Level Monitoring System for Waste Oil Containers

M. Moura, M. Tasa, O. Olejniczak, N. Ahmad and the Spring 2012 EPS@ISEP Supervisors[†]
School of Engineering, Polytechnic Institute of Porto, Porto, Portugal
http://www.eps2012-wiki4.dee.isep.ipp.pt
epsatisep@gmail.com

***Abstract*—**Waste oil recycling companies play a very important role in our society. Competition among companies is tough and process optimization is essential for survival. By equipping oil containers with a level monitoring system that periodically reports the level and alerts when it reaches the preset threshold, the oil recycling companies are able to streamline the oil collection process and, thus, reduce the operation costs while maintaining the quality of service. This paper describes the development of this level monitoring system by a team of four students from different engineering backgrounds and nationalities. The team conducted a study of the state of the art, draw marketing and sustainable development plans and, finally, designed and implemented a prototype that continuously measures the container content level and sends an alert message as soon as it reaches the preset capacity.

Keywords—Arduino, sensor, waste oil, container, WiFly, battery.

I. Introduction

THE goal of the project was to develop a level monitoring system for existing waste oil containers. It has already been really difficult to reach an agreement about a final and appropriate solution. We have been looking for special and necessary equipment, which would make the ideas become real for the whole week. At the beginning we had to check the inside of the container. It was necessary because in one of our tasks we had to decide where and how the components could be fixed and placed.

To distribute the conception we needed firstly a special kind of sensor, and secondly we needed the monitoring system that would send automatically an alert message when the container would be full. The special box, which would keep all things together, was very important too. We had to consider the possibility of correctly programming this equipment.

This paper includes the following sections: introduction, state of the art, marketing plan, sustainability study, project development, conclusions and references.

II. State of the Art

Level measurement sensors are used to measure fluid or solid levels within a range. Generally, these sensors produce an analog output that directly correlates to the level in the container. To create a level management system, the level sensor output signal can be connected to a micro-controller. The micro-controller can process the inputs from several sensors simultaneously and, additionally, send information to a communications module for transmission. If, for example, the communications module provides connection with the Internet, an administrator/manager can remotely access the sensor data and check for alerts regarding the minimum/maximum level [1].

A. Level Sensors

Level sensors detect the level of a substance in a container or in its natural form. The sensor can be continuous or detect given value. Continuous level sensors measure level within a specified range and determine the level of substance, while point-level sensors only indicate whether the substance is above or below the sensing point.

There are several physical and application requirements that affect the selection of the level monitoring method for industrial and commercial processes. The physical requirements that condition the selection criteria include phase (liquid, solid or slurry), temperature, pressure, vacuum, dielectric constant of medium, density (specific gravity) of medium, agitation (action), acoustical or electrical noise, vibration, mechanical shock, tank or bin size and shape. Among the application constraints there are price, accuracy, appearance, response rate, ease of calibration or programming, physical size, mounting of the instrument, monitoring and robustness to environmental constraints, etc.

Ultrasonic devices are contactless sensors, i.e., they are transceivers that send and receive signals as a radar or sonar [2]. Ultrasonic sensors (Figure 1) generate high frequency sound waves and measure the returned echo.

Figure 1 – Ultrasonic sensor.

Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object. This technology can be used for measuring wind speed and direction (anemometer), the level of a tank and the speed through a fluid. To measure the liquid in a tank, the sensor measures the distance to the surface of the fluid (Figure 2).

[†] The supervisors of the Spring 2012 European Project Semester at ISEP (EPS@ISEP) were António Ferreira da Silva, Benedita Malheiro, Manuel Santos Silva, Maria Cristina Ribeiro, Nídia Sá Caetano, Paulo Ferreira and Pedro Barbosa Guedes.

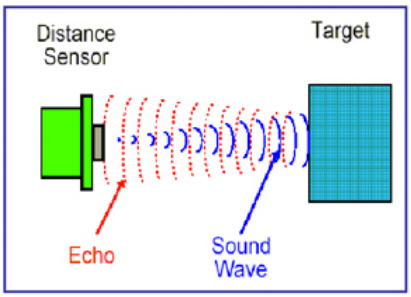

Figure 2 – Ultrasonic measuring.

Ultrasonic devices typically use a transducer, which generates sound waves in the ultrasonic range (above 18 kHz) by converting electric energy into sound, and, upon receiving the echo, convert the sound waves back into electric energy, which can be measured and displayed. This technology is limited by the shape of surfaces and the density or consistency of the material.

In this project we will use the ultrasonic HC-SR04 module to measure the internal level of the container.

B. Battery

A battery is an electrochemical cell or enclosed and protected material. The battery can be charged electrically to provide a static potential for power or released electrical charge when needed [3]. The basic elements of a battery are an anode, a cathode and an electrolyte. The cathode is a metal that is combined with oxygen. The anode is a metal that would oxidize if it were allowed to and is more likely to oxidize than the metal that forms part of the cathode. There are different types of batteries: lead acid battery, Nickel-Cadmium (Ni-Cd) battery, Nickel-Metal Hydride (Ni-MH) battery and Lithium ion (Li-Ion) battery.

We chose a lead acid battery. This type of rechargeable battery is inexpensive, has a backup emergency power source and can hold the charge for up to 3 years [4].

C. Micro-controller

A micro-controller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals – see Figure 3.

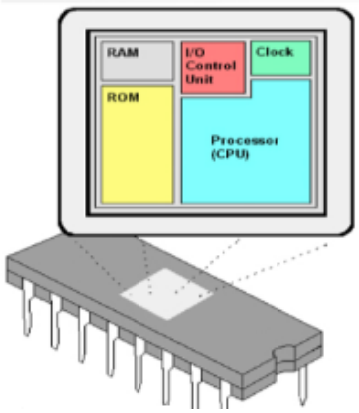

Figure 3 – Micro-controller main modules.

Micro-controllers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications [5]. Micro-controllers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, micro-controllers make it economical to digitally control even more devices and processes.

The Arduino Pro Mini (Figure 4) is the micro-controller selected to control all system components.

Figure 4 – Arduino Pro Mini micro-controller board.

D. Communication

Wireless communication allows the transfer of information between two or more points that are not physically connected. In this project we will use a Wi-Fi communication system to transfer data between the measurement system and the Web interface. Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards". However, since most modern WLAN are based on these standards, the term "Wi-Fi" is used in general English as a synonym for "WLAN" [6].

A device with a Wi-Fi interface can connect to the Internet via a wireless network access point. An access point (or hotspot) has a range of about 20 m (65 ft) indoor and a greater range outdoor. The hotspot coverage can comprise an area as small as a single room with walls that block radio waves or as large as many square miles — this is achieved by using multiple overlapping access points.

We chose the WiFly Shield shown in the Figure 5 to establish the data link between container and remote Web server.

Figure 5 – WiFly shield.

III. Marketing Plan

Entrepreneurs had to work hard to ensure the survival of companies. We are going to launch a new level-measuring product called the *level1000*. The level monitoring system is mainly directed to recycling companies that want to have an edge over competitors.

Table 1 holds the results of a study conducted by Egi Energy, a partner recycling company, during the month of April 2012. The company has a total of 486 containers distributed over Porto and 214 of them are waste oil containers.

Table 1 – Egi Energy container data.

Capacity (l)	140	160	240	360	370
Quantity	50	69	13	176	47
Weekly collections	1	4	13	14/16	4
Monthly collections	5	15	10	56	15
Workers					4
Average course length (km)					125

The collection courses are defined after the passage of an inspection team that verifies the content level of the containers. The containers above 50% of their capacity are included in the following collection course.

We found four different recycling companies in Porto metropolitan area and assuming that each company has 200 oil containers, there are approximately 800 containers in this region for a population of 1.3 million, i.e., there is one container for 1625 people. Since the population in Portugal is 10.6 million according to the 2012 census, we can estimate that there are 6510 containers in Portugal. Although these numbers are hypothetical, they provide a glimpse of the potential market. Figure 6 introduces the problem statement.

for recycling companies
that recycle waste oil
the level monitoring system
is a solution
that reports the container capacity status
unlike no other product through
through a Web interface.

Figure 6 – Problem statement.

In the first year, the primary marketing objective is to sell 200 pieces (*level1000*) at 300 € per unit. This price is based on the cost of the prototype and the number of expected sales is based on the market study we conducted. In the second year, we expect to achieve a sales revenues of 60 000 € and to reach the break.

A. Market Situation

Our product is innovative and we are entering in a new market. At the moment we have to deal with hypothetical companies. They can enter to the market, if they want, that is why we need to estimate future competitive threats. The reasons that lead companies to enter in new markets can be many:

- There are high profit margins in the industry;
- Demand is unmet (insufficient supply) by the industry;
- There are no major barriers to entry;
- There is future growth potential;
- Competitive rivalry is not intense;
- Gain a competitive advantage over existing firms is feasible.

The most common sources of new competitors are:

- Companies competing in a related product/market;
- Companies using related technologies;
- Companies already targeting your prime market segment but with unrelated products;
- Companies from other geographical areas and with similar products;
- New start-up companies organized by former employees and/or managers of existing companies.

In Portugal there are no similar products.

B. Market Description

The measuring systems market consists of business and private consumers who need measuring systems for their machines/equipment/products. Business segments will be targeted during the first year.

Level1000 product purchasers have diversified needs, i.e., the customer may need to: (*i*) customize the level threshold for containers with diverse capacity; (*ii*) know the container status (full or not); (*iii*) continuously know the container level; or (*iv*) know when container has to be cleaned.

C. Competitors

No competitors were found in the Portuguese markets. We believe that there must be some similar companies/products, but we are not aware of them and we believe that, if they exist, they are not our direct competitors.

D. Objectives

We set achievable objectives for the first two years. In the first year we want to consolidate a position in Portuguese market by getting to know the market and creating a good image among the customers. This image will be based on the quality of the service and communication as well as on the trust relation built with the customers.

The main goal-related issues are:

- Operating goals – To establish a well-known brand and create a memorable image projecting, quality innovation and value we need to invest in marketing.
- Tactical goals (first two years) – To improve and refine the product features and the product.
- Strategic goals – To build a customer network and to expand to foreign markets.

E. Segmentation and Marketing

As a first step, we decided to sell our product mainly to the customers that want to know the container capacity status (full or not). These customers may want to buy our product because it will help reduce the transportation and labour force costs.

The first target is to reach the segment of recycling companies that collect waste oil. The waste oil is collected

from containers located in different areas in a city. Waste oils are thrown away after they were used for cooking, in machines and vehicles. In the case of domestic cooking, bottles are thrown into the containers located in residential areas. Using our product, the recycling companies can collect the waste oil more effectively.

Our first market will be in Portugal in the city of Porto and surrounding districts. Since this project results from a joint cooperation between Instituto Superior de Engenharia do Porto (ISEP) and Egi Energy, the latter will be the first to buy and implement our solution. Egi Energy has 36 waste oil containers in the city of Porto and 178 in the Porto metropolitan area.

F. Marketing Strategy

The marketing mix is a business tool used in marketing products. We will use 4P system (place, price, promotion and product).

G. Market Positioning

Using product differentiation, we are positioning the *level1000* as most versatile, convenient, value-added model for professional and personal use. The marketing strategy will focus on the level monitoring system with a Web interface as the main feature differentiating our product from others.

H. Product Strategy

The *level1000* will be sold with a one 3-year warranty plus a free maintenance service for the first year. The product will continually be improved, but we don´t expect to release a new version before the second year. We are trying to upgrade it by using new technologies. Building the *level1000* brand is an integral part of the product strategy. The brand and logo will be displayed on the product and packaging.

To create a good image among the customers we have to provide a very good service. The customer should be able to contact the support team easily and never be abandoned when problems occur. We want to build the image that "Your problem is our problem" in order to create a loyalty bond between the customer to our company.

I. Pricing Strategy

The *level1000* will be introduced to the market for 300 € per unit. This price reflects our strategy: first, we want to attract new customers and, secondly, to get a good market position. So it will be difficult for our competitors to aim our product. There will be discounts for acquisitions larger than 10 units, i.e., the price will depend on the contract terms.

J. Promotion Strategy

To advertise our product we are going to use mainly three channels:

- Internet marketing – the Internet will be our main marketing and sales channel;
- Product demonstration – In first year we will do demonstrations for companies. In the following years, we intend to participate in fairs over the Europe.
- Word-of-mouth –We hope that this methodology will promote the product among the second segment (private users).

K. Action Programmers

The *level1000* will be introduced in July. Following are summaries of the action programs we will use during the first 10 months of next year to achieve our stated objectives.

L. Budget

Total first-year sales revenue for the *level1000* is projected at 30 000 € with an average wholesale price of 300 € per unit. We anticipate a first-year loss of up to 25 000 € on the *level1000* models and 5000 € for marketing (creating a working production system and a reliable brand). Break even calculations indicate that the *level1000* will become profitable after the sales volume exceeds 30 000 €.

M. Marketing Conclusions

This marketing plan shows the position where we are at the moment. After analysing our marketing situation and strengths, weaknesses, opportunities and threats (SWOT) of our prospective company, we can state that we have quite good starting position. Several essential issues still need to be addressed: How to reach the target groups? How to advertise the product? How to organize the production system? How to get financed for the advertisement, development and production? The first two years will be focussed on the organization of the company, *i.e.*, the implementation of the answers to these questions.

IV. Sustainable Development

The word sustainability is derived from the Latin *sustinere*. Sustainability is an emergent concept that reveals deep concerns about fundamental values and the continued existence of the human race. While the definition of sustainability varies from people to people, the question it addresses is universal. This has resulted in the most widely quoted definition of sustainability and sustainable development.

A. Relevance of Sustainability

Sustainability is important because all the choices we pursue and all the actions that we take today will affect everything in the future. We need to make sound decisions in the present in order to avoid limiting the choices of generations to come.

B. Product Sustainability

In our project we the idea of sustainability revolves around the social, environmental and economic perspectives. From the environmental point of view, we wish to find and apply environmental friendly solutions that reduce the negative human impact, *e.g.*, intend to use recyclable and renewable materials and energy sources. We are also concerned with the energy and process efficiency. Figure 7 presents the three E of sustainability: Environment, social Equity and Economy [9].

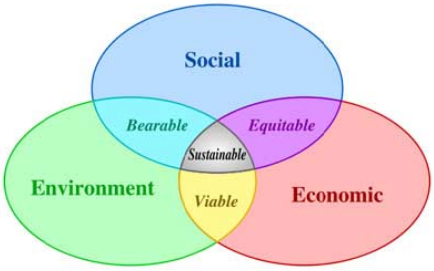

Figure 7 – The three E of sustainability.

C. *Eco-efficiency*

Basically, eco-efficiency is an answer to the need of sustainable development to employ quantitative tools and related respective goals compliant with policies. The ultimate aim of eco-efficiency is to achieve significant reductions in the total use of natural resources. Eco-efficiency also offers clear quantitative measures and targets for the attainment of this goal [7]. The main aspects of eco-efficiency are:

- Reduction of energy, water and virgin material use;
- Reduction of waste and pollution levels;
- Incorporation of life cycle principles;
- Consideration of the usefulness and recyclable of products/services at the end of their useful life;
- Increased service intensity.

D. *Life-cycle Analysis*

A product life-cycle approach to sustainability measures a company's total environmental impact—from raw materials, to production, distribution, consumer use, and disposal of the product by the consumer. Figure 8 displays the recycling diagram [8].

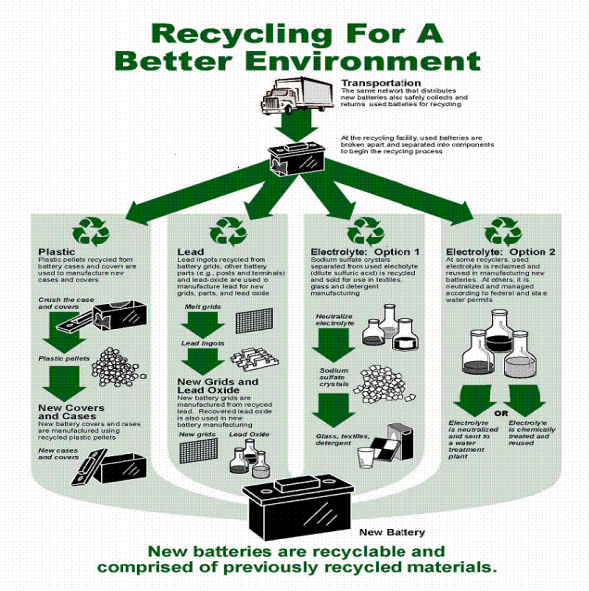

Figure 8 – Recycling diagram.

E. *Sustainability Conclusions*

In the last 20 years we can see changes how people are thinking. They have started thinking about the future and how they can be more effective. By being effective we mean not to spend too much energy, time and money for useless things. Even for companies it has become more and more important to think about their products/services as a part of environment. Companies have to be sustainable and they have to think widely to be successful in markets, because nowadays making profit is not an easy task to complete and not all companies can do that. Of course being sustainable is a long-term process with big investments. Sustainability from company point of view means that it has no negative impact on the global or local environment, community, society, or economy.

V. Project Development

A. *Design*

The level monitoring system must be placed inside the container and on top of the bin – Figure 9.

Figure 9 – Container with the level monitoring system.

This was the set up used for development and testing. Figure 10 displays how the components were placed inside the control enclosure.

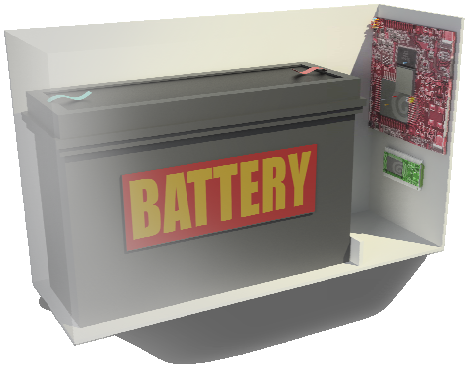

Figure 10 – Inside the level monitoring enclosure.

B. *Architecture*

The system comprises two ultrasonic sensors, control, communications and Web application modules (Figure 11).

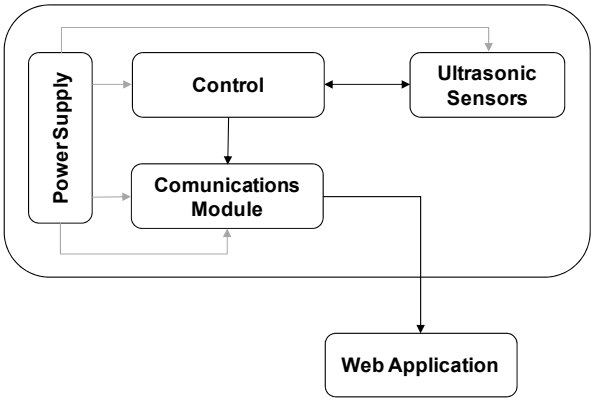

Figure 11 – System architecture.

C. *Ultrasonic Sensors*

The ultrasonic HC-SR04 module has a working range from 2 cm up to 400 cm with a ranging accuracy up to 3 mm. The module includes ultrasonic transmitters, receivers and a control circuit. To start ranging it requires a triggering high-level signal for at least 10 µs. The module automatically sends eight 40 kHz pulses and detects the pulse reflection. If the signal returns it will output a high signal with a duration corresponding to the time elapsed between the sending and returning of the ultrasonic signal.

D. *Control*

The main goal of the control system is to monitor the container level and communicate the sensor readings via a Wi-Fi connection to a remote Web application for storage. Users can then access this information via a Web browser.

The Arduino Pro Mini, which is the core of the control system, implements an infinite loop composed of ultrasonic ranging, reporting sensor levels to remote Web server and sleep stages.

Before starting to program the microcontroller, we created a simple control block diagram – see Figure 12.

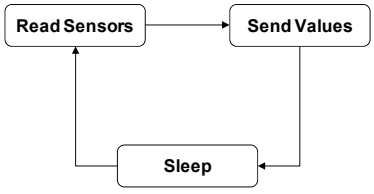

Figure 12 – Block diagram

E. *Schematics*

To adapt the signal level between the Arduino Pro Mini 5 V signals and the WiFly module 3.3 V signals, we used an "XBee Explorer Regulated" board.

We encountered a problem between the WyFly module and the microcontroller: we could read data sent by the WiFly module but could not send commands via the serial interface. After several tests and searching online, we concluded that this serial RX problem was frequent. To solve this issue, we added a logical level converter (LLC) from 5 V to 3.3 V and connected the Arduino virtual TX pin (pin 3) to the LLC module and the LLC directly to the WiFly RX pin.

We had another problem with the WiFly module because none of the pins used to wake up the WiFly were used. The Wi-Fi board has 49 pins and the WiFly board has 20 pins and, as a result, the FORCE_AWAKE pin referred in the manual sheet is one of the pins left unconnected. After some tests, we found that we could wake up the WiFly by setting the WiFly reset pin to ground (not mentioned in the WiFly manual).

Figure 13 shows the connections between the different modules.

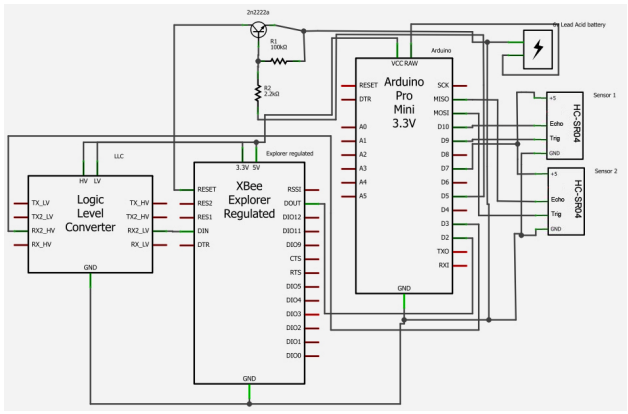

Figure 13 – Module connection schematics.

We have an additional circuit with a transistor to pull the reset pin of the WiFly to ground and wake up the module, including a 100 kΩ resistor to make it stable and a 2.2 kΩ resistor to limit the current at the transistor base pin.

F. *Web Interface*

The Web interface was developed in Java and was deployed on an Apache Tomcat server. Figure 14 displays the main page together with the container status page. The main page offers two options: to check the container status and to edit the container settings. The container status button redirects the user to the `ShowSensorValues` servlet. Thus servlet reads the file containing the container content level data and does displays the information to the user.

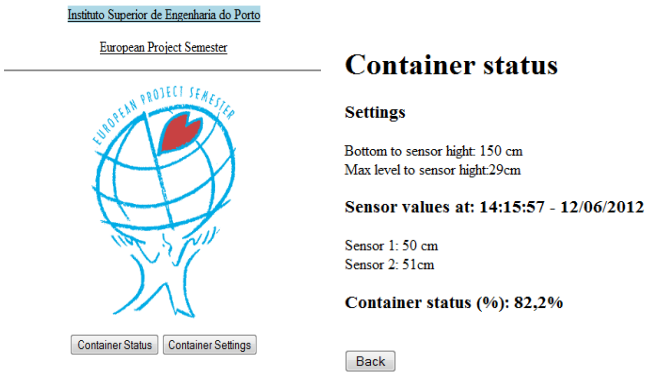

Figure 14 – Web interface.

This is one example of the output and it shows the current container settings, the sensor values and after processing we have the fullness of the container in percentage (%).

The container settings button directs the user to another page where he can define the threshold values for the container content level. This feature allows the system is able to handle different size containers.

VI. Conclusion

The prototype of the level monitoring system for waste oil containers was developed in three months. The first weeks were spent on understanding and getting familiar with the project. We reviewed many options and had numerous brain storms about sensors, communication modules, batteries and protective boxes which would help make our ideas real and did not exceed the predefined budget. The marketing plan and the sustainability aspects concerning our project were analysed.

The first activity was to identify the project tasks, the Gantt chart and allocate the tasks between team members. Secondly, the containers were analysed to decide where and how the monitoring system could be fixed and placed. Then, the prototype was designed, built and tested. Finally, the Web interface application was developed, allowing customers to use a Web browser to verify the container status.

The prototype uses two ultrasonic sensors (Ultrasonic Distance Measuring Module HC-SR04), an Arduino Pro Mini and a Wi-Fi shield to monitor and report the container content level. We chose a lead acid battery to power the system because it is rechargeable and has a low price. We designed and built an aluminium box to hold and protect the components of the monitoring system.

References

[1] Milan Verle, PIC Microcontrollers, MikroElektronika, 2008. Available at http://www.mikroe.com/eng/chapters/view/1/introduction-world-of-microcontrollers/.

[2] Thunder World, Truck Radar Parking Sensor, 2012. Available at http://thunderworld.in/truck_radar_parking_sensor.

[3] Freecircuits, Basics of Batteries and Cells, 2012. Available at http://freecircuits.org/2011/07/basics-batteries-cells.

[4] First Nation Battery, Industrial Lead Acid Batteries: Types and their selection, 2004. Available at http://www.battery.co.za/download/dl/IndustrialBatteriesTypes&Selection.pdf.

[5] Circuitstoday, Microcontrollers, 2011. Available at http://www.circuitstoday.com/basics-of-microcontrollers.

[6] Webopedia, Wi-Fi, 2011. Available at http://www.webopedia.com/TERM/W/Wi_Fi.html.

[7] Jukka Hoffrén, Strengths and Weaknesses of Eco-efficiency, 2012. Available at http://koti.mbnet.fi/~jukkah/EE_analysis_JH.pdf.

[8] Tonolli Canada, Recycling for a Better Environment, 2012. Available at http://www.tonolli.ca/recycling-batteries.

[9] Wikipedia, Sustainable Development Diagram, 2012. Available at http://en.wikipedia.org/wiki/File:Sustainable_development.svg.