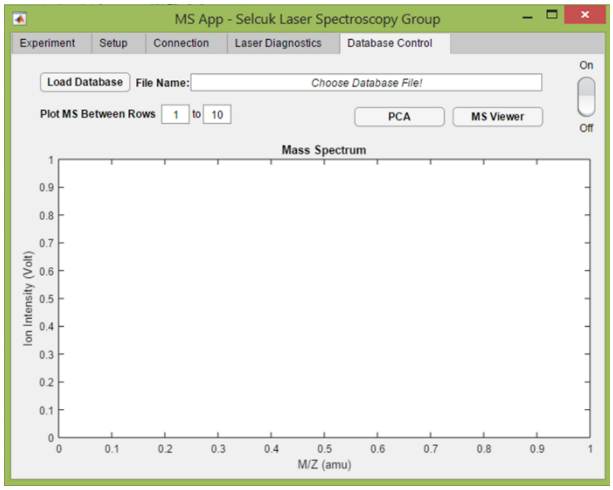

Figure 3. Database control section consists MS viewer button and a statistical analysis button to perform PCA.

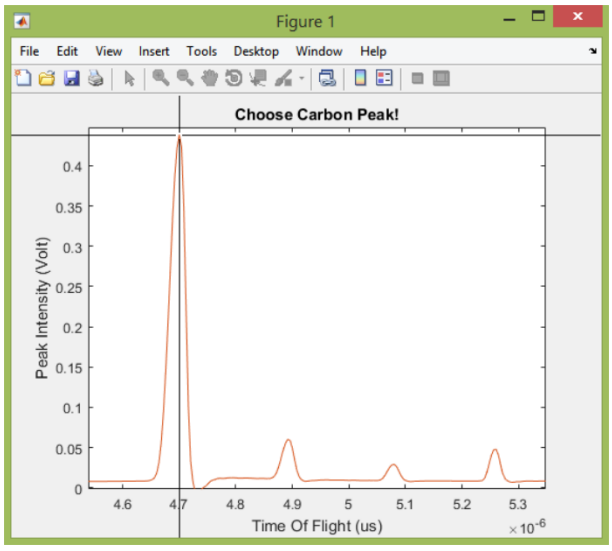

Figure 4. Reference peak selection on the read MS spectra to perform time of flight to mass spectrum transformation.

Following the time of flight spectrum transformation to mass spectrum, the user can view all collected mass spectra by using "MS Viewer" button, the opening window seen in fig. 5. On the other hand, the user can investigate statistical results by using PCA visualization tool as seen in fig. 6.

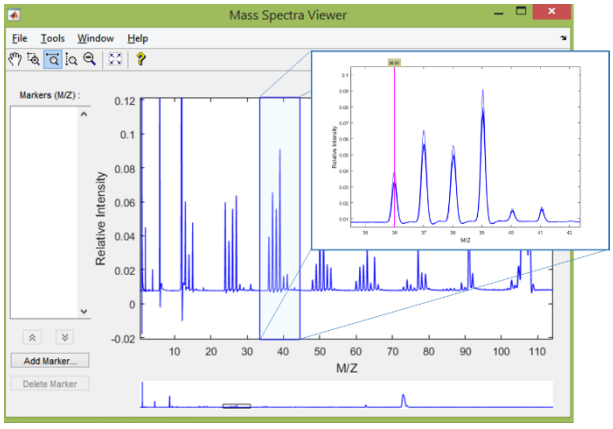

Figure 5. MS Viewer window opens when the user clicks MS Viewer button seen in Fig. 3. The user can select desired peaks to build a marker list into the left-hand side section.

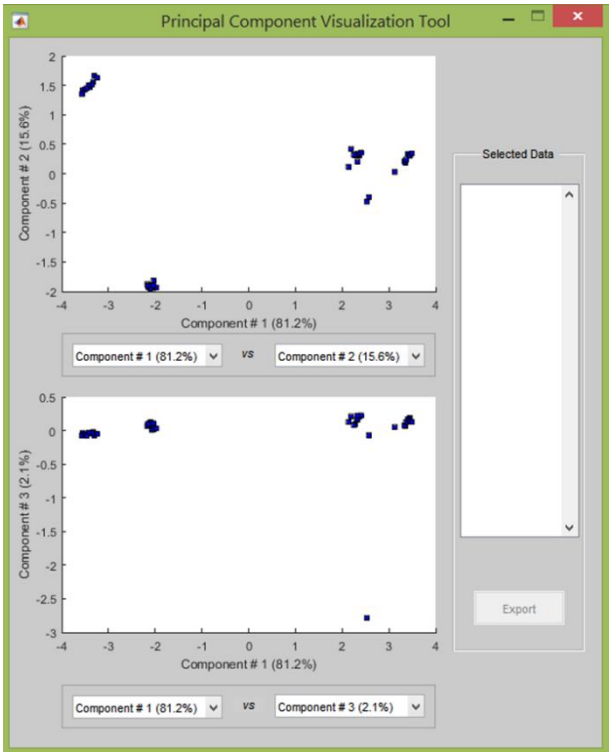

Figure 6. The user can investigate statistical results by using PCA visualization tool.

As a result, the fs-TOF-MS data sets were acquired as raw electronic signals, converted to digital values by using oscilloscope via TCP-IP. The obtained spectra were in the time of flight space first and after calibration, spectra were transformed into mass space.

We have got a great success to reduce the numbers of steps and time duration spend for the manual data processing procedures of the mass spectra analysis from weeks to seconds. Thus, we can eliminate the possibility of the unintended human errors appears in these manual procedures.

Within the context of this work, we built a backbone of the flexible program, which can be manipulated by customs needs, changing experimental setup and/or new unused statistical procedures in laser TOF-MS.

Analysing fs-TOF-MS data using multivariate statistical method, which suggests a new opportunity to use this program in real-time cancer detection research.

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