Internet of things applications on monitoring hydroponics through wireless sensor networks

Andreas Komninos[1,2], Georgios Georgiadis[1], Andreas Koskeris[1], and John Garofalakis[1,2]

[1] University of Patras, Rio, 26504, Greece {akomninos,garofala}@ceid.upatras.gr
[2] "Diophantus" Computer Technology Institute and Press
{ggeorg,koskeris}@westgate.gr

Abstract. This paper presents the development of a scalable hydroponics monitoring system and data processing through wireless sensor networks. We implement novel hardware and virtual sensors through abstraction in an IoT management platform. We introduce the concept of collaborative machine learning from multiple sites to improve prediction and discuss related project challenges.

Keywords: Hydroponics · Internet of Things · Machine Learning.

1 Introduction

Internet of Things (IoT) is an active research topic, where sensors and smart devices facilitate the provision of information and communication [2]. IoT systems have found significant application opportunities in the agricultural sector. Environmental problems like rainfall decrement and drought have led farmers to abandon traditional ways of farming and follow farming based on IoT technologies [1]. In IoT-based farming, a system is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, etc.) and automating the irrigation system which helps the farmers to monitor the field conditions from anywhere. By using various sensors for monitoring, precision agriculture is achieved, with associated savings in energy and water consumption, as well as reduction of fertilizer and chemicals used to support plant growth. Hydroponic agriculture is a method of growing plants in water based nutrient rich solution system, in which a greenhouse contains rows of substrate material (e.g. rockwool) where plants are placed (Fig.1). Since this substrate contains no nutrients, it is continuously watered with a nutrient-rich solution, however this process requires careful balancing of the nutrient solution in order not to exceed certain values and destroy the plants [3]. In this project we propose a full scale system that leverages Machine Learning (ML) to improve predictions by sharing knowledge between multiple farming sites and also evaluate the data and operational parameter requirements minimizing storage and processing needs.

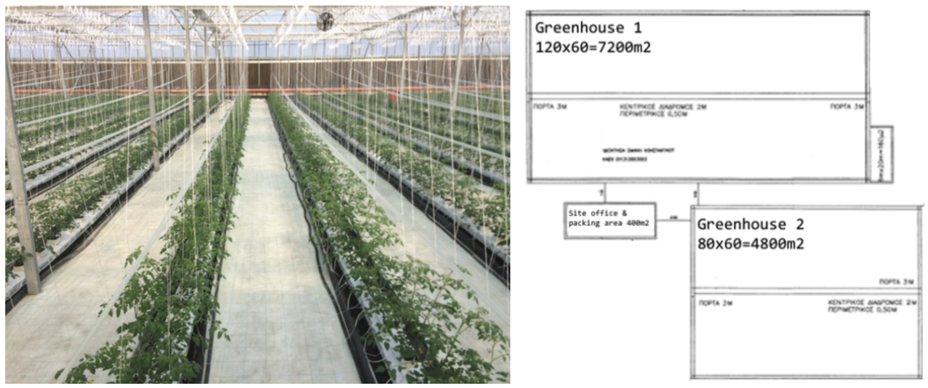

Fig. 1. The tomato hydroponic farming site of the project.

2 Related Work

At the moment most of the related research work regarding hydroponics is concentrated around monitoring of the environmental parameters or controlling automations inside the greenhouse. In the past, research on IoT-enabled hydroponic systems has focused mostly on system properties and architecture (e.g. [5]), with most research focusing on monitoring specific types of sensor values, such as water quality. However, in such systems, the weak point here remains the need for heavy agronomist involvement in the process [4]. In our project, we propose the use of machine learning to assist agronomists in operational decision making and to detect anomalous events. We move the state of the art by designing a collaborative ML architecture, where data and models from multiple sites can be shared, so as to improve predictions for a community of hydroponic site operators and increase the value of the system.

3 Current status

We developed an embedded wireless sensor network for a tomato hydroponic greenhouse in the area of Mesolongi in Western Greece. The architecture of this system is shown in Fig.2 and consists of the wireless sensor network inside the greenhouse which transmits all the necessary environmental parameters to an Internet of things (IoT) platform. Previous work focuses on hardware sensors, but a novel approach in our project is that we support "virtual" sensors, which are essentially data obtained from external APIs or other internal data sources, queried via scheduled scripts. These are outlined in Table 1.

4 System Specifications

We configured different sensors on Arduino Uno boards, forming different "sensor packs" with various sensors attached. The different sensor packs communicate

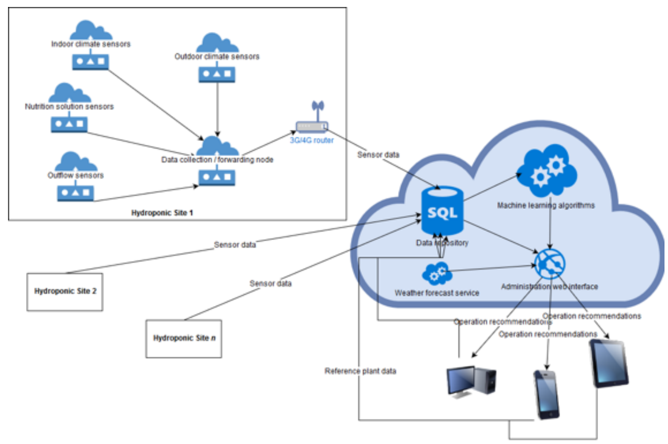

Fig. 2. System architecture.

Table 1. System sensors

Hardware Sensors	
Indoor environment	Temperature, humidity, light level, solar irradiance
Substrate sensors	Soil moisture, soil temperature
Outdoor climate	Wind speed, wind direction, light level, rainfall
Water quality	PH, electric conductivity of water outflow
Virtual Sensors	
Weather station	Meteorological data & forecasts from the OpenWeatherMap API
Nutrition scheduling	Agronomist-maintained spreadsheet log of watering time, duration, and nutritional content composition

via XBee modules (IEEE 802.15.4/Zigbee) in a star arrangement, to organizer nodes. Coordinator nodes forward information to the server, through wired Ethernet connections. Coordinators are configured using the Arduino Mega board because of the heavier computation demand.

The agronomist of the site takes regular observations from the witness plants. These observations are collected using a mobile device, running a web-based application to collect the relevant data (foliage, plant height, stem width, fruit size and state etc.). Data is uploaded directly to the server using a wireless (Wi-Fi) connection.

5 IoT data management platform

For the collection of data, we use the open-source ThingsBoard IoT platform, abstracting hardware and virtual sensors. This platform is configured to model the site as a set of assets (there are two greenhouses, each one being an individual asset), devices (each sensor pack or virtual sensor is modelled as a single device) and operators with various roles (site supervisor, agronomist). The platform

Table 2. Sensor packs

Wireless connectivity		
Plant row packs	Soil moisture, soil temperature (optional)	On individual plant rows.
Outflow packs	PH, electric conductivity	Outflow collection points across the site.
Indoor climate packs	Temperature, humidity, light level and irradiation	Equidistant locations across the site.
Ethernet connectivity		
Coordinator packs	These collect data wirelessly (via Xbee) from multiple other sensor packs (plant row, indoorclimate and outflow)	Collect, store, pre-process and transmit the data to the server.
Weather station pack	This integrates all the outdoor sensors for the site, sending data directly to the server.	Single location on the site

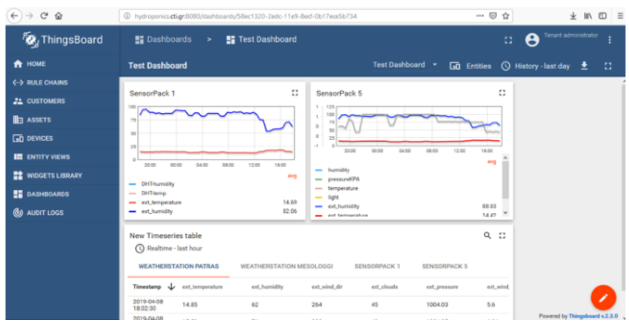

Fig. 3. IoT management platform interface.

offers the ability to visualize the data at an aggregate or individual sensor basis (using custom-designed data visualisation dashboards, Fig. 3), and to establish alerts for operating conditions exceeding specified thresholds. The sensor packs and virtual sensors communicate data to the platform using HTTP REST APIs.

6 Conclusions and Future Work

We presented an IoT-enabled hydroponic system based on Arduino sensor packs, producing recommendations to professional agronomists. Field test results have shown that the proposed system is working satisfactorily, comparing the values of the recorded sensor data against measurements with professional instruments. We are in the process of implementing quality improvements of predictions by collecting data from multiple sites. In this way, a community of hydroponic installation operators can benefit from the knowledge contributed by others, and therefore solving the "starting user problem". A further advantage of this approach is that it may minimize the need for IoT equipment, as fewer sensors will be necessary for accurate monitoring and predictions.

The project must still meet significant challenges. Power management tests of the arduino boards show that the 9V battery on each board doesn't last more than 36 hours of continuous operation. A solution may be to power the boards using power over Ethernet (POE) or solar panels. Another challenge relates to the connectivity of sensor nodes. We are modelling a hybrid solution using Xbee micro-mesh network and Ethernet connectivity for some nodes, but the changing conditions in the greenhouse may pose challenges, as plants grow and may interfere with wireless links. Finally, the biggest challenge relates to managing the large volume of data. Based on our limited data collection we believe that we will be able to offer useful insights from ML, but it is unknown how much data is necessary to achieve useful results. We need to carefully balance the accuracy of predictions with the requirements for data storage and processing power.

7 Acknowledgements

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