AISS4SA
Artificial Intelligence & Smart Sensing for Smart Agriculture

PRINCIPAL ACADEMIC TUTOR

Stefano Mariani
Dept. of Civil and Environmental Engineering, Politecnico di Milano

ACADEMIC TUTORS

Valter Carvelli
Architecture, Built Environment and Construction Engineering Dept., Politecnico di Milano

Chiara Corbari
Dept. of Civil and Environmental Engineering, Politecnico di Milano

Stefano Invernizzi
Dept. of Structural, Geotechnical and Building Engineering, Politecnico di Torino

EXTERNAL INSTITUTIONS

CentraleSupélec,
McGill University

EXTERNAL TUTORS

Filippo Gatti
CentraleSupélec – Laboratoire de Mécanique de Paris Saclay

Hamid Akbarzadeh
Bioresource Engineering and Mechanical Engineering Departments, McGill University

TEAM MEMBERS

SIlvia Capozzoli
Electronic Micro and Nanosystems, Politecnico di Torino

Alessandro Marchei
Embedded Systems, Politecnico di Torino

Lucrezia Piccari
Systemic design, Politecnico di Torino

Executive summary

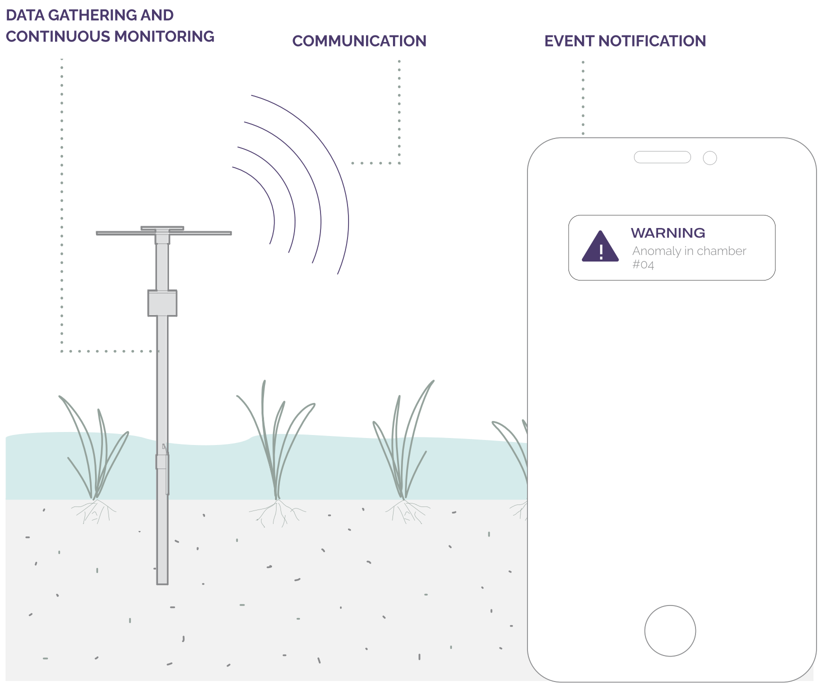
Main Issue: Rice cultivation, crucial for global food security and the economy, especially in regions like Asia and Italy, depends on maintaining consistent water levels in paddy fields. However, climate change and desertification are threatening water availability, while levee damage caused by burrowing animals and heavy rains leads to water loss, jeopardizing both crops and the environment [3]. Current monitoring methods are limited, forcing farmers to manually inspect chambers daily, which is time-consuming and inefficient.

Proposed Solution: The AISS4SA project aims to optimize water usage by implementing a modular system that monitors water levels in different paddy field chambers. The system detects anomalies such as water leaks and alerts farmers via mobile notifications, indicating the exact location of the problem. This enables quick intervention, preventing water loss and reducing manual inspection efforts. The system is characterized by its affordability, modularity, ease of maintenance, and user-friendliness, making it accessible and practical for widespread adoption.

Advantages: The solution offers several advantages. It saves farmers time by automating water level monitoring, reduces water consumption and lowers costs associated with restoring optimal water levels. Additionally, preserving the water levels in rice paddies helps protect the ecosystem and cultural heritage of regions like Vercelli, Novara, and Pavia, where rice farming is part of the cultural heritage. The system's low-cost components and modular design make it easy to maintain and upgrade, offering a sustainable and long-term solution to the problem of levee damage.

Key Words

Smart Agriculture, Rice cultivation, Water Management, Sustainability, Innovation, Impact



Project description written by the Principal Academic Tutor

Bio-mimicking has emerged as a way to attain unprecedented performances by smart systems, in terms of resilience under the adverse effects of climate change. In recent ASP projects, we proposed to exploit origami/kirigami-inspired morphable structures to react in real-time to the changing environment and reduce the energy footprint. We also proposed smart sensing systems to collect data and process them in situ, to reduce the water footprint of crop production.

With a similar perspective, the goals of this multidisciplinary project are:

- In the field of agriculture, to review the state-of-the-art concerning the use of deployable protection structures for crops.
- To identify how bio-mimicking can provide benefits in terms of electrical energy production through PV panels, reduction of the water consumption for irrigation through the proper use of Artificial Intelligence tools and agro-hydrological models fed by meteorological forecasts in real-time, to reduce the effects of extreme temperature risks, to overall enhance the production yield by providing the proper, controlled micro-environment to the crops.
- To validate the proposed solution through a mock-up, assessing also how it can beneficially interact with crops in the presence of vegetable growth.

Such goals can be effectively attained only if engineering, architecture, and design provide a truly multidisciplinary environment.

Team description by skill

AISS4SA project has three members: two engineers and one designer. To best exploit the multidisciplinary background and in order to have a clear overview of the improvements, everyone in the team was always informed about the activities being carried out. The most technical parts of the project have been solved by the members with the most relevant background, whereas the research and field test phases as well as final outputs involved the entire team.

Silvia Capozzoli was the Team Controller, managing the communication between the team and the tutors.

Along with Alessandro Marchei, she took part in the development of the prototype (Computing Device, Sensors, Radio Communication and Power System) and of the app. Due to their studies they were responsible for most of the technical parts of the project, as well as for the data analysis of test results.

Lucrezia Piccari has been resposible for the context research, interviewing stakeholders, understanding the irrigation system and analyzing the state of the art. She also designed the final shape of the module and prepared most of the presentations.

Goal

AISS4SA project aims to develop a solution that is able to improve water management optimization in rice cultivation.

The analyses conducted on the context and state of the art led to the definition of the following objectives:

- Continuous monitoring of water levels in the rice paddies during irrigation periods of the chambers
- Monitoring of water temperature to detect any thermal fluctuations that could compromise cultivation
- Analysis and collection of data related to water levels, with detection of anomalies
- Communication of data to the farmer to promptly signal the presence and location of such anomalies, allowing for immediate intervention

To meet these needs, it was necessary to develop a project that could adapt to a variable number and size of chambers, depending on the farmer's requirements, and that would also be cost-effective and easy to maintain.

Additionally, given the usage context, the solution had to be water-resistant.

Considering the landscape importance of the rice paddies in the Vercelli, Novara, and Pavia regions, the solution also needed to be visually unobtrusive to avoid disrupting the landscape, while still being visible when field interventions were required.

Understanding the problem

Rice cultivation requires larger amounts of water compared to other crops, such as corn and wheat, because the plant needs to be partially submerged. In fact, water, especially in the Italian climate, acts as a temperature regulator, protecting the plant from temperature fluctuations, particularly in the early spring months. Additionally, it helps supply nutrients, reduces the need for pesticides, and provides structural support. The water level varies depending on the growth stage of the plant [1].

To maintain a uniform water level, and thus an even soil surface, fields are divided into chambers connected by a network of canals that allow water to flow by gravity. However, sometimes the levees are damaged by animals, such as moles or insects, causing water leaks. For this reason, farmers must check all chambers daily to prevent water loss [2].

This issue results in wasted time and money for farmers, as well as unnecessary water waste. Given the current climate challenges and predictions of worsening droughts in the coming years, such waste must be avoided [3].

Exploring the opportunities

The state of the art reveals that in this filed there is still work to be done. The use of sensors and technologies for monitoring paddy fields is still in the study phase. This is proved by the fact that no such technologies are currently on the market. The case studies found are either in the development stage or have stopped at a research stage, without entering the mainstream.

However, elements common to several technologies have emerged, such as the presence of a camera that allows one to remotely observe one's rice fields, or the use of batteries to power the sensors. However, batteries have a limited lifespan, which means they need to be replaced or recharged and, consequently, require additional efforts.

Another aspect to consider, as some projects have pointed out, is the cost, which must be as low as possible for the technology to be affordable. In fact, the greatest difficulty in keeping prices down is the fact that rice fields are divided into chambers, each of which must be monitored by one or more sensors. This requires the purchase of a certain number of modules.

These considerations have given us useful information for our project.

Generating a solution

The project consists of four phases:

1. Continuous water level monitoring
2. Detection of anomalies
3. Communication of anomalies
4. Reporting the location of the anomaly

The product delivers real-time data, such as mapping water levels and temperatures in each chamber, while continuously analyzing the collected information to offer insights on the overall safety of the irrigation system. It can also identify anomalies and detect water loss caused by system failures or damage to the chamber borders.

With the use of water level sensors, the system is capable of monitoring water levels in real time, accounting for the plant's specific water needs at different growth stages. The sensor monitors water temperature, gathering data on day/night thermal variations and identifying any significant temperature fluctuations. This information is transmitted to a central unit via LoRa technology, a low-power wireless communication system that supports data transmission over distances of up to 5 kilometers or more in open areas. The data is then relayed to the user through an app, enabling them to decide if intervention is necessary.

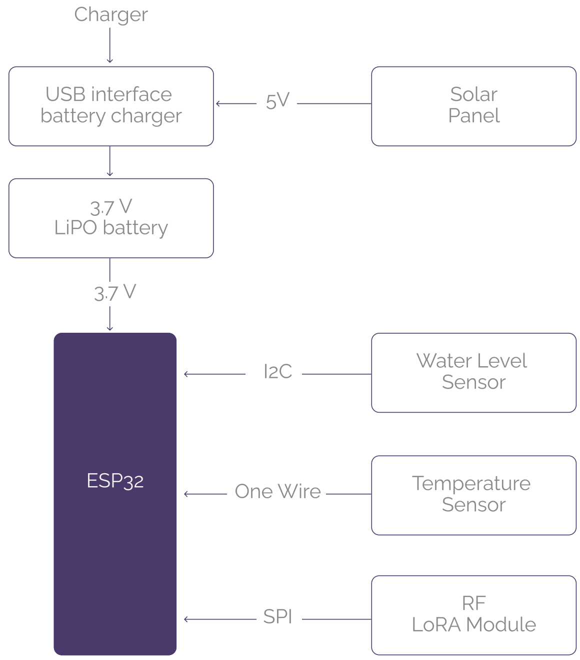
The system is powered by solar panels, reducing the labor required for battery maintenance. As a result, it provides continuous 24/7 monitoring and alerts for water levels and temperatures across all chambers within a rice paddy. The app delivers precise and timely visual notifications, detecting any specific chamber at risk of damage or water loss.

To ensure accurate monitoring, each chamber must be equipped with at least two water level sensors. To minimize costs, the modules are designed using commercial off-the-shelf components, which are easily accessible and replaceable, thus reducing maintenance expenses and extending the system's lifespan.

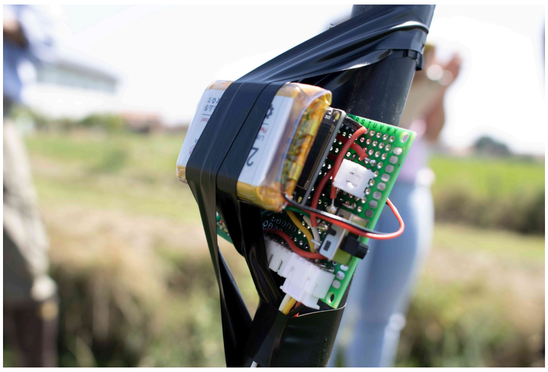
A cover protects the electronic components from sunlight.

The solution is designed to be visible but non-intrusive. It is placed near the paddy field embankments so as not to interfere with operations during the rice growth process. The use of solar panels makes it independent of external power sources, avoiding the need for cables or frequent battery replacements. Additionally, its modular structure provides flexibility and easy adaptability to the varying needs and land sizes of each user.

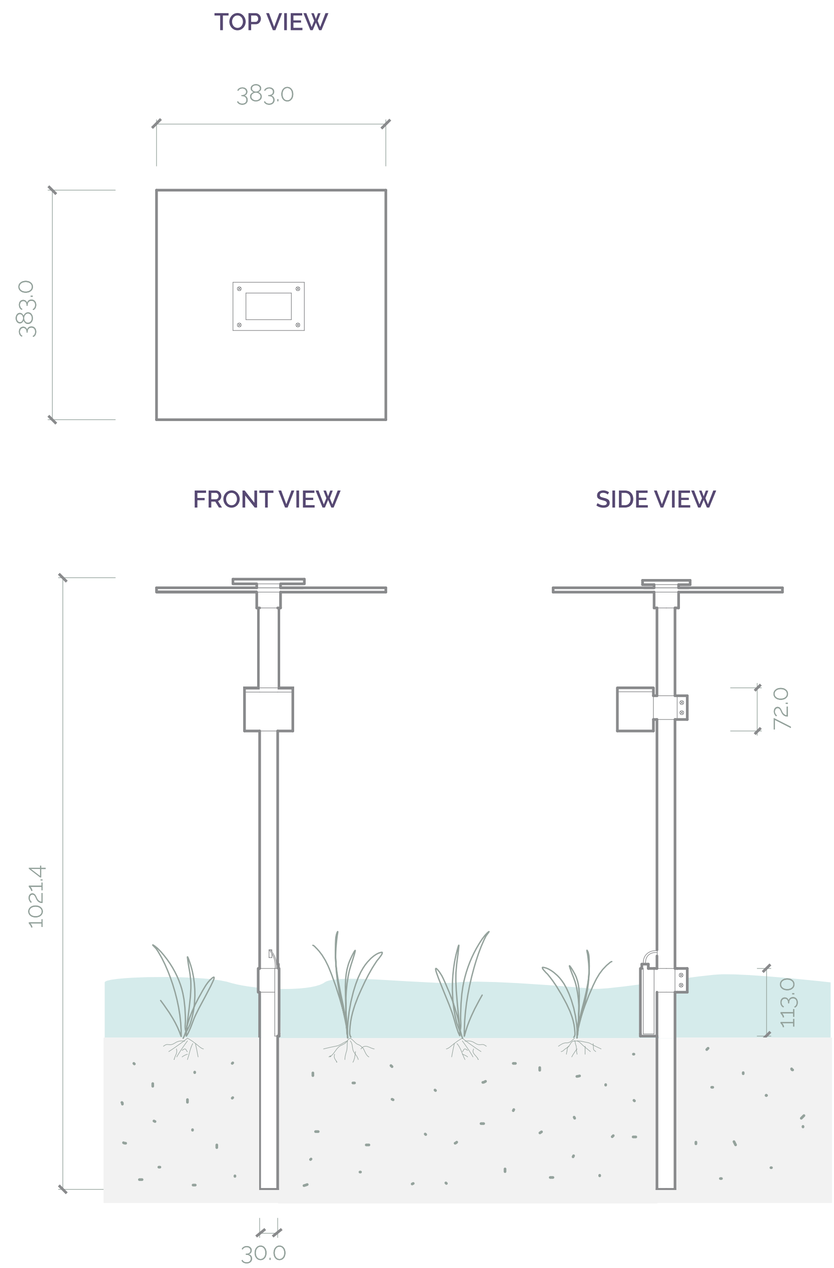
Graphical representation of the module



On the left: battery and LoRa system
On the right: water level sensor



Technical drawings of the module



Dimensions in mm

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