A Monitoring and Control Software Tool to Assess Process and Production Data in Olive Oil Production Units

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Abstract. Monitoring of production processes in the agricultural and food sector can provide significant advances in equipment life and product quality and furthermore improve visibility and trackability in the digital supply chain context. On the other hand, automation and control are of major importance for flexible and sustainable production systems that minimize labor costs reduce down time and operation and maintenance (O&M) costs. In this context, an efficient Monitoring and Control software Tool (MCT) for assessing the operation data of an olive oil production facility is proposed. The design architecture of the system is presented followed by practical implementation data obtained at a small industrial scale olive oil producing facility. Initial results and information obtained constitute a solid basis on which to found a future full-scale application of the proposed tool to monitor all stages of the production facility.

Keywords: monitoring and control, process and production data, olive oil production.

1 Introduction

Olive oil constitutes a major product in the area of the Mediterranean and a key ingredient of the diet of the region. Furthermore, its production is a major source of income for thousands of farmers in a significant number of small to medium scale production facilities. It is therefore imperative to perform research on how to optimize both the olive cultivation (Orellana et al., 2011) and the production process of olive oil as this will have a direct effect on the quality of the final product (Kalogianni, 2015; Ortega et al., 2016;), on waste and energy management and thus on the economy of the process and the competitiveness of the associated businesses.

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Modern Information and Communication Technologies (ICT) can certainly play a key role in the pursuit of enhanced product quality in the food sector. In particular, monitoring and control systems and tools can improve visibility and trackability, creating a digital supply chain in a production process, thus help assess key data and plan interventions in the production facility in order to optimize the performance and efficiency of the production cycle and the quality of the final product. For example, Jimenez et al. (2008) propose the development of a dedicated system based on an artificial neural network for real-time prediction of the moisture and fat content in olive pomace using two-phase olive oil processing. A similar approach of using a method based on Neural Networks (NN) is also presented in Jiménez et al. (2008) and Jiménez et al. (2009) in an effort to optimize the operation of the Horizontal Centrifugal Decanter (HCD) in the olive oil production process. Esposto et al. (2009) propose the use of a specialized analytical system (EOS – Electronic Olfactory System) with a total of six (6) metal oxide sensors (MOS) installed only in the malaxer. A similar system (EOS) with six (6) MOS has been also used by Lerma-García et al. (2009) for the monitoring of the oxidation level of the Virgin Olive Oil (VOO). Escuderos et al. (2013) propose the use of 14 tin dioxide sensors (SnO_2) used for the analysis of olive oil production, however, at the expense of complexity and use of custom made sensor technology

The current paper presents the design and pilot test application of a **Monitoring and Control software Tool (MCT)** in a small industrial-scale olive oil production plant used for research and educational purposes located at the Alexander Technological Educational Institute of Thessaloniki (ATEITh). Compared to the work presented above, the proposed system is characterized by its simplicity using widely available sensors, and the use of common industrial protocols, its flexibility in operation and its ability to **present real-time information** in what's most important, a **user-friendly interface.** Initial results are encouraging about the potential use of the tool to obtain and visualize important information to assist in the assessment of key data in the production process.

The paper is organized as follows: first the system layout and architecture is presented with details of its characteristics, followed by a description of the pilot test facility. Then, the developed software and its use in the test rig facility is presented with a description of the scaling up procedure of the application of the tool to include all key parameters in a small scale olive oil production unit.

2 System architecture

The basic principle of the system architecture is to have a modular structure with discrete layers that can be easily integrated into a seamless application. The overall system architecture includes four (4) layers:

- A layer including embedded sensors of various types located at various points along the production line
- A data aggregation layer using a standard microcontroller or a programmable logic controller (PLC)

- A data manipulation layer using an industrial computer where the web server components and the applications are installed
- An on-line data monitoring and visualization layer, with (i.e. remotely) or without (i.e. locally) a web based interface.

The basic system architecture is presented below:

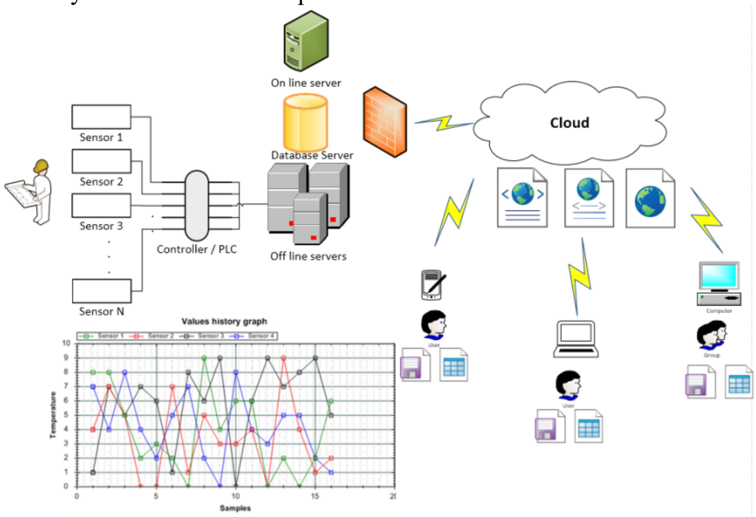

Fig. 1. MCT system architecture

Embedded production sensors provide raw data to the microcontroller/PLC with the use of external hardware interfaces and dedicated firmware software. The microcontroller handles raw data by using specific sampling rates and finally supports bidirectional wireless or wired data communication with the mainframe computer.

The MCT recognizes the available sensors for each recording, schedules recordings at specific sampling rates, provides data visualization screens for all sensors (real-time and historical values of the sensor), identifies out of range values and provides appropriate feedback to the system and the user and finally saves the recording in the popular XML (eXtensible Markup Language) format. Moreover the proposed tool can compare specific sensors from historical data and export historical recordings to the popular comma separated values (CSV) format for promoting interoperability with third party software. The tool is developed in the C# programming language.

3 The test rig facility

Experiments were performed using a small industrial-scale (nominal capacity 500 kg_{olives}/hr) olive oil production unit (Alfa Oliver 500, Alfa Laval) located at ATEITh (Figure 2). The scale of the plant allowed taking into account process variables and their variations in an actual production scale. The unit consists of olives washing and leaves removal machine, a toothed disc crusher combined with a pit removal system (operated optionally), 2 malaxers with capability of simultaneous operation under different conditions (temperature, modified atmosphere, open/closed, paste dilution rate) a two-phase decanter and a disk centrifuge both with capability of regulating process temperature and water dilution rate. The processing plant is completed by two temperature regulated water tanks one for dilution at different process stages and the other for temperature regulation of the malaxers.

Fig. 2. Olive oil production facility at ATEITh

The operation of the production facility is controlled via a panel located in the central part of the unit. It is important to note that the user interface of the application is rather minimal, allowing only basic information to be viewed in small displays, a fact that necessitates the presence of an operator to record key data about the production process. Therefore, no analytical data, sampled and manipulated at a frequent and regular basis can be obtained, nor is it possible to keep a detailed historical track, to facilitate the assessment of the production process and most importantly, its effect on the quality of the final product.

The production facility has a control panel with four TLK-31 microcontrollers that communicate through the RS-485 shield (Figure 3) using the MODBUS - RTU industrial protocol (Kunte and Shaikh, 2015).

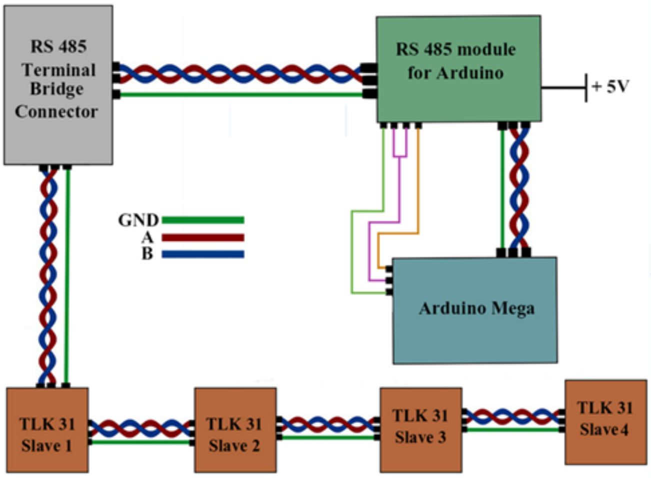

Fig. 3. MODBUS - RTU Industrial Protocol.

The temperature sensors and the flow sensors provide data via a standard microcontroller, in this case an Arduino Mega, to an off-line computer which processes the data and acts as a server. The Arduino Mega is connected to the Server using the APC 220 (418-455Mhz) wireless radio communication antennas (Figure 4).

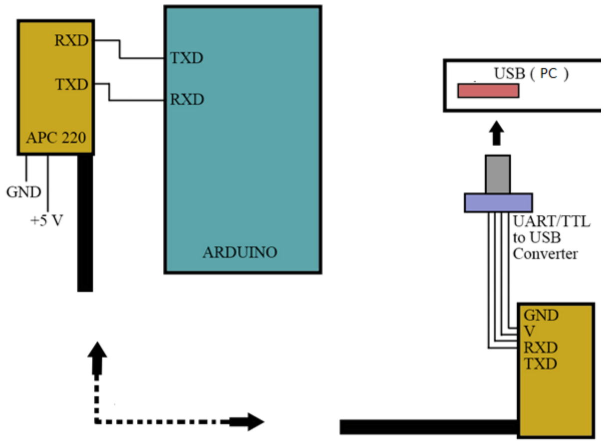

Fig. 4 APC 220 wireless radio communication antennas.

4 Developed Software

The initial pilot case application included the incorporation of four PT-100 sensors connected to the TLK-31 microcontrollers. Two of the sensors were located in the malaxers and the other two in the water tanks. The system has also the ability to connect to up to four flow sensors (G1/2" OF-201, 1-30 L/min, 3-12V DC, Accuracy: +/- 0.5%, max pressure: 0.5 MPa at 20 oC) for measuring water or oil quantities. All sensors have been calibrated before connecting them to the Arduino Mega (ATmega1280 microcontroller). Suitable, user-friendly interfacing has been developed and the user can monitor and store information in a compact and efficient manner. At a first level, the number of sensors, sample rates and scheduling options can be easily adjusted, as seen in the Figure 5:

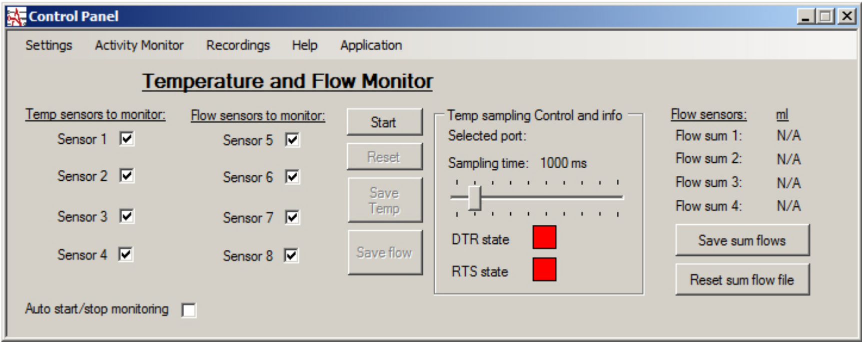

Fig. 5. Recording parameters

Excess limit information can be easily captured (textbox with the red background color in Figure 6). Different visualization patterns (e.g. lines, bars etc.) can be used, as seen in Figure 6:

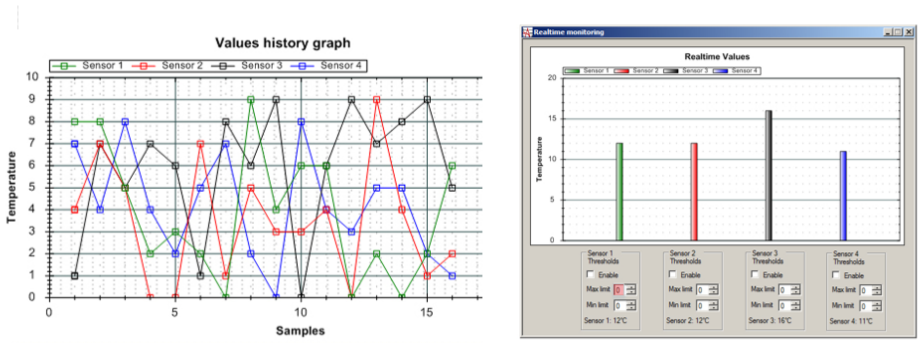

Fig. 6. Data visualization options

The user has also the option to save the current session and then view/compare sensor information from multiple recordings to assist the assessment procedure. Last but not least, the user can export a recording session in a popular format like Microsoft Excel for easier manipulation, as seen in Figure 7:

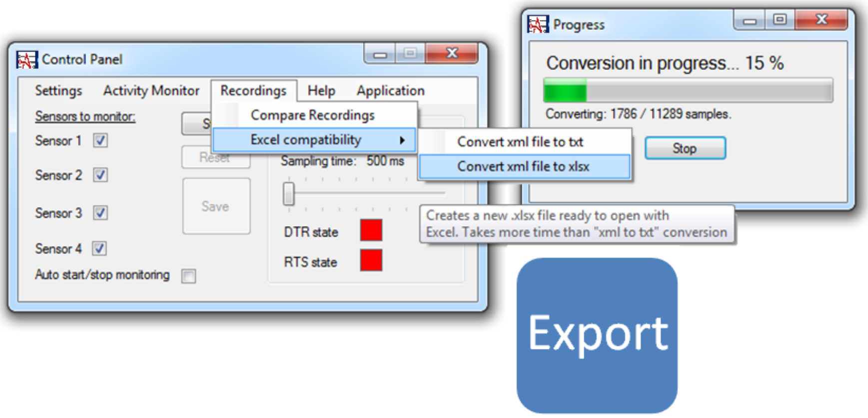

Fig. 7. Data export capabilities

Finally, the server runs the Apache Web Server and the MySQL database in order to publish data to the remote users. Users can log in to the web interface tool, perform real time monitoring of the olive oil unit operations and analyze past recordings (Figure 8).

Fig. 8. Web-Based Monitoring tool.

5 Scalability potential

From the analysis presented above, it is clear that the proposed MCT is a valuable tool for the operator to obtain a thorough and clear picture of key data about the production process that enables the assessment of the operation, the identification of points where key adjustments can be made furthermore recorded data can be used to correlate final product quality with key process variables.

Further work is underway to expand the potential suite of measurements and provide a scalability potential of the method. Important issues that are currently under investigation include:

- To increase of number and type of sensors (e.g. flow, pressure, etc.) in order to measure and control process variables and in order to perform in-line rapid measurements of olive oil quality
- To obtain a tool that enables in-depth research of process variables on olive oil quality
- To obtain a critical mass of recordings that will allow useful correlations between the quality of the final product and key variables in the production process.
- To enhance the applicability of the method by introducing a fully functional web-based approach where users can remotely manage olive oil facility.
- To develop suitable educational material and enrich the educational process at ATEITh both for students of the agricultural/food sector and the IT/automation sector, based on the application of the tool.

6 Conclusions

In the previous section the design and development of a Monitoring and Control Software Tool for enabling the better assessment of key data in a production line has been presented. Initial tests have been performed for an olive oil production unit facility located at ATEITh using real time measurements from a set of temperature sensors. These tests showed the capability of the system to display in a user-friendly manner and record valuable process data (temperature and flow rate for the moment) which can be further used for valuable correlations between process variables and quality as well as an input for process control. The preliminary results obtained show the great potential of the tool to assist in the assessment and better operation in general of the production process. Further work is underway to scale up the application up to its full potential.

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