

The Development and Implementation of an Aquaponics Embedded Device for Teaching and Learning Varied Engineering Concepts*

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Practical work is an important part of the educational process. In this paper the requirements, hardware and software architecture development and the implementation of an aquaponics embedded device (laboratory model SmartVegeTech) are presented. This system has the possibilities of remote control, rich user interface and other features. The SmartVegeTech system could be used in education in different engineering fields such as control engineering, process engineering, software engineering, as well as agricultural engineering. The educational tasks in control engineering as well as initial feed back from students will be presented.

Keywords: aquaponics; remote control; control engineering; process engineering; software engineering; agricultural engineering; education

1. Introduction

In today's world there are a number of important research initiatives and educational challenges in areas of: renewable energy sources, energy savings, bioengineering, agricultural engineering as well as food production. They require a multidisciplinary system approach to solve them and present-day engineering education is not adequately preparing young engineers for the challenge. Therefore, education for these areas demands usage of multidisciplinary approach based on active learning in laboratories, learning on real life systems and practical work (among many other changes). The education of present day engineers demands a combination of knowledge, skills as well as multidisciplinary approach in solving different problems. Multidisciplinary learning activities along with multidisciplinary learning tasks, demonstrate how different subjects are integrated and applied in real life problems. Active learning and learning on real life examples increase a student's performance in science, engineering, and mathematics [1]. One of the greatest challenges for teaching and learning in engineering field is to provide illustrative examples for active learning where students will be able to practically use their knowledge and understand implementation of different engineering concepts on the real life problems. Implementation of different educational set ups connected to the Internet in order to provide web based remotely controlled

experiments could provide an opportunity for better education for all engineering. A number of researches emphasise the need for practical training in engineering education using advantages that an ICT system offers (virtual and web laboratories as different laboratory set ups supported by ICT) [2–5]. It is clear that multidisciplinary tasks, problem solving approach and presentation of different engineering problems on real life examples could provide the opportunity for increased motivation of students, define problems in new ways, explore multiple perspectives, challenge their thinking, and develop the real-world skills needed for planning and carrying out multidisciplinary engineering projects (leading to better educational results). Using laboratory models that could demonstrate different concepts present useful educational tool.

In this paper we will present the development and an implementation of low price aquaponics embedded device—a laboratory model SmartVegeTech system (SVTS) as one representative of laboratory models that could contribute to better learning and understanding of complex and multidisciplinary engineering tasks. Also, the possible educational tasks as well as initial students feedback will be presented. It is important to present that multidisciplinary educational set ups based on real life examples have potential to increase student's motivation to learn some of the engineering field such as control engineering. Also, multidisciplinary tasks provide great opportunities for students to under-

stand their engineering field in the broader context and to understand specific tasks of their own field.

2. Literature review

Teaching engineering and engineering concepts demands work both on knowledge and skills and it requires intensive laboratory work [6]. Modern technologies enable both, using real life laboratories as well as remotely controlled laboratories and even virtual laboratories [7–10]. Also, it is clear that students who are living in modern digital age demand different approach for increasing their motivation for different engineering tasks. At University of Kragujevac, the Faculty of Engineering we introduced approach that students in engineering fields need to have multidisciplinary laboratory tasks in order to understand the position of their engineering field and interconnection with different engineering and scientific fields. Among other laboratory set ups the model of aquaponics system is developed and introduced for practical and active learning of students. Aquaponics (sustainable food production system) is the combination of aquaculture (fish farming or aquatic animal farming) and hydroponics (growing plants in media other than soil, water for instance) [11, 12]. On the one hand, while commercial aquaponics is a multi-million dollar a year industry, the basic principles and equipment remain easily transferable to the classroom to provide an educational set up for the teaching and learning of different engineering fields: control engineering, process engineering, software engineering, agricultural engineering [13, 14]. On the other hand, training on this kind of equipment and its commercialization could contribute to the answer to some major challenges when considering the fact that an increasing human population combined with the fact that arable land expansion has slowed down substantially in the last 50 years as well as the amount of water eligible for irrigation will again put in to focus issue of food production. Producing healthy food in a clean sustainable way means saving resources and the environment which is part of the seventh UN millennium development goal, therefore education in different fields is very important for reaching this objective.

There are a number of systems which can commercially cost about 7,000\$–10,000\$ or more but still haven't the possibilities of remote control, rich user interface and other features that the SmartVegeTech system provides. The cost of the SmartVegeTech is less than 500\$. Other low cost aquaponic solutions currently on the market are Earth Solutions Little Tokyo Aquaponics Container Gardening, Raup Aquaponic System 250wl,

AquaBundance Aquaponics System Charcoal or educational systems such as F-5 Fantastically Fun Fresh Food Factory and Home Garden Nelson and Pade. Aquaponics systems are used as commercial systems but they are also used for educational and research purposes at different Universities especially in teaching sustainability, agriculture, agricultural engineering and food production [15–18] (Vancouver Island University [19], The Aquaponics Group at the University of Hawaii's Aquaculture-Hub [20], The University of the Virgin Islands Aquaponics System [21], Aquaponics—University of Arizona [22], Aquaponics at Stirling University [23]). The SmartVegeTech system is developed primarily as an educational set up but with wider objective: to serve as a computer added (and remotely controlled) educational model for educational purposes in broader engineering disciplines (control engineering, software engineering as well as agricultural engineering). Presented model is also used for the training of people in sustainable farming and other fields of training and education [24].

The SmartVegeTech system is designed to support the simultaneous cultivation of plants and aquatic animals in a symbiotic environment where the animal effluents that accumulate in the water are used and filtered out by the plants as nutrients, after which the water is recalculated back to the animals. Since the fertilizer is fish waste, unlimited amounts of plants can be grown with a relatively small amount of water. Building a solution around this logic, called the Hydrogen cycle, we developed an educational device for engineering education, respecting the principle of the sustainable cultivation of vegetables with low consumption of soil, water and energy resources. Of course, there is a number of different implementations of aquaponics systems considering technical, usage and other exploitation aspects [25].

The presented aquaponics SmartVegeTech system is designed to be used in different engineering fields, starting with control engineering (Concepts of modelling and system analysis, Algorithm management in a broader sense as well as restriction factors in the real functioning of the system) software engineering (development of different software add-ins for the presented software solution or development software solution using different platforms) and agriculture and agricultural engineering (applying engineering science and technology to agricultural production and processing).

3. The development and implementation of a laboratory model

3.1 Requirements for the laboratory model

As it has been mentioned, aquaponics is the combi-

nation of aquaculture (fish farming) and hydroponics (growing plants in media other than soil). Fish and plants are living organisms that will die if not properly cared for. Giving students the responsibility for maintaining aquaponic setups will help engage them but should be overseen by a responsible adult. Generally, it is important to provide a proper living environment for living organisms.

According to literature [26, 27] fish should be kept at 24.5°C in a 24-week growth circle. Feeding rates started at 2.5% per day for a 100g fish and would be gradually reduced to 1.25% per day for fish of 400g. With this regime, fish were expected to reach a market size (700g) in 24 weeks. The plants grown were selected according to their commercial importance and their conductivity factor (CF, $100 \mu\text{S} = 1 \text{ CF}$) that indicates their tolerance to different concentrations of minerals and their ability to extract minerals including nitrogen. Three groups were found in literature: Group 1, (high CF (20–40, tomato and egg plant)); Group 2, (medium CF (10–20, lettuce, basil, chives, spinach, parsley and cucumber)), and Group 3, low range of CF (2–10, water cress).

The plants should be grown in greenhouse conditions at an air temperature of 22–25°C. So, it is important to ensure provision of adequate control and management systems for the problems of fluid transport, storage and fluid retention in tanks, transfusion, as well as temperature control.

3.2 Technical requirements of the model

The system was realized as an automated low cost embedded system, it allows users with no farming or technology experience to plant vegetables using vertical farming logic [27].

The whole system could be powered by solar or wind energy (if it is possible depending on geo location) or in a classic way.

The VegeTech Embedded system shown in Fig. 1, consists of three basic layers:

- The physical layer consists of an eBox processing unit and Interface for measurement and control (IMAC) which over an RS232 connection communicates with the eBox and control hardware components, obtains sensors' analog signals and digital input/output signals.
- The eBox hosts a custom OS design based on Windows Embedded compact 7 and the given eBox BSP. To provide the desired functions we included functionalities shown on the left side of the diagram.
- The application layer consists of C++ libraries, 3rd party gSoap library and Silverlight for embedded libraries. The database is SQL Compact 3.5.

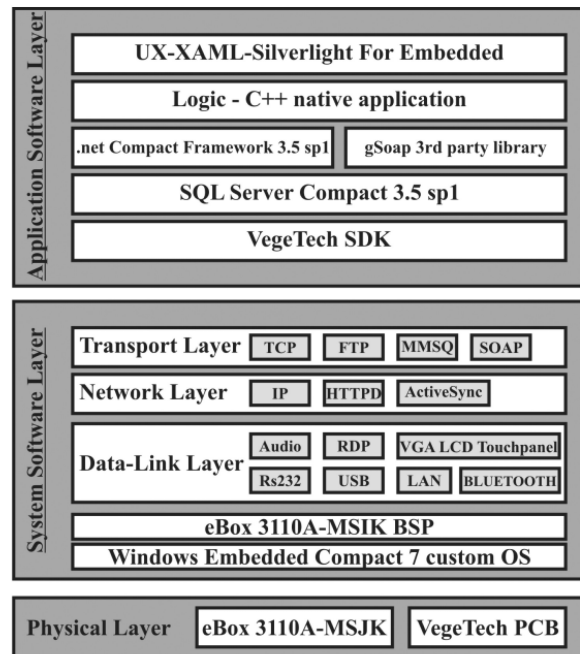


Fig. 1. VegeTech Embedded system architecture based on 3 layers.

Most importantly, the system requires minimum human support so that users of the system can work during the day without worrying about their smart farm.

3.3 Hardware architecture of the VEGETECH

The hardware architecture consists of three basic parts: a system for irrigation (includes tubes, el.vents, sensors, pump, aquarium with fish and reservoir), an embedded SVTS (includes eBox [28], IMAC and optional display) which is placed in one control box-table, and the third part is plant beds with vegetables.

A small and energy efficient embedded device for project realization was used. The choice was an eBox 3310A-MSJK [29] portable device small and powerful enough to perform the given tasks including internet connectivity, real time processing and intuitive user interface.

The prototype parts shown in Fig. 2, were designed to be small (0.4*0.3*1.2 m), lightweight (total mass 8 kg) and easy to assemble (five minutes for assembly). The prototype demonstrates how the embedded solution can control three types of processes: the water cycle which is similar for aquaponics and hydroponics systems, the fast flood and drain needed in aquaponics and slow drip irrigation and which is used in classical planting in glass gardens. To ensure safety, plastic box for the placing of the control switch and bridge, which control high voltage elements and protect other elements against failure (short circuit), were provided to eliminate the chance that the user will have contact with them.

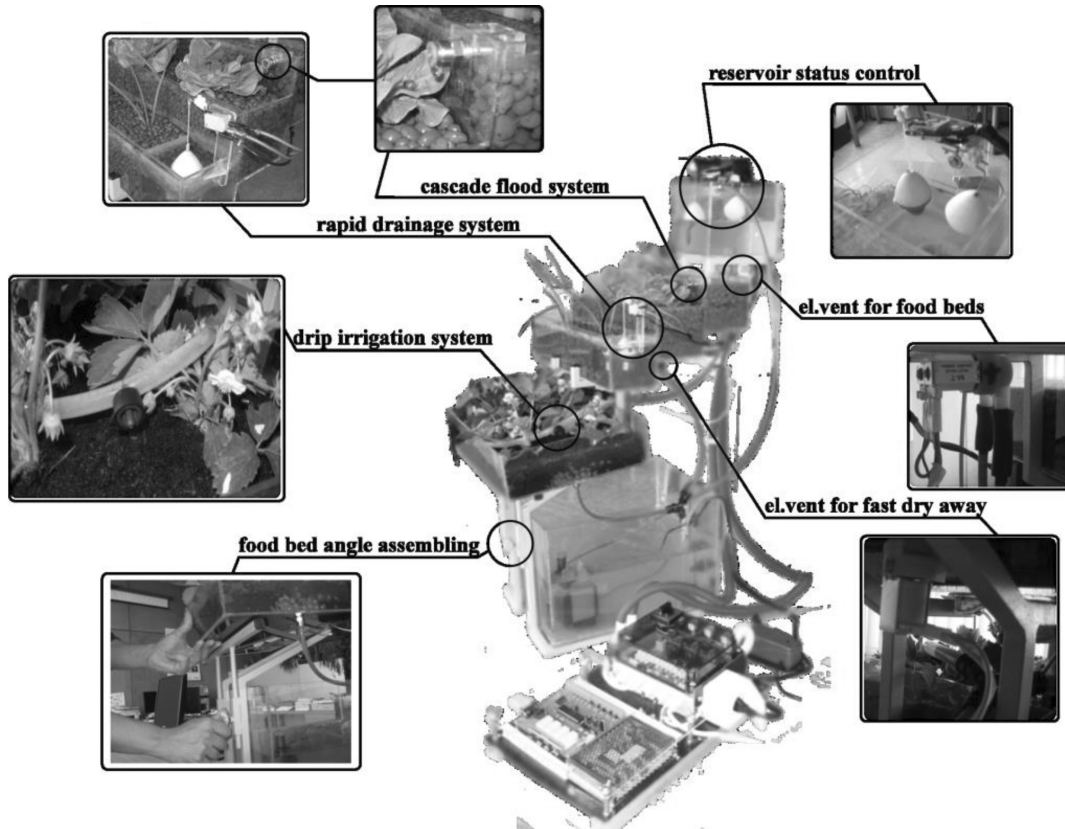


Fig. 2. Prototype and its basic elements of an Aquaponics Embedded Device for Teaching and Learning Varied Engineering Concepts.

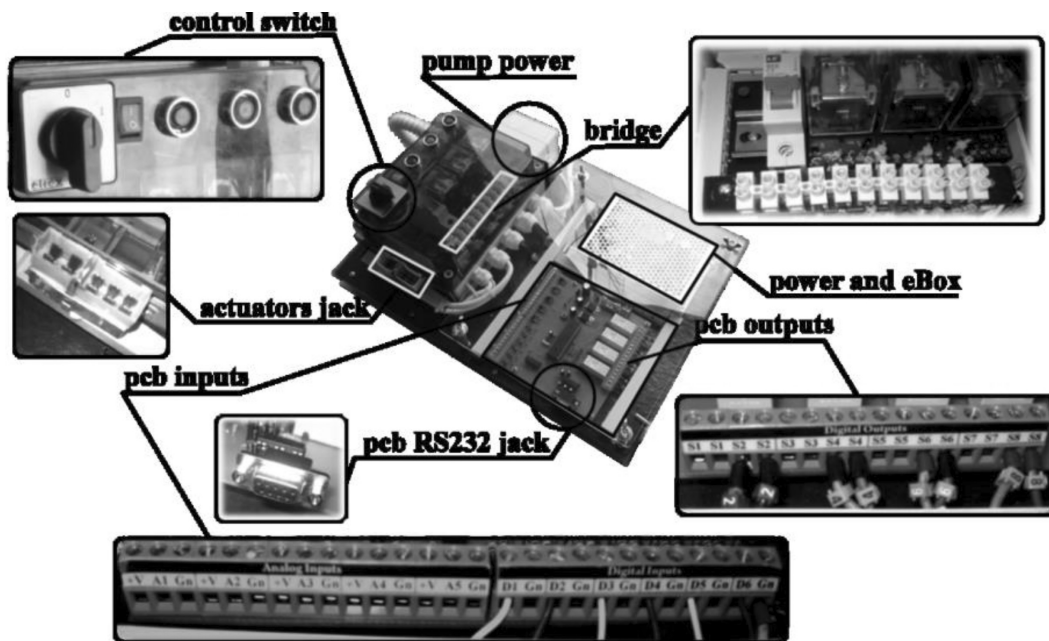


Fig. 3. Prototype hardware components of the IMAC system.

For easier assembling a simple plug-in jack for actuators and inputs is provided, the user only has to plug the actuator's jack into the appropriate signed slot and turn on the system (see Fig. 3).

The main processing unit is the eBox which has

two processes. The first and main process is called operate; it uses parameters from local compact storage, reads data from the IMAC and does calculations for controlling hardware components. The eBox communicates with the IMAC mother-

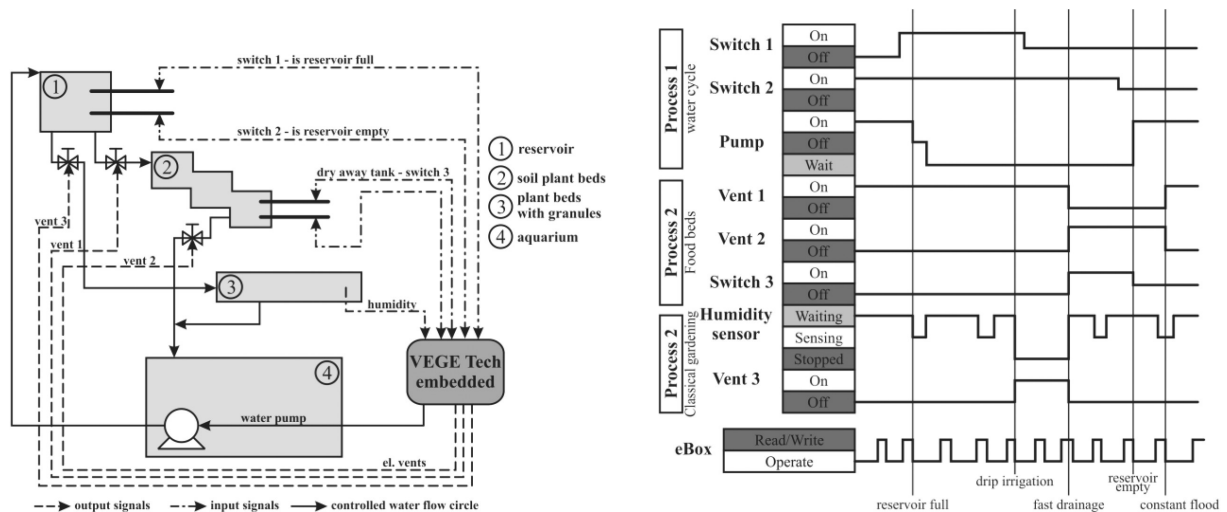


Fig. 4. Left sketch of data flow through prototype and right -processing data time diagram.

board via an RS232 connection and on the eBox commands the IMAC to read the analog signals from the sensors and converts them to digital. The second process is the soap listener which on request sends the current state of system.

The IMAC and other low voltage electronics are protected by a plastic panel which can be easily removed in case the user wants to scale the system. System scaling is possible through the provided input/output slots, they are all marked with appropriate numbers and the user will have instructions from the expert system on how to connect new plant beds, actuators or sensors to the IMAC.

On the left of Fig. 4 a prototype sketch with signed input, output signals and water cycle is shown to illustrate what they are controlling. Basically, three processes are controlled; firstly, the water cycle through switch 1, 2 and the water pump. This process is responsible for the that reservoir and whole system always having enough water for irrigation. The second process demonstrates a simple aquaponics/hydroponics irrigation system based on controlled flow. The third process demonstrates how our solution can control drip irrigation.

On the right of Fig. 4 prototype data time diagram with assigned important events and data changes when they occur is shown.

3.4 Software architecture of the VEGE TECH

The OS platform is Windows Embedded Compact 7, with Silverlight for embedded Virtual Labs that will provide our end users with a rich and intuitive interface for monitoring and profiling the device, without a previous training course or work experience with similar devices. The core of logic is a C++ native application which controls all processes and components [28].

It communicates over a reliable RS232 connection with the IMAC, a component realized with a microcontroller on a Printed Circuit Board (PCB). It reads a digital signal as well as analog inputs from sensors, converts them, and sends values to the eBox, also according to instructions from the eBox it controls the water pump, electrical vents and sensors. Prototype realization if the IMAC is based on the Microchip microcontroller dsPIC30F3014, which has enough resources to control up to 10 individual prototype food beds at once in commercial usage. For the Update-Upload-Improve (UII) system support, Windows Azure was used, because big traffic and big amounts of data are not expected, but only periodical updates, so it is “pay what we use” (Fig. 5).

Also, the UII realized as a service will provide for researchers ability to develop their own applications for consuming web services and data in their laboratories and help our system to grow.

In Fig. 6 the proposed user interface is shown. Firstly, it gives the user an insight into the available fish and plants in the database. Secondly it gives commands on how to profile the device and connect parts according to the settings interface. In the settings interface the user can profile every food bed according to his needs. It is necessary to choose the plant, fish and type of planting (aquaponic, hydroponics or drip irrigation) and the stage of plants. Also, it is important to provide a system of food bed volume and pump power, which is how the system will be able to control flow-irrigation.

3.5 Provided functionalities of the system

The system can be easily profiled according to the kind of vegetable, users want to plant and according

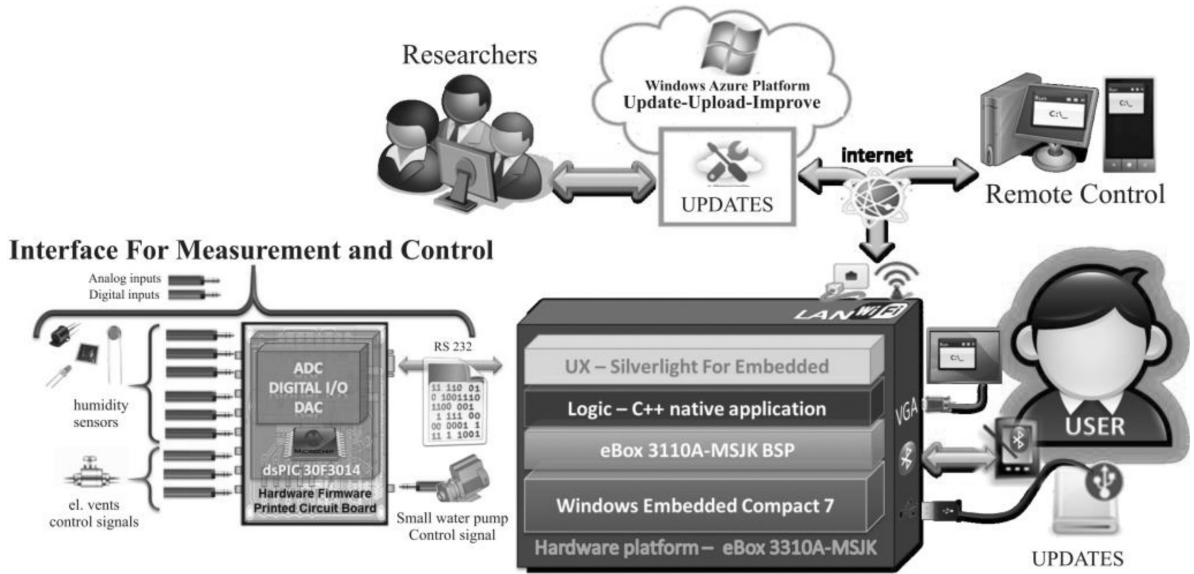


Fig. 5. The IMAC with software architecture and environment.

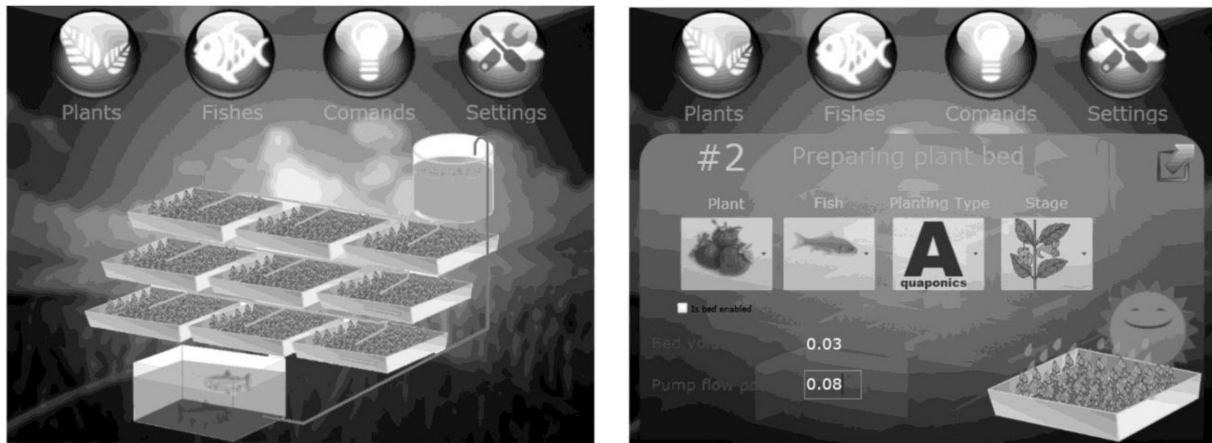


Fig. 6. User interface in solution.

to the geo location. This means that when a user decides to change the kind of vegetable, he doesn't need to change the whole system or additionally learn about how to grow different cultures. All he needs to do is to choose the desired vegetable on the menu, plant culture, and periodically update the system software to take up-to date parameters from the central server. Also, the direction and slope of the plant beds are very important, because the angles of sunbeams are different depending on the geo location, so the hardware is easy to adjust. All software and data needed to calculate the condition sets and control hardware components are stored in the embedded system, so that it can operate even when an internet connection is not available. The user can monitor the process via an LCD display, Bluetooth connection or from a remote PC (display is not necessary). When the device is connected to the internet it could be updated automatically from

the central server. On other hand, the data acquisition system from every single installed device can help developers and researchers to improve system efficiency via the UI system.

4. Possible educational implementations and tasks

4.1 Different educational implementations

The specified system could contribute to learning and could be used as a very useful educational device to demonstrate how a system of coupled water tanks works, how to apply measurement techniques, sensors, hardware components, how to develop useful control software and add ins, as well as to make different experiments with biosystems as a part of biosystems, agriculture, and an agricultural engineering laboratory.

As a part of control engineering education:

- The presented laboratory model could be used as a practical show case of a system with feedback and to depict general ideas, and terminology.
- Using the laboratory set up, students could get familiar with different sensors and their implementation in a laboratory environment as well as with the connection of different hardware and software.
- Students could acquire knowledge in modelling, process identification as well as in the definition and setting of various control algorithms (P, PI, PID, . . .).
- Get practical experience in the application of process computers (PLC, HMI, etc) and software for the implementation of specific control strategies.

As part of software engineering education:

- Programming of embedded processing devices, as well as development of a source code for computation in a dsPIC30F3014 microcontroller. Microcontroller based IMAC communicates with external computer with RS232 port and simple protocol (sending and receiving results in the form of ASCII strings)/ Source code is available so students could develop their own applications for control of described system.
- Development of software interfaces for different operating environments (different plants and different aquatic animals).

Agricultural engineers may perform tasks such as:

- Planning and development of irrigation and water control systems.
- Performing environmental impact assessments and sustainability assessments on food production using the aquaponics system.
- Analyze how flows and aeration in beds increase for example, oxygen availability to the plants and calculate more uniform nutrition supply.
- Analysis and definition of the best constant flow—pumping rate for specific system and settings.
- Definition of the best pH and chemicals in the water supply system in order to provide the highest production of plants.
- Make the best balance in the system for maximal gain (economical and environmental).
- Optimization of growth and nutrition issues in order to scale up the system to a commercial level.

Generally, the presented system could be used in different engineering, as well as in different multidisciplinary educational fields. One of the great advantages of the presented system is its scalability,

so the system could be used as a small scale system for educational purposes but also could be easily expanded to a commercial level. Another great advantage of the system is the fact that the presented laboratory set up looks more like a real life system than a laboratory set up.

4.2 Possible educational usage with example of project task

The presented laboratory set up, became a part of the education process during 2010 at the Faculty of Engineering of the University of Kragujevac. The laboratory set up was presented to students from the departments of Automatic Control and Industrial Engineering from the Faculty of Engineering as part of the course-control and measurement systems. Students were divided in groups of 4 and they had 3 educational (as well as development of new software wizards using the information from literature) tasks that were mentioned in the section above. The practical work with the laboratory set up lasted 6 weeks in order to make plants and fish growth obvious and to provide enough time for testing of different control strategies.

In the first step is necessary:

- Before the students tested the solution in practice the lecturer personally tested basic functionalities such as providing the given flow, software verification writing unit test and using Windows Embedded Compact Test Kit. Also, lecturer tested the flow and prototype without fish and plants to ensure that basic functionalities worked in practice.
- Students got information on how to the control device tester and successfully profiled the device to work for current configuration (two food beds, one aquaponic type and one classic drip irrigation). The user chose the right vegetable and fish from the slide menu and let the solution work.

Since the system is very flexible and could be used in different educational fields the number of different educational tasks is very large. Here we will state some characteristic educational tasks for students:

1. The Smart VegeTech System (SVTS) is a complex computer controlled system consisting of a large number of mechanical, electrical and control components, in order to provide balance in two biosystems (aquatic animals and plants). The first task for students is a detailed analysis of the system, a presentation of block and functional diagrams and a description of its functionalities. Students also need to describe potential constraints of the realized model and to define a suggestion for further development.
2. From a remote computer, using the web based

interfaces, students could access the eBox and download the log file with information of all inputs, outputs and sensors (measured temperature of water in the aquarium in last 24h, as well as the temperature of the air in the room where the system is placed). Based on this data students need to draw time diagrams of all inputs and outputs, as well as values on the sensors, and to provide identification and modeling of existing system.

3. For more advanced control engineering classes students could develop different control algorithms and test them on a real system by uploading them using the developed interface. After that they could monitor selected control strategies and compare them by monitoring different parameters (starting from the parameters on the sensors up to growth of the plants and aquatic animals).
4. In agriculture and agricultural engineering students could monitor the growth of the plants (using the web camera as part of the system) from a remote computer. They could control different parameters (temperature, humidity, flow of the water and in addition they could provide different chemical add-ins in the presented system) in order to define the best nutrition strategy for the living organisms. The same procedure could be set for aquatic animals adding an automatic feeding system and acquisition data from that system, in addition to other elements students could provide different strategies for the coupling of different species (plants and fish). The information from these tasks could be used in the development of predefined software wizards and interfaces for the automatic set up of parameters (Fig. 6 right). Making new wizards and add-ins could provide more options in the software solution (right now the software supports 3 groups of plants and 1 group of fish).
5. Students need to provide techno economical analysis in order to prove sustainability of the system, as well as the preconditions for its scale up for commercial purposes.

The system efficiency now depends on the parameters—we used parameters from literature but we hope that through time we will build a community of experts who will continue to research and improve the system.

It is clear that presented educational set up could be used in different educational fields. Possible educational usage and project task in the field of control and industrial engineering will be presented. It is also clear that system could be used in different engineering fields mentioned above.

As a part of different courses (such as Control Engineering, Concepts of modelling and system analysis, etc.) this project task has been given to the students of the Faculty of Engineering. Control strategy should be achieved by controlling/monitoring the level of liquids in the lower tanks, irrespective of changes in the position of valves that allow filling upper tanks. There are many possibilities for creating different control algorithms, which later can be tested experimentally by changing the parameters of the system and the introduction of disorder that clearly exist in the presented system. Synthesis of control algorithm is always based on pre-existent information on the model of controlled process and the available signals. Identification of the model is a special mission, as well as skills acquisition and signal processing.

Project Task. The plant is a tank filled with fluid (water). Output parameter is the level of fluid and temperature in the tank with fishes. The level of fluid is influenced by input flow and output flow. It is free to select control variable and disturbance. The task is to present solution for regulation of the level of the flow in the tank, simulation of results on computer, and verification of suggested solution:

1. The structure of the system: Define all components of system, describe it, and present mathematical model of the system. Students should present: Functional schema and description of work; Detailed and realistic (nonlinear) mathematical model of the plant in a broader sense; Static characteristic of the plant; Linearization of mathematical model of the plant near working point (defined with x% of maximal height of fluid level in the tank; different for each student); Structural block diagram of the system in continual and digital version; Check of stability of linearized model (using MatLab and Simulink, present linear and nonlinear model (continual and discrete).
2. Identification of the plant: Nonlinear Simulink model is the basis for further simulation and for experiment and parameter identification. Identification of the plant gives opportunity to examine effects of influence of model, input, sampling time, identification method on the quality if a model is developed. Procedure of identification of model using MATLAB and verification should be described.
3. Synthesis control algorithm: Selection of structure and adjustment of parameters of PID control algorithm. In this step, continual and digital PID algorithm should be defined.
4. The analysis of the system: Analyze dynamic features of the system with feedback using programming packages Matlab (to give the para-

meters and analyze the dynamic response in selected working point, the frequency characteristics of the system, poles and zero pole, etc.).

5. The results of the simulation: Simulation of function of control system with real aspects of the system (real plant is not linear). Test the validity of the control algorithm, digital and continual and present the appropriate diagrams.

Students report from the laboratory exercise should have this 5 sections plus conclusion.

4.3 Evaluation of usage and educational results

The presented system was introduced to students from the departments of Automatic Control and Industrial Engineering from the Faculty of Engineering. Students used the system as laboratory set up at their course during the educational process and filled on-line questionnaires in order to present their experience and evaluate benefits from the presented system (the results are presented in Table 1). The positive response from the student population was undivided; they highly evaluated organization and character of the Aquaponics Embedded Device for Teaching and Learning. The students accepted this educational tool and responded with the response that the system fulfilled planned educational goals, and that they completely understood the laboratory experiments' goals and tasks of exercises. The students also pointed that the system is user-friendly and easy to use. Students' questionnaire—character and organization of the web laboratory (Table 1).

It is important to emphasize that there was no negative reaction, and more important conclusion is that the specific set up could contribute to better and more quality understanding of the educational material.

5. Discussion

In this paper we presented a laboratory set up aquaponics embedded device—the laboratory

model SmartVegeTech system (SVTS). The SVTS provides good examples of maximized aquaponics production (by having a real life system) for education and demonstration purposes. The requirements for the laboratory model the conceptual architecture, hardware and software architecture and some functionalities of the system are also presented. The presented laboratory set up has both, advantages and disadvantages.

Advantages of the laboratory model:

- The system does not require too much human support (a few minutes daily). It is a completely new technology based solution.
- The microcontroller based IMAC can work independently of the eBox if there is OS failure, it will keep the last given state and will ensure that the hardware will not make any damage. After restarting the eBox communication will be continued and the device will work as before.
- The rich user interface makes work fluent no matter if the user had previous experience with farming or similar devices.
- The embedded part of the solution is completely automated, it is safe and easy to assemble.
- The food beds construction and material are not strongly defined, so the user could save money and build their own food beds and would only have to buy the VegeTech embedded system.
- The model is cheap comparing commercially available solutions and it also has additional functionalities such remote and Internet based control.

Disadvantages of the laboratory model:

- Despite the good results on the testing solution it is not tested in full commercial conditions, this means bigger food beds, a bigger number of plants and fish.
- If the user does not have an internet connection he cannot use full features such as remote controlling.
- As already mentioned, fish and plants are living organisms that will die if not properly cared for.

Table 1. Students' questionnaire—Effects of implementation

Effects of implementation of web laboratory	Mark (1–5) 5 the greatest				
	1	2	3	4	5
System provides better training					
Improves organization of course					
Improves character of lectures					
System helps to define problems in new ways and explore multiple perspectives					
System makes laboratory exercises easier and more interesting					
Decrease time of preparation for laboratory exercises					
Multimedia character of course					
Increased stimulation and motivation for students					

The presented laboratory set up can be easily upgraded and could be used in education and training in different engineering fields. A number of laboratory exercises could be performed on the described model:

- Control engineering (Concepts of modelling and system analysis, Identification of plan Algorithm management, Synthesis control algorithm, Restriction factors in the real functioning of the system, An analysis of the system).
- Process engineering (Problems of fluid transport, storage and fluid retention in tanks, and transfusion into the tanks; Chemical treatment or fluid mixing in the tanks, Control of levels and flow into the tanks is one of the central issues of process/chemical engineering systems).
- Software engineering (Programming and control of embedded systems, Programming of embedded systems, Development of software add-ins, Development and comparison of different software components on the same hardware platform).
- Agriculture and agricultural engineering (Irrigation, Drainage, Water control systems, Analysis of ecological advantages, It could be used as a research tool for optimization of the production of different plants, Analysis of organic fertilization of plants with natural fish emulsion).
- Even more, the aquaponics system has been introduced to schools around the world and students are learning through practical work in biology, horticulture, chemistry, math, agriculture, business, culinary arts and more (training of people for sustainable food production).

Another potential problem is the potential for lack of clear results in the area of agricultural engineering education. Different treatments will usually provide clear differences in plant growth. For instance, plants may grow faster on fish effluent than in tanks with no fish. However, each setup could be different, and the results may be hard to predict. One interesting feature of the described system is the ability to provide a learning facility for young people whose needs are not met in mainstream education, as well as for community service participants.

6. Conclusions

Engineering education demands intensive laboratory work, usage of different set ups, development of problem solving skills for students and intensive use of information and communication technology. In the modern educational era it is very hard to provide interesting, challenging and multidisciplinary educational tasks and set ups for students in order to

provide their understanding of engineering concepts, improving their skills and providing them a real life example that they could find in their future engineering careers. We presented the development of Aquaponics Embedded Device for Teaching and Learning that could be used for teaching and learning in different engineering fields, starting from control engineering, software engineering, up to agriculture and agricultural engineering. In this paper it is also presented potential educational tasks for students in the field of control engineering as well as the feedback from the students of the third year of mechanical engineering study program. It is important to mention that the developed system could be used in different fields, that it provides platform for real life examples and that students, in addition, consider introduction of such system beneficial for their engineering education. Presented system has some limitation starting from technical and software limitation, but it provides the good starting point for development of more complex multidisciplinary educational systems. Also, it will be necessary to use this system for a couple of years as laboratory set up in engineering education to realise the draw backs as well as a full potential of the system.

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