SWAMP
SMART WATER MANAGEMENT PLATFORM

Project nº: 777112

D2.6 Specification

Editor:

Author(s): Eric Grassl, Kari Kolehmainen, Plinio T. Aquino Jr., Rodrigo Filev Maia

Status – Version: 1.0

Date: 10 10 2018

Distribution – Confidentiality: Confidential / Public

Code: 777112-SWAMP – D2.6 Specification.docx

Disclaimer

Participant no.	Participant organisation name	Part. short name	Country
1 (European Coord.)	Teknologian tutkimuskeskus VTT	VTT	FI
2	Intercrop	ICRO	ES
3	University of Bologna	UBO	IT
4	Consorzio di Bonifica dell'Emilia Centrale	CBEC	IT
5	Quaternium	QUAT	ES
6 (Brazilian Coord.)	Federal University of ABC	ABC	BR
7	Centro Universitário FEI	FEI	BR
8	Federal University of Pernambuco	UFPE	BR
9	LeverTech Tecnologia Sustentável	LEV	BR
10	Brazilian Agricultural Research Corporation	EMBR	BR

Document revision history

Date	Issue	Author/Editor/Contributor	Summary of main changes
10 October 2018	1.0	Eric Grassl, Plinio T. Aquino Jr., Rodrigo Filev Maia	Initial specifications
29 October 2018	1.1	Eric Grassl, Plinio T. Aquino Jr., Rodrigo Filev Maia, Kolehmainen Kari	Updated according to revisers' comments

Internal review history

Date	Reviewer	Summary of comments
22 October 2018	Kolehmainen Kari (VTT)	Accepted with minor changes
25 October 2018	João Henrique Kleinschmidt (UFABC)	Accepted with minor changes

Table of contents

Abbreviations

IoT	Internet of Things
LoRa	Long Range Radio
NUC	Next Unit of Computing
CBEC	The Consorzio di Bonifica Emilia Centrale

1 Introduction

Recently, freshwater usage and pollution have come to a critical level, resulting in a probable lack of freshwater for food production, environment and urban use in the next decades. Furthermore, agriculture is responsible for 85% of freshwater consumption worldwide and, according to the US Census, the global population will grow to 9.2 billion in 2050. Thus, to preserve the current per capita supply, food production will have to increase approximately 50% and, as a result, it is expected an increase in freshwater demand in the next decades [1].

Optimizing water usage is important for future food supply security as well as financial profitability of farming. Where irrigation is needed, it is an expense that can be optimized to provide maximum yield for least amount of expense. Monitoring soil and crop parameters produces data that can be used for systematic optimization of water usage. The IoTRobot can contribute with high granularity data which can be also used along with other SWAMP devices' data for creating digital twin of the soil and plant, enabling usage of advanced simulation and modelling of crops.

The user of poor-quality water can influence negatively food production resulting in great losses. There are many critical water quality parameters such as temperature, pH and salinity. For instance, crop growth can reduce when salinity is excessively high, and the water infiltration process can decrease when salinity is low. Furthermore, poor quality water can result in drought even though the soil appears wet. Hence, techniques for monitoring water quality have been extensively considered in literature [2].

Traditional methods of water monitoring demand laboratory analysis and water sampling, resulting in a probable late detection of water contamination and high costs. On the other hand, the measurement of water quality through physicochemical parameters can be executed in a fast, online, and low-cost way [3]. Thus, water quality monitoring techniques that measure water physicochemical parameters through cheap and off-the-shelf sensors are widely explored in the literature. Figure 1 shows an example of a water quality monitoring system proposed by [4].

FIGURE 1 – A WATER QUALITY MEASUREMENT SYSTEM PROPOSED BY [4].

Therefore, this project aims to expand approaches such as [3], [4] and [5] in order to assist food producers to avoid losses due to poor-quality water and help them to achieve sustainable water usage. To reach this goal, a real-time and spatiotemporal water-quality monitoring system, denominated IoTRobot, will be created. It will be capable of measure physicochemical water-quality parameters and provide their location and time besides of providing services based on this data. Furthermore, the IoTRobot uses the concept of IoT (Internet of Things) since it combines people, processes, devices, and technology with sensors and actuators in a ubiquitous way [6]. Lastly, the IoTRobot must be able of moving in the water and avoid obstacles in an autonomous way since it is going to be used in water bodies such as rivers, lakes and ponds. To reach the autonomous locomotion, an embedded navigation system will be created and added to the IoTRobot.

2 Architecture

The IoTRobot's objective is to assist farmers to avoid unexpected losses due to poor water quality by providing a fast way to detect and react to contaminations or undesired water quality. In other words, its objective is to provide a real-time and spatiotemporal physiochemical water-quality system. To reach this objective, it is necessary the use of an embedded system that combines sensors, services, and communication with other devices. Thus, the next sections will describe the project's architecture.

The IoTRobot's architecture is divided in 3 layers and 4 modules. This division was made aiming an architecture where each module will have one responsibility and each layer will have one purpose. The next sections will focus on detailing this architecture.

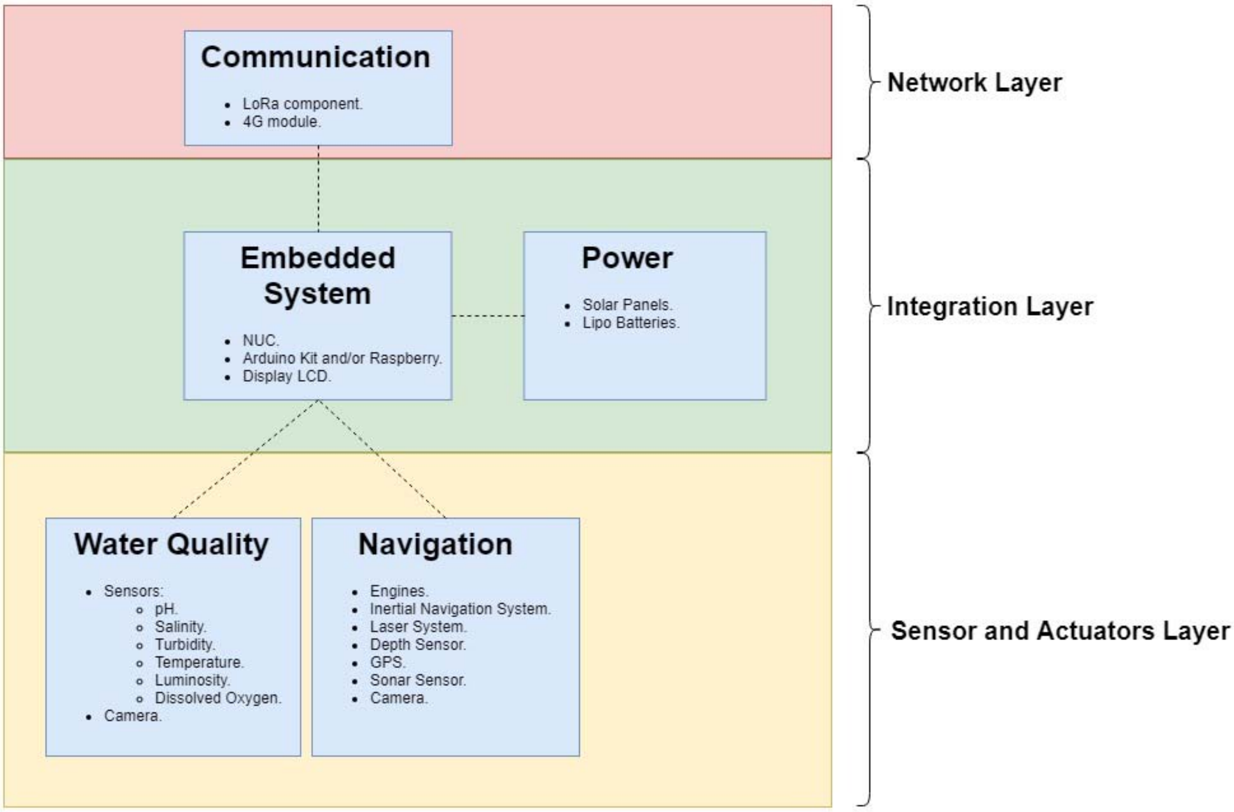

FIGURE 2 – IOTROBOT'S MODULES.

Data collection system used for gathering data about soil and plant parameters is similar to IoTRobot on layer level. Connection between Sensor and Actuator layer and Integration layer can be wired or wireless. Integration of contextual information is done on cloud service.

2.1 Network Layer

The network layer is responsible for sending data through the network by sending and answering requests and it is composed by the communication module which is described in the next section. Network layer is connecting cloud system to the IoT embedded system.

2.1.1 Communication Module

The communication module aims to provide means to the system to access the network in order to receive and send requests. It is composed by a wireless network component using LoRaWAN protocol and/or a 4G module which are described below:

Component	Description
LoRa	Long Range (LoRaWAN) is a wireless data communication protocol used for IoT devices.
4G module	Module that enables 4G communication technology to the system.
Wifi module	Wifi access module that can be used in cases where wifi communication is possible

These components will be tested in order to measure packet size, range and energy the consumption. Thus, the best suitable component will be chosen and used in this module. Choice of right module depends on available infrastructure and communication bandwidth requirements.

2.2 Integration Layer

The Integration layer is responsible for collecting sensor data, process this data and respond to requests that come from the Network Layer. This layer is also responsible for managing the system's power consumption and navigation. It is composed by two modules that will be described in the sections bellow.

2.2.1 Embedded System Module

The Embedded System module is responsible for integrating the Water Quality and Navigation modules and manages the system's power consumption. Furthermore, the spatiotemporal information collected by the Navigation module will complement the water quality parameters information and it will be sent to the network. Also, the data collected by the Navigation system will be used to control the engines autonomously and to create maps of the underwater surface and borders of the water body. This module is composed by the following components:

Component	Description
NUC[1]	Embedded computer responsible for integrating sensor data with the network environment.
Arduino Kit and/or Raspberry	They are used for sensor integration and to assist the NUC. They will be used as a comparison study of the embedded architecture on the water surface.
Display LCD 7 Touch Screen and smartphone	It serves as a feedback screen to display the system's information when it is on the field.

Local gateway is responsible of collecting data from the sensors and relaying them to cloud service using facilities offered by network layer. Data that local gateway collects is measurements from soil and plant sensors, weather instruments, power module, etc.

2.2.2 Power Module

Since Water Quality monitoring is a critical operation, the IoTRobot should work with less interruptions as possible. Thus, the Power module should be able to provide and collect enough power aiming the IoTRobot's continuous functioning. Therefore, this module is composed by:

[1] Next Unit of Computing (NUC) is a 4 x 4 inches (10.16 x 10.16 cm) personal computer designed by Intel.

Component	Description
Lipo/LiFePO4 Batteries	Lightweight batteries that keep the IoTRobot functioning at night or when there is not enough light to depend on solar panels.
Solar Panels	Generates power to keep the IoTRobot functioning and/or recharge its batteries.
Solar Charge Controller	MPPT Charge controller chargers batteries when solar array is producing power and provides regulated 12V drain from the batteries

The Embedded System module can use the data collected from the luminosity sensor to switch between the power consumption strategies, which are listed below:

- Battery only: when there is not enough light to depend upon solar panels.
- Solar Panels only: when there is enough light to depend upon solar panels and the batteries are fully charged.
- Solar Panels while recharging batteries: when it is possible to depend upon solar panels and recharge the batteries at the same time.

If Solar charge controller is integrated into the system, it can take care of switching between battery and solar power according to the need. MPPT controller offers also detailed status information of the state of the solar power system,

2.3 Sensors and Actuators Layer

The Sensors and Actuators Layer is composed by components that collect data of the environment and also components that act on the environment. Sensors will be used to collect data from the environment and this data will be sent to the Integration Layer. Furthermore, in this project, the actuators are components related to the equipment's locomotion and will act based on decisions made in the Integration Layer. This layer is composed by two modules which are described in the next sections.

2.3.1 Water Quality Module

The Water Quality module's goal is to execute the real-time water quality monitoring through measuring physicochemical parameters. It uses cheap and off-the-shelf sensors to measure these parameters which are listed below and described according to [7]:

Parameter	Description
Water pH	The pH indicates if a solution is basic or acidic. The substance can cause chemical burn in case it is too acidic or too basic.
Water Turbidity	Turbidity indicates how light is scattered and absorbed by particles and molecules. It can result in increases of water temperature because it can promote microorganism's growth and convert light into heat.
Water Salinity	It is the amount of salt in a water body. It determines what organisms will live in that environment. Salinity is inversely proportional to the dissolved oxygen.

Water Temperature	The water temperature is related to other parameters such as turbidity and dissolved oxygen and can be used along with other sensors data to analyse the water quality.
Water Dissolved Oxygen	It is the amount of oxygen that is dissolved in a given medium. It is a key factor for marine life and it is determined by water volume, flow, temperature, and types of organisms living in it.
Luminosity	Indicates the amount of light in an environment.
Air humidity	Air humidity is taken by weather instruments located with the gateway system
Air temperature	Air temperature information is gathered by soil sensors as well as weather instruments.
Air pressure	Air pressure is gathered by weather instruments.
Wind speed	Windspeed is gathered by weather instruments on the location of the gateway
Wind direction	Windspeed is gathered by weather instruments on the location of the gateway

Furthermore, this module will also capture camera images that will be stored in the system together with all sensor information, so they can be used by machine learning algorithms. Lastly, the data collected will be sent to the Integration Layer that will be responsible for further processing.

2.3.2 Navigation Module

The Navigation module aims to provide autonomous locomotion and spatiotemporal measurements to the IoTRobot. Thus, this module's purpose is to complement the Water Quality data by providing spatiotemporal information about those measurements and enable smart locomotion in water bodies where avoiding obstacles such as rocks and branches may be necessary. The list bellow shows this module's components and their purposes:

Component	Description
Engines	A set of engines used for locomotion in water bodies.
Inertial Navigation System	It helps the IoTRobot to have a stable navigation in water bodies.
Laser System	It maps the underwater surface and the borders of a water body. It is also used to detect collisions.
Depth Sensor	It is used to avoid obstacles that might prevent locomotion such as branches and rocks. It also maps the depth of water bodies.
GPS	Provides the IoTRobot's location and enables the system to collect spatial-temporal data.
Sonar Sensor	It is integrated with the laser system and it is used to map obstacles on the water surface.
Camera	As specified for the Water Quality model in Section 2.3.1.

3 Use Case

The IoTRobot can be used in many scenarios where water quality management is needed and where the is a high risk of contamination. Some of its functionalities are:

- Detection of water contamination in real-time.
- Mapping of underwater surfaces.
- Measure the depth of water bodies in real-time.
- Navigate through the water body.
- Provide localization in real-time.

The next section focusses on describing a use case for the IoTRobot where these functionalities will help food produces to achieve better water quality and usage.

3.1 Pilot: Smart Water Distribution (Reggio Emilia, Italy – CBEC)

The Consorzio di Bonifica Emilia Centrale (CBEC) is a reclamation consortium of the Emilia-Romagna Region in Northern Italy, responsible for the irrigation and water drainage of an area of nearly 3,130 km2 where most water required for irrigation is withdrawn from the Po river (Figure 3). The water is distributed to the farms by an intricate irrigation infrastructure composed of more than 3,580 km of canals, more than 200 small streams, six draining plants, and 72 pump stations with an overall capacity of 416 cubic meters per second.

Figure 3 - WATER DISTRIBUTION MANAGEMENT PILOT: OPEN EARTH CANAL (LEFT), MANUAL OPERATION (CENTER) AND WATER INTAKE (RIGHT)

The supply and irrigation network consist of open channels on the ground. Relevant widths characterize the main canals and therefore their filling for the irrigation season involves the use of substantial water volumes that are not always recoverable for irrigation purposes. Water losses are due to infiltration through canal banks and bottom, as well as to the management of the irrigation network that requires the filling of long canal stretches and several minor streams to accommodate farmer needs. Furthermore, the irrigation network also acts as drainage network for the cultivated areas.

The IoTRobot could be a useful device to assist in the CBEC water management by providing means to map the underground surface, achieve a better understanding of a water body's behavior, and measure important information such as water quality parameters, depth and flow. First, water contamination could be detected in a certain area of the canal and measures could be taken quickly to avoid eventual spread of it. Second, the depth of the canal could be measured in many regions and a drought can be foreseen. Third, the GPS information provided can be used to analyze the water flow and behavior in the canals. Lastly, the data collected can be stored in the SWAMP platform and other SWAMP applications can use it in order to achieve better water management.

3.2 Pilot: Variable Rate Irrigation (MATOPIBA, Brazil)

The MATOPIBA region (Figure 4) encompasses the Brazilian states of Maranhão (MA), Tocantins (TO), Piauí (PI) and Bahia (BA), and is one of the most critical irrigated agricultural frontiers in the country, located in the *cerrado*, a savannah climate subtype. Irrigation is mostly performed by thousands of centre pivots, each one with an average size of 100 hectare.

FIGURE 4 - CENTER-PIVOT IRRIGATION PILOT: LOCATION OF THE PILOT SITE (LEFT) AND CENTER PIVOT IRRIGATION FOR SOYBEAN CROP (RIGHT)

The soybean production in the region reached about 5.5 million tons in 2016 in a total cultivated area of about 1.52 million hectares. Despite those significant numbers, the production losses are estimated in 40% of the crop due to drought occurred during the 2015/16 season. The production from many properties was only 30 sacks per hectare, while an average of 58 sacks was expected. With irrigation and investments in soil fertility, some producers expect that this number can reach 80 sacks. Although irrigation is an alternative, its expansion depends on technologies that improve operating costs and promote sustainability. For example, a red flag was lifted in 2015/16 and imposed double charges to the energy used in irrigation. The increase represents a cost of seven sacks per hectare against three and a half sacks with a typical energy charging.

The IoTRobot could be used to assist MATOBIPA water management by providing a better understanding about the water body used for irrigation and measuring important water quality parameters. First, the information collected could be used in order to prevent farmers against a possible drought such as the drought occurred during the 2016/16 season. Second, water quality parameters can be used to avoid the use of poor-quality water which can have a negative impact in food production and water usage. Lastly, the data collected can be stored in the SWAMP platform and other SWAMP applications can use it in order to achieve better water management.

4 Challenges

The IoTRobot will be responsible for monitor the water quality of water bodies used in food production processes such as rivers, lakes and ponds. It will move on the surface of those water bodies aiming to make spatiotemporal measurements. Thus, it must be capable of collecting physicochemical parameter of the water, providing real-time location, autonomous navigation and efficient power consumption. Based on these requirements, the next sections explain the challenges that will be faced.

4.1.1 Sensors Maintenance

Although the off-the-shelf sensors offer a cheap and real-time approach to water-quality monitoring, they may require frequent maintenance that can result in higher costs. Therefore, a maintenance technique will be studied to prevent this scenario where the harsh conditions of the environment forces the frequent maintenance of the equipment. Thus, it is expected that the system gives a warning when there is a chance that the sensors' data is being modified. This could happen in scenarios such as:

- The sensors are covered by sludge or mud.
- Some sensors have been damaged.
- Some sensors need adjustments.

4.1.2 Environmental Conditions

The IoTRobot will be used in uncontrolled environments such as rivers, lakes, and ponds. Therefore, it must be able to resist tough conditions in those environments such as high humidity and velocity of water flow. Hence, the IoTRobot's metal components must be protected against issues such as corrosion caused by the high humidity, water infiltration and impacts resulted from a fast water flow.

4.1.3 Power Management

The IoTRobot should keep functioning as much time as possible. The power management should be able to keep it working even in dark days where there is not enough light to depend on solar panels. Thus, power strategies such as sleeping schedule will be applied to minimize the chances of the system run out of power. Some challenging scenarios where the power management strategies should work on are:

- Places where there's few daylights such as in northern countries.
- Bodies of water where there is a lot of obstacles, which will result in an increase in power consumption since the navigation system will be more active.

4.1.4 Navigation

Navigation should be autonomous, energy efficient and consider obstacles such as rocks and branches since the IoTRobot will navigate through uncontrolled environments. Consequently, a navigation system that guarantees autonomous mobility and safety will be created, which can be challenging due to its complexity.

5 Summary

This document describes the initial specification of the IoTRobot and describes its architecture in detail, a use case, and challenges that must be considered during its development.

The IoTRobot presents a real-time and spatiotemporal approach to measure water quality by using cheap and off-the-shelf sensors besides of using the IoT concept to integrate collected data with the SWAMP platform. Its goal is to help food producers to achieve a better water usage and avoid unexpected losses due to poor quality water and contamination.

The next steps include:

- Compare and test components such as sensors, communication devices and microcontrollers.
- Defining a scheduling strategy for the sensors.
- Navigation and obstacle detection tests.
- Integration tests.
- Field tests.

6 References

[1] W. A. Jury and H. J. Vaux, “The Emerging Global Water Crisis: Managing Scarcity and Conflict Between Water Users,” *Adv. Agron.*, vol. 95, no. 07, pp. 1–76, 2007.

[2] K. Singh, P. Kumar, and B. K. Singh, “An associative relational impact of water quality on crop yield: A comprehensive index analysis using LISS-III Sensor,” *IEEE Sens. J.*, vol. 13, no. 12, pp. 4912–4917, 2013.

[3] N. A. Cloete, R. Malekian, and L. Nair, “Design of Smart Sensors for Real-Time Water Quality Monitoring,” *IEEE Access*, vol. 4, no. 9, pp. 3975–3990, 2016.

[4] S. K. Vaddadi, “Development of Embedded Wireless Network and Water Quality Measurement Systems for Aquaculture,” *Sixth Int. Conf. Sens. Technol. Dev.*, pp. 637–641, 2012.

[5] K. Gopavanitha and P. G. Scholar, “A low cost system for real time water quality monitoring and controlling using IoT,” *2017 Int. Conf. Energy, Commun. Data Anal. Soft Comput.*, pp. 3227–3229, 2017.

[6] P. P. Ray, “Internet of Robotic Things: Concept, Technologies, and Challenges,” *IEEE Access*, vol. 4, pp. 9489–9500, 2016.

[7] J. Stevenson, R. Mckenzie, J. Wood, and L. Hayden, “A comparative study to the 2011 / 2013 water quality assessments in the Pasquotank Watershed in Northeastern North Carolina with a sea level rise component,” *2015 IEEE Int. Geosci. Remote Sens. Symp.*, pp. 153–156, 2015.