

# A MULTI-PARAMETRIC SYSTEM FOR MONITORING THE FERMENTATION PROCESS

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**ABSTRACT:** The developed system is a multi-parametric one that aims to monitor the fermentation process and based on acquire data to be able to control the process. By controlling the fermentation process the system actually needs to be able to accelerate the processor if is the case to be able to inhibit the process.

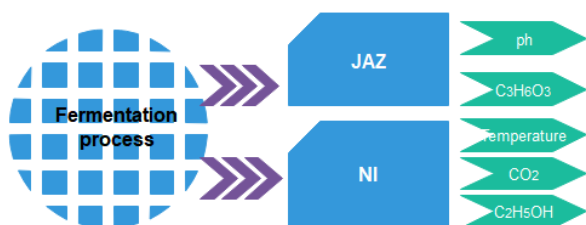
**KEYWORDS:** fermentation process, data acquisition , multi-parametric system

## 1. INTRODUCTION

The developed system aims to monitor the fermentation process and based on acquire data to be able to control the process. By controlling the fermentation process the system actually needs to be able to accelerate the processor if is the case to be able to inhibit the process.

Ethanol fermentation is a process during which organic material is converted to simpler compounds, such as sugars [1]

The system is a multi-parametric system. The ph of the solution, the concentration of lactic acid, the temperature, ethanol concentration and CO<sub>2</sub> concentration are monitored.



**Figure 1.** Overview of multi-parameter fermentation process monitoring system

## 2. DATA ACQUISITION USING THE JAZZ SPECTROMETER

As presented in the figure above, the Jazz spectrometer is used to acquire information regarding the ph of the monitored solution and information about the concentration of lactic acid.

This sub system for spectroscopy was integrated in the developed monitoring system by mean of a Raspberry Pi3B+ mini PC.



**Figure 2.** Raspberry Pi3B+ mini PC

The mini PC is using a Broadcom BCM2837B0, Cortex-A53, 64-bit, quad-core SoC at 1.4GHz processor with 1GB LPDDR2 SDRAM,

includes an Wi-Fi dual Band 2.4GHz/5GHz IEEE 802.11 b/g/n/ac, Gigabit Ethernet over USB 2.0 4 USB ports and video output trough HDMI. The OS and software is stored on a micro SD card.

to 8 spectrometer modules to make Jaz the first analytical instrument easily adaptable for the field, lab or process environment. Jaz can also connect to a computer via the USB port[2]



Figure 3. The Ocean Optic Jaz Spectrometer

Jaz is built on a platform that expands to include a light source, rechargeable lithium-ion battery and up

This solution was chosen because of the slow speed of the fermentation process so an automated system for data acquisition was necessary. The compact size and capabilities of the Raspberry Pi3B+ makes it suitable for developing such a system.

In order to make it possible for the Raspberry Pi3B+ to collect data from the Jazz spectrometer the python-seabreeze API was used. SeaBreeze is a minimalistic, multi-platform device driver for Ocean Optics spectrometers, designed specifically for embedded applications needing to run in resource-constrained hardware environments[3].

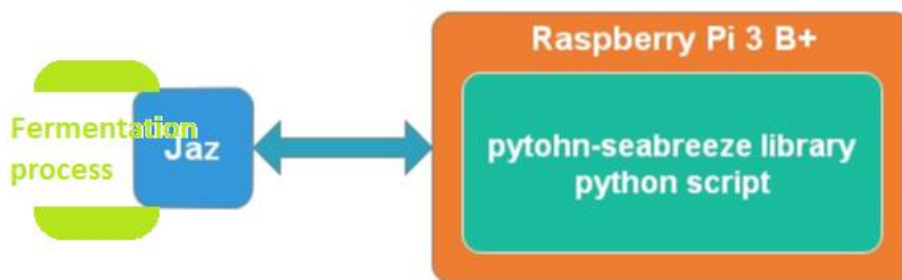


Figure 4. Data acquisition regarding the fermentation process using the Jaz spectrometer.

Python-seabreeze is the easy way to access your Ocean Optics spectrometers from python. It wraps the SeaBreeze library provided by Ocean Optics to communicate with the spectrometer.

If SeaBreeze is not available it can fallback to a pyUSB based reimplementation.

Through this subsystem using the Python-SeaBreze library script information regarding ph and lactic acid can be collected and using the hardware capabilities of the Raspberry Pi3B+ can be eater stored of transited using a network connection .

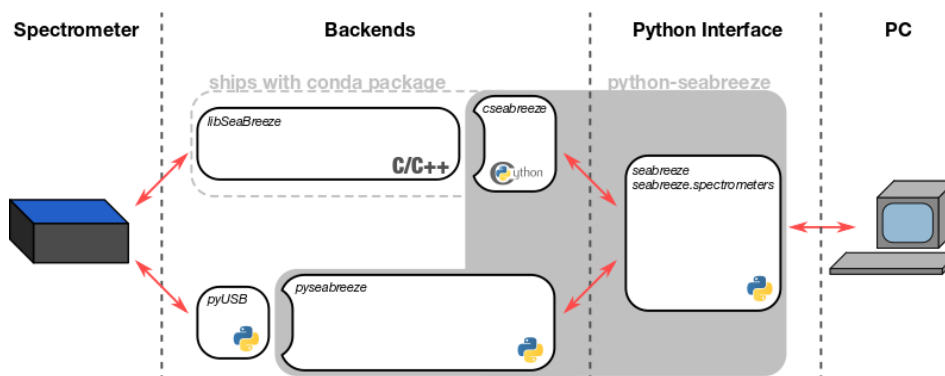


Figure 5. Python-seabreeze.

The Raspberry Pi 3 B+ is connected to the Jaz spectrometer and runs a Python application which connects to a MySQL database to store the data received from the Jaz spectrometer. The SQL database was chosen due to its flexibility and low resource use which for the system is a necessary characteristic.

The Raspberry Pi 3 is an versatile device that can be used in various applications including applications tightly connected with medical information system MEDIS.NET and with laboratory information system LabIS [4].

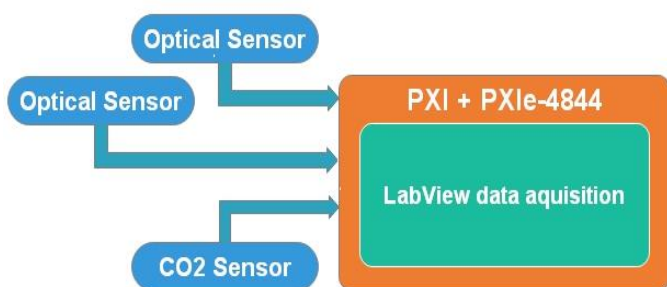
### 3. DATA ACQUISITION USING THE NI PIXE-8180 AND THE NI PIXE-4844 OPTICAL INTERROGATOR

The PXI-8108 is a embedded controller for PXI and Compact PCI systems [5], that includes 10/100/1000BASE-TX Ethernet.

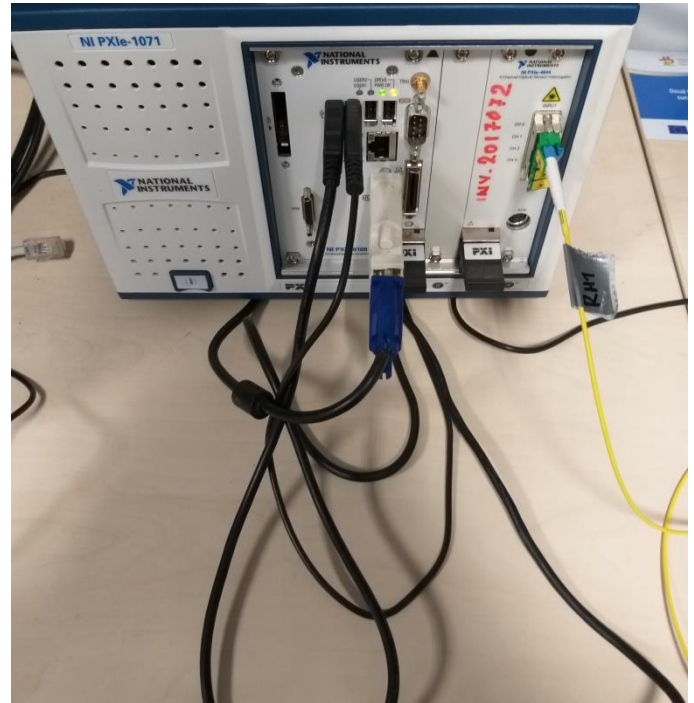
On this controller the PXIe-4844bdual-slot data acquisition module for fiber Bragg grating (FBG) optical sensors is installed. The PXIe-4844 includes an optical core with high-power, low-noise swept wavelength laser with fiber Fabry-Perot tuneable filter technology from Micron Optics [6].

Using the developed sensor, and also FBG temperature sensors from Fiber Sensing, information regarding the ethanol concentration and temperature in the fermentation chamber is acquired. Also and NOx sensor is used for determining the CO2 concentration.

Thus using the NI bases subsystem 3 parameters are collected.



**Figure 6.** DAQ system using the NI PXI and NI optical interrogator



**Figure 7.** Setup of the NI PXI 1071 and NI 4844 optical interrogator.

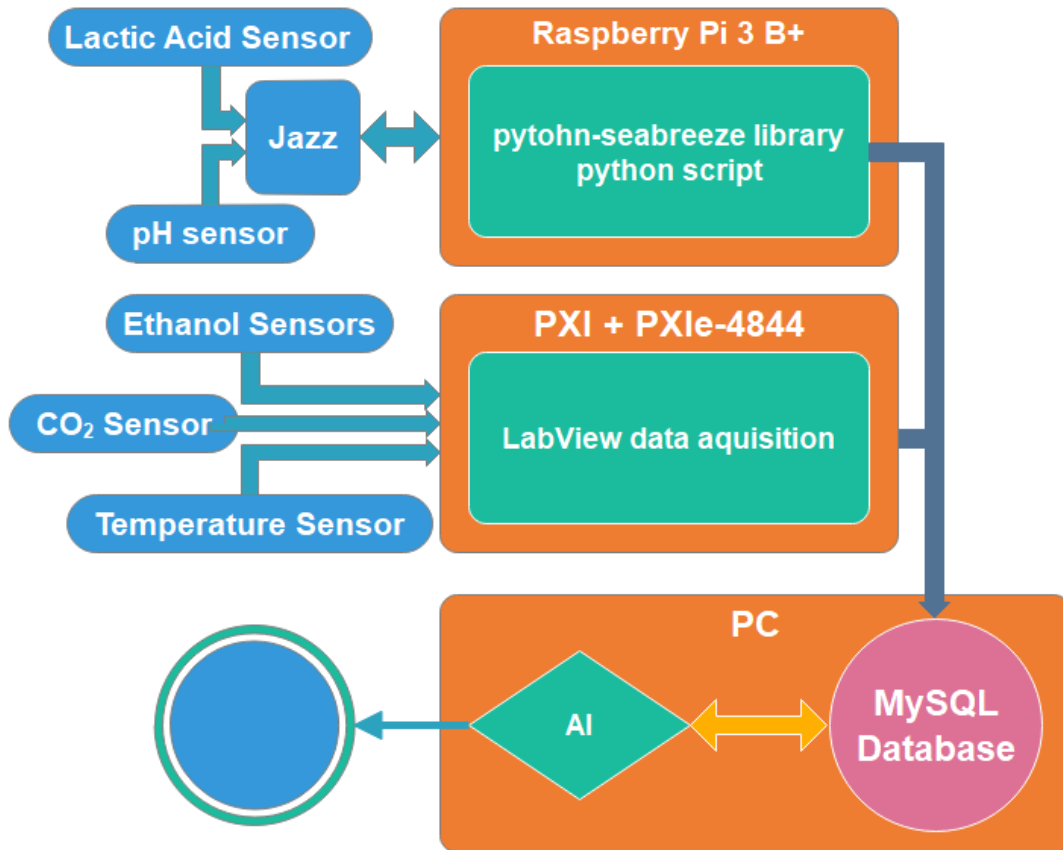
### 4. SYSTEM OVERVIEW

The system has two main subsystems, the first one based on the Jaz spectrometer and the second one is based on the NI PIX with the NI PXI 4844 optical fiber interrogator.

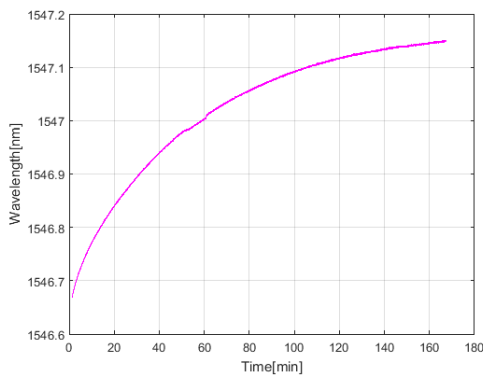
Together these two sub-systems are integrated in one multi-parameter system for monitoring the fermentation process.

The integration of the two sub-systems is realized using the Ethernet capabilities of both subsystems (the Raspberry Pi3B+ mini PC and the NI PIX system). All collected data is transmitted and stored in a database. The solution used for this application is an MySQL database as presented in the figure below.

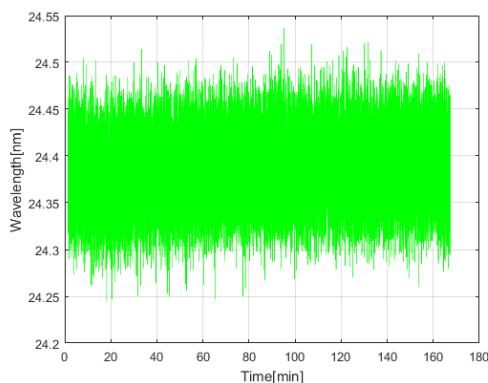
MySQL is much faster in terms of performance, and users still have access to all the necessary features they would through other database platforms [7].



**Figure 8.** Overview diagram of the multi parameter system for monitoring the fermentation process.



**Figure 9.** Evolution of ethanol concentration at 40% alcohol and 25°C



**Figure 10.** Temperature stability during the measurement 25°C

During the measurement the temperature was stable, with a minimum of 24.2441286°C and a maximum of 24.53640814°C.

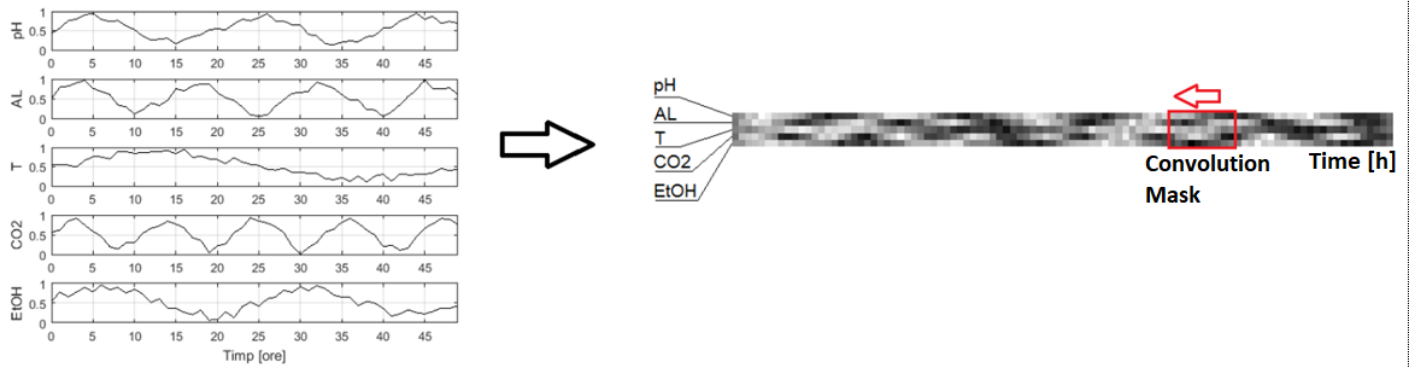
## 5. DATA PROCESSING

Combined processing and integrated measurement analysis is a rational approach to regulating the fermentation process if we have five characteristics measured and entered in the MySQL database: acidity (pH), lactic acid (AL) concentration, temperature (T), the concentration of carbon dioxide (CO<sub>2</sub>) and the concentration of ethanol (EtOH).

This approach fits into the concept of sensory fusion and can give more precise results and a higher confidence than those obtained with a single sensor.

A viable option is the use of processing methods capable of learning from previous process developments, known as artificial neural networks. A successful variant in many areas of these methods is that of neural convolution networks (RNCs) that are part of the broader network of Deep Neural Networks (DNN). A series of recent studies have shown that RNC has the ability to learn the particularities of a process, synthesizing complex data structures and extracting the characteristics of the measured data and performing the sensory fusion.

In the case of processing the measured data during the fermentation process, a set of



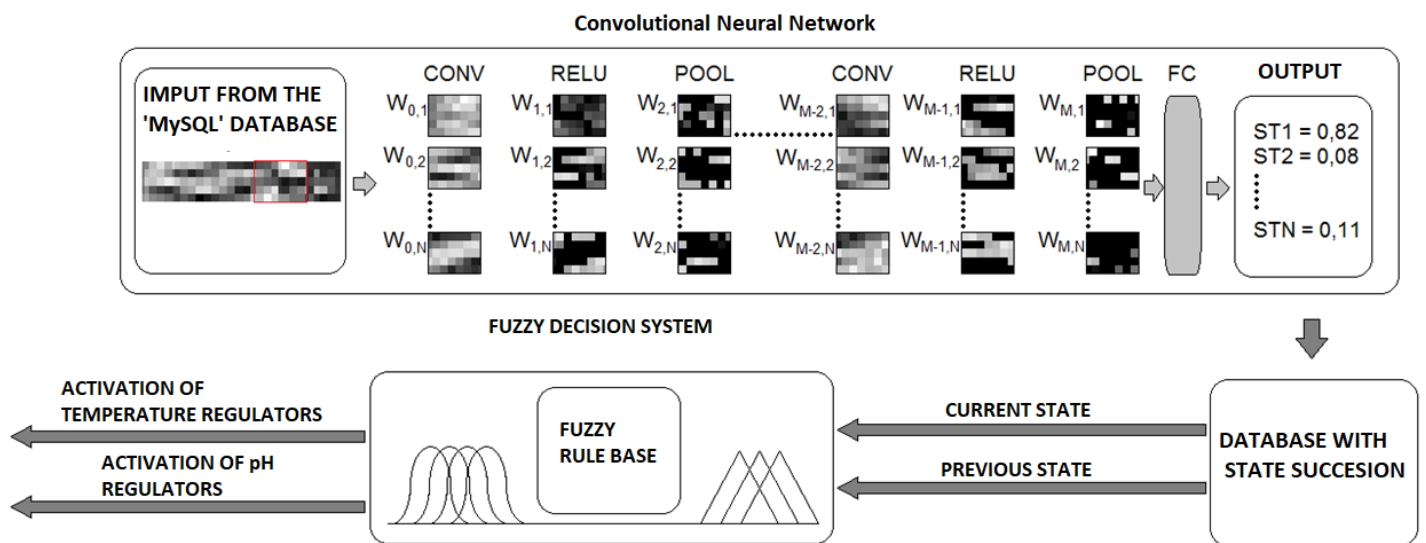
**Figure 11.** The obtained convolution mask ( matrix)

The matrix of states is read as input of the convolutional neural network. The convolution mask goes through the matrix of states by reading step by

characteristic states of the process  $ST_i, i = 1 \dots N$  characterized by specific traits over a certain period of time are initially established. The purpose of RNC processing is to identify a certain state of information obtained from data measured on the 5 channels.

Data stored in the MySQL database is normalized and loaded into a 5-line matrix (MST). The number of columns of the matrix is determined by the time it takes to identify a particular state of the process and the sampling time of the measurements. The matrix obtained (Figure 11) is refreshed whenever a new measurement value is read in the MySQL database.

step the measurement data. The magnitude of the convolution mask is set to include a significant set of data to identify any state.



**Figure 12.** Decisional system

The data is processed within the network and finally the state identification score is determined by the total connected network (FC) module, thus fusing

the data. The set score is actually the probability with which a certain state of the fermentation process has been identified. The identified states are

saved in a database in order to be able to monitor the sequence of process states. The current and the previous state are passed to the fuzzy decision system that sets the process control parameter values (in this case temperature and pH value) so that it produces optimal results.

The described system performs the primary level sensory fusion through the MTS matrix and then identifies the state of the process by the score of the total connected network. This can be achieved by adjusting the fermentation process based on the measurements made with the five sensors.

## 6. ACKNOWLEDGEMENTS

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