Embedded System for Smart Vineyard Agriculture

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Abstract— This paper proposes a system for smart vineyard agriculture. In the town of Naoussa, which is known for its wine making and trade activities, we approached the local wine makers and agreed on certain digitally enhanced facilities that could be offered by an embedded system. This paper describes the problem and analyzes the way it was formed along with a respective literature review on the subject. We present the platform we used and we explain our design methodology decisions as regards the system's main functional parts. Hardware and software requirements are identified as we move towards a power-efficient, embedded system that uses sensors to acquire critical environment measurements and inform agriculturists or farmers through the GSM Short Message Service (SMS). The hardware design and the respective software structure are presented, leading to a proposal about creating a specialized board. The code structure is explained and the main parts of the system are discussed. Finally, conclusions are stated and a possible future full-scale single PCB, governed by the principles of Open Source Hardware, is considered.

Embedded systems; vineyard agriculture; smart farming

I.INTRODUCTION

The penetration of smart computing devices into everyday life is nowadays a given fact. Terms like *ambient intelligence* and *ubiquitous* or *pervasive computing* describe the trend of embedding information processing techniques into our work, leisure and life transparently and yet effectively. In this context, "smart agriculture" comes as a natural scientific activity that aims to serve both humans and their environment simultaneously. The use of smart, easy-to-use, transparent, computing devices can prove highly beneficial in maximizing the products of cropping systems, while maintaining a sustainable and eco-friendly farming practice.

This paper presents an attempt to create a smart embedded system that will aid vineyard agriculture in a cost effective and flexible way. We decided to take up this effort because our department is situated in Naoussa, a town in the northern part of Greece, which bases much of its economic activities in wine making and trade. The local wine cooperative, Vaeni, has long been an active player in this typical Greek usiness area and it is worth mentioning that it recently achieved the greatest wine trade deal ever signed between Greece and China [1]. We, information about the process of vineyard agriculture along with its respective problems.

Namely, we addressed the problem through a design process, which is presented in Fig. 1 and is divided in seven phases. Initially, we had extensive meetings with cooperative representatives along with three farmers who have large experience in vineyard farming and wine production Consequently, we consulted two agriculturists with expertise in wine making and aging. The acquired details were significant and quite informative. All the respective parties agreed that a frequent information update about weather conditions in the vineyard is of absolute necessity. This update should be carried out every hour and it should include the ambient temperature and humidity, because these two factors have a great impact in most of the thereafter stages.

Furthermore, these two measures, apart from being instantly transmitted, they should as well be properly processed in order to formulate a comprehensible suggestion message that will also be transmitted to respective users.

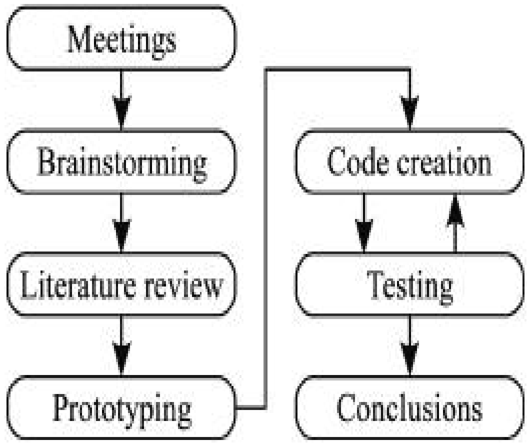


Figure 1. Design process

During the brainstorming phase, we considered various solutions that could meet the diverse initial demands and we examined the potential platforms and hardware equipment that could be utilized. Our final decisions are presented in the second and third sections of this paper.

As regards similar efforts, NASA proposed a prototype that refers to the creation of a digital farm system that transmits information about agricultural activities [2]. Other cases include RF and WiFi transmission of sensor-acquired data [3], [4], [5]. In the SMS type of communication we can identify the *botanicals* initiative [6] [7], while an effort that utilizes the Arduino platform is mentioned in [8]. In the Greek area, similar attempts are carried out by the company "inventor engineering" [9] and by a joint five-partner research project called "HydroSense" [10].

II. PROBLEM DECISIONS AND DESIGN METHODOLOGY

Our system is based upon the Arduino platform (http://www.arduino.cc), which is an open-source electronics prototyping board (Fig. 2). It features an Atmel AVR 8-bit micro-controller (ATmega328P) and a number of easily accessible digital and analog I/O pins. It can be programmed and powered through a USB port and power can also be provided through a DC-in jack.

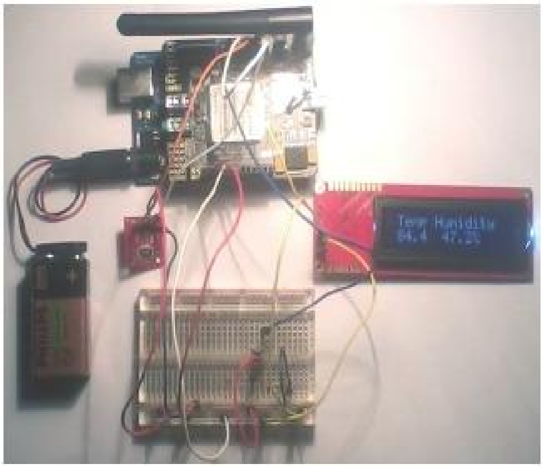
Figure 2. Arduino Uno

This board has become widely popular in communities that are not only technology oriented. A vast amount of information about it can be found over the Internet and diverse projects have been built around the Arduino board. These projects range from infrared controlled helicopters [11], medical jackets [12], interactive artwork [13], autonomous vehicles [14] and sensor networks [15] up to smart home applications [16], undersea robots [17] and 3D printing [18].

Apart from its popularity, the Arduino Uno board, that we selected, is characterized by high versatility and low power consumption. These were the key factors for its selection along with its open hardware philosophy that we also aim to follow. In particular, ur initial requirements regarding hardware and software can be listed as follows: easy and direct prototyping, user-friendly programming environment, hands-on debugging abilities, low power demands, significant user support, access to all hardware and software details, straightforward product packaging, ability to make one compact PCB, low manufacturing costs and as much fault tolerance as possible.

These requirements were largely satisfied by a system that would combine the Arduino Uno platform along with commercially available *shields* and distinct electroni parts. Shields are add-on boards that can be plugged on top of the Arduino PCB using the female connectors appearing in Fig. 2 and extending its capabilities. Among the various existing shields we identify their common philosophy: they are easy tomount and cheap to produce. As a result, one of our targets is to build a new shield that will be directly oriented towards vineyard farming.

III.HARDWARE DESIGN AND SOFTWARE STRUCTURE



Moving on to the software of the system, we state that we used the Arduino development environment, which is actually based on *Processing*, an open source language and development tool that follows the object-oriented paradigm (http://processing.org). Our code is straightforward and specific and it does not need the support of an underlying operating system. It is divided in two main parts, with the first part being directed towards user initialization parameters. Specifically, the user is notified through the LCD screen to enter a permanent phone number that will receive the SMS messages and the current date and time in a single-stage data setup.

The second and main part of the code contains all the necessary data acquisition and decision-making commands to monitor the farming procedure. The SHT15 sensor is being polled every 3 seconds in order to acquire temperature and humidity measurements, which are subsequently displayed on the screen. Through a series of decision tructures we constructed a moderate expert system, based on the advices we received from vineyard agriculturists. These structures formulate a respective message that can be transmitted to the farmer on an hourly or monthly time schedule. These messages can be warnings about sudden and severe weather changes, advices for a required cropping action or simple notification postings about the current state and health of the far.

The system code was compacted to just over 600 code lines and it was developed in a month’s time with test and debugging lasting an additional 20 days. It contains 7 functional modules (procedures and functions) and was made possible by 3 created libraries. A typical excerpt of the code appears in Fig. 4. The code, along with all the hardware design models are provided through an open-source governed license. Our intention is to follow the open philosophy that rules both the hardware and the software of the Arduino attempt in the spirit of open source hardware that gains increasingly more popularity.

Our current step is to create a specialized shield (Arduino pluggable board) that will host all the parts in one single add- on PCB. This shield will be stacked upon the GPRS shield to formulate a three-layer board structure, which will be housed in a prefabricated enclosure with an opening for the LCD screen. This intent can become possible through the Fritzing Fab service (http://fritzing.org), which provides a free design environment that directly leads to PCB sketches. In particular, the fritzing environment allows users to design their actual breadboard-based project and it directly reflects the project to a potential PCB of a shield in an automated way. Of course, post processing is allowed in order to let the users tide-up and formulate their product according to their taste and housing needs. Fig. 5 presents our respective project design of Fig. 3 inside the Fritzing environment. The similarity of look-and-feel proves the user-friendliness of the respective initiative.

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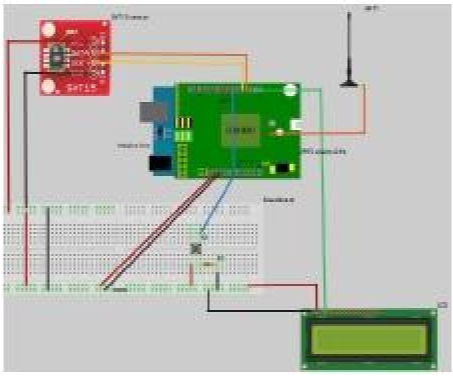

The purpose of this shield-making decision is to allow the easy expansion of the system with even more stackable shields that will permit the increase of the potential functionality. Specifically, a WiFi shield could allow an alternative communication path and a MicroSD shield could enhance the storage size for vast data archiving. Finally, a motor shield could drive diverse modules that would aid the cropping procedure.

In order to materialize this shield-stacking technique, we had to carefully design our PCB in such a way that all available I/O ports would still be offered in female connectors and we attempted to occupy as little digital ports as possible so as to leave available ports for other future shields as well.

IV. CONCLUSIONS AND FUTURE WORK

Smart digital farming can prove useful in vineyard agriculture. Our first experiments in real-life conditions seem to prove our initial expectations and our cooperation with wine making farmers and agriculturists will provide even more feedback for program enhancements and code fiddling. The required manufacture and infrastructure costs were kept low, taking under consideration that we are still in the prototype phase, and simplicity was adequately achieved, although this often comes opposing to advanced user interaction abilities.

Apart from raw labor cost savings, we expect our system to aid in water management optimization, better soil nutrition, decreased fertilization, farming automation, improved maintenance reaction times, food-chain monitoring and statistical data dissemination. On top of that, we expect this automation to ease the risks taken by farmers and allow more young people to invest in vineyard farming activities, knowing that agricultural skill and advice can be at the their disposal uninterruptedly through simple digital communication means.

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