AIS4SIA

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Executive summary

The increase of the frequency and strength of extreme meteorological events related to climate change is a trend that will characterize the upcoming years. Droughts are part of this scenario, resulting in a great threat to one of the most crucial human activities, agriculture. With the decrease of availability of water, its optimal management will be a critical aspect for the survival and success of farmers' business. Vines are one of the most valuable crops suffering from the alteration of regular seasonal cycles, which represents a dramatic threat for this economic sector.

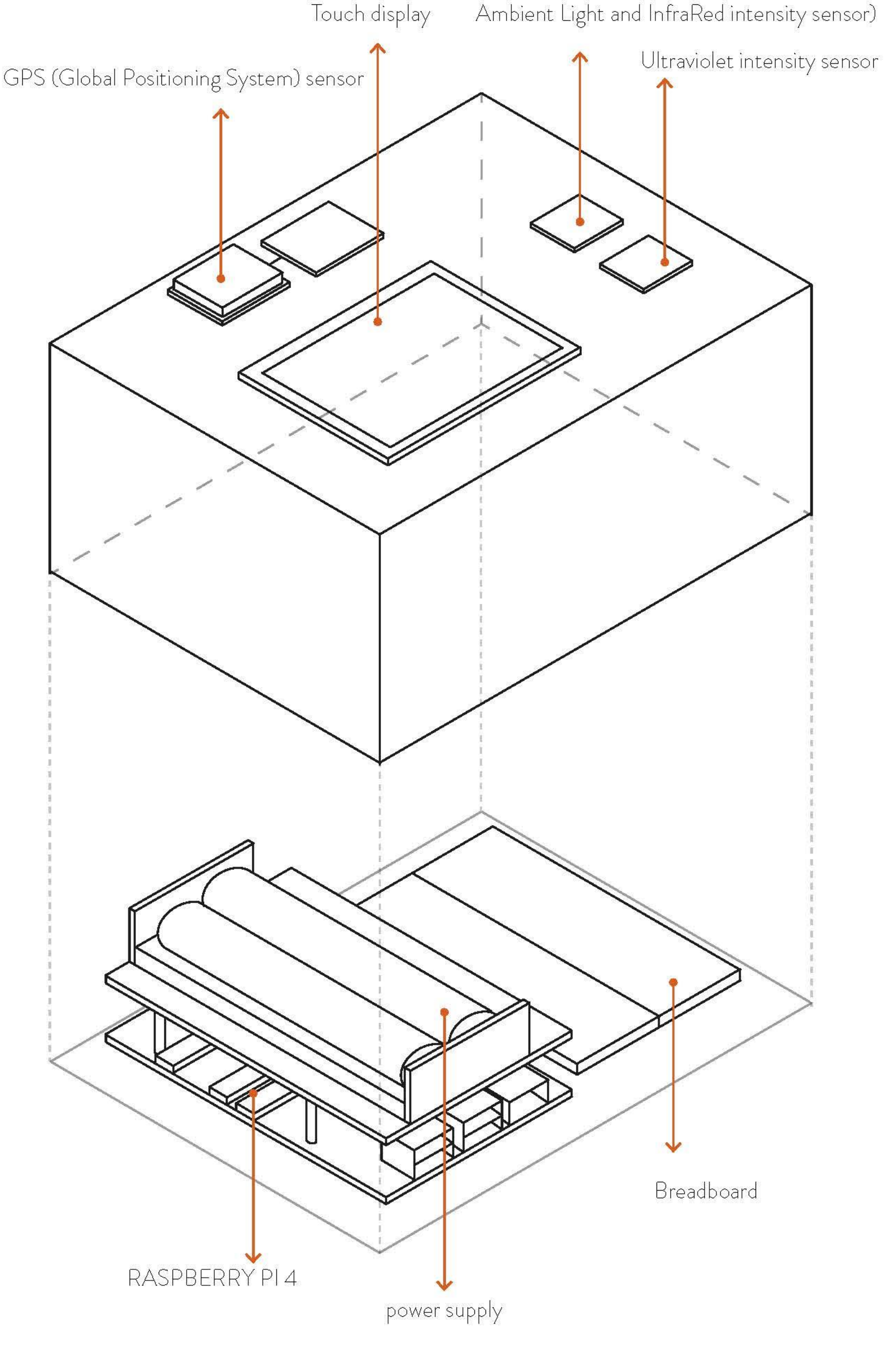
AIS4SIA project tries to deal with this problem with the aid of technology and artificial intelligence. One effective way to monitor the health status of vineyards is offered by Crop Water Stress Index (CWSI), a quantitative measure of the need of water of a plant. We study, design and implement an intelligent autonomous system to measure the spatial and temporal distribution of CWSI on a crop field, offering a valuable instrument to have a precise insight into the health of vineyards and define targeted interventions to recover the optimal water conditions needed to achieve desired characteristics of the production. Furthermore, geospatial and historical analysis of CWSI can be performed to gain insight into the characteristics of the crop field and infer connections with the productivity and harvest.

The proposed solution is a system composed of two main parts: the sensing module that collects climatic data throughout the vineyard and the computational engine that calculates the value of the CWSI based on such data and generates a georeferenced heatmap. Its potentialities have been tested in a data collection session in a vineyard owned by Azienda Agricola Balladore Pallieri through a low-cost prototype composed of miniaturized sensors mounted on a Raspberry Pi that we designed and assembled ad-hoc for the purpose. This on-field campaign helped us to verify the validity of the concept and its implementation to collect climatic variables and elaborate the data into real CWSI heatmaps. Moreover, it contributed to highlight the areas of improvement of the design, showing its advantages and criticalities.

The system well fits the current state of society responding to one of the most urgent challenges: climate change. The system provides value as a data monitoring tool able to inform the farmers on the hydration condition of the field almost at real-time with great level of geographic detail, enabling a wise water management and boosting plants care. The possibility to control the production in terms of both quality and quantity results into a reduction of risks and a strategic advantage. Moreover, it increases the resilience of the economic system to climate change, encouraging the penetration of advanced technological solution into this fragile sector.

Key Words

Vineyards | Artificial intelligence | Water management | Climate change


Touch display
Ambient Light and InfraRed intensity sensor)
Ultraviolet intensity sensor
GPS (Global Positioning System) sensor
Breadboard
RASPBERRY PI 4
power supply

Project description written by the Principal Academic Tutor

AIS4SIA project proposes an automatic system for monitoring the health of vine plants through their water stress, to possibly mitigate the increasingly frequent extreme meteorological events such as droughts. The envisioned system measures the spatial distribution of the so-called Crop Water Stress Index (CWSI) on the crop field, to help the farmers to have a precise control of their vine's health and, therefore, of the final quality of their product.

The physical solution is composed of two parts in which sensors are placed: a fixed sensing module and a movable one, based on a drone. This choice is made to assure the correct acquisition of all the parameters needed for the calculation of the CWSI. After having collected the measurements, an associated computational engine computes the local CWSI index and generates a georeferenced heatmap of the vineyard. Furthermore, exploiting the geospatial and historical analysis of the CWSI, insights into the characteristics of the crop field and inference of the connections with the productivity can be performed as well. The solution has been tested via a prototype and a data collection session in a vineyard.

The project is a non-invasive technology that brings agriculture, a field known to be still stuck in the past, closer to the adoption of future technological solutions.

Team description by skill

The challenges of the project induced us not only to merge our academic skills with a multidisciplinary approach, but also to learn new arguments and put our hands on techniques and themes completely new for us. In particular, we had to adapt our scientific and industrial-oriented background to the characteristics of agricultural sector, learning the basic notions of biology and agronomy.

- Laura*, Materials and Nanotechnology Engineer:* she contributed with her expertise of physics and thermodynamics to define the processing of environmental data to obtain the water stress index and with her knowhow about the design, implementation and interpretation of scientific experiments during the on-filed data collection session that we conducted.
- Gabriele, *Telecommunication Engineer*: he contributed with his know-how about data storage systems, IoT and telecom technologies to the design and implementation of the software and of the hardware of the data collection prototype and of the final solution.
- Pietro, *Mechatronic Engineer*: he contributed with his knowledge about drones, robotics and automation to the design and implementation of the software and of the hardware of the data collection prototype and of the final solution.
- Carlo, *Mathematical Engineer*: he contributed with his background about statistics and data analysis to the processing and interpretation of environmental data to obtain the water stress index and the implementation of predictive models.
- Giuseppe, *Building Engineer*: he contributed with his knowledge about thermodynamics to define the processing of environmental data to obtain the water stress index and with this experience of management of complex building projects to the elaboration of a business model for the proposed solution.
- Margherita, *Building Architect*: she contributed with her expertise to manage complex architecture projects to the design and implementation of the prototype of the on-session data collection and of the final solution, adapting it to the needs of the stakeholders.
- Alice, *Industrial Product Designer*: she contributed with her know-how on design of industrial and engineering products to the definition of the system capturing the needs of the stakeholders.

Goal

The goal of our project is to offer a solution to combat and reduce the impact of droughts on vineyards that are becoming more and more threatening for the agricultural sector due to climate change. With the aid of technology and artificial intelligence, the idea is to develop a system able to automatically inspect the water stress of plants that represents a quantitative indicator of the health status.

In such a way, the objective is to combine environmental data collected from moving drones and standing sensors in order to offer a monitoring system for vineyards to have an insight of the health of their plants, outperforming human eye and satellite images in term of precision and detail. Therefore, the solution we propose can be the key to design specific interventions in the field to restore the water stress to optimal levels and to develop predictive models of the productivity of the vine correlating it with historical and geographical analysis of data.

In this way, the aim is to offer to vineyards a competitive advantage in terms of optimization of crucial resources, water in primis, and of control of the status and outcome of crop fields to face the challenges of climate change that are expected to become more and more threatening in the following years. At the same time, we try to design a solution not interfering with the vineyards operations, always keeping an eye on the economical sustainability of the solution for the very fragmented economical sector of vine producers.

The principal target of our project is not only to study and design a possible solution, but to practically show its potentialities assembling a prototype able to collect the data needed to extract the water stress index, displaying it with a heatmap. As a result, we dedicate a large part of our effort to the design and implementation of a physical system able to collect the environmental data in vineyards and of a data processing pipeline to produce the corresponding geographical map of the water stress, trying to infer the productivity through a predictive model.

Our final goal is to facilitate the adoption of Agri-Tech technologies in small rural realities increasing their resilience towards future environmental scenarios and, at the same time, favoring the integration of the traditional knowhow of elder generations of farmers with the technological expertise of younger ones.

Understanding the problem

AIS4SIA projects targets the issues caused by droughts in vineyards. Therefore, we study the climatic trends regarding extreme meteorological events at regional and continental scale, focusing on their impact on the agricultural sector, particularly on vineyards, enlightening a phenomenon that is becoming more and more threatening.

Some basic notions of biology and cultivation techniques of vines have been acquired in order to have a better understanding of the needs and weaknesses of the plant. This analysis is conducted also with some interviews with agronomists and people working in the sector that helped us to identify the focal points of the problem and suggesting us the path of water stress monitoring to face droughts together with their needs in terms of compatibility with existing infrastructure, non-invasiveness, production requirements and economical affordability.

Finally, an analysis of existing Agri-tech technologies and companies is conducted, showing us the promising directions to innovate in the sector combining the intelligent monitoring of water stress with prediction of the output of crop fields.

Exploring the opportunities

The interviews with agronomists and people working in vineyards together with an analysis of existing Agri-tech technologies and companies show us many open directions of development of new technological solutions. Indeed, the inclusion of artificial intelligence in the sector is at its very early stages due to the extremely variable nature of the environmental factors, whose single effect is difficult to be predicted with accuracy.

Therefore, the following aspects made us agree to explore and develop the solution we propose.

1) The indication of water need as a crucial aspect for the health of plants, 2) the existence in the literature of Crop Water Stress Index (CWSI) to quantitively monitor it, 3) the affordability and ease of use of sensors needed to collect the environmental data to compute CWSI and 4) the possibilities offered by data visualization and predictive models.

Generating a solution

The first step in the implementation of AIS4SIA solution is the definition of the relationship connecting the environmental parameters and the CWSI through thermodynamical laws involving air pressure, humidity, wind speed, ultraviolet (UV) radiation, infrared (IR) radiation and temperature of the canopy of the leaves.

Before the implementation of the system, a regression analysis correlating the CWSI computed from satellite data and the productivity of a vineyard in specific location is carried to confirm the intuition of the goodness of CWSI for health monitoring.

The application of the final system passes through the definition of five fundamental requirements identified by our stakeholders that are:

1. non-invasiveness with respect to agricultural techniques;
2. automation of the monitoring process;
3. data-driven conclusion about the health status of the crop field;
4. affordability of the system for companies with small power of investment;
5. ease of use of the system with an intuitive interface and basic instructions needed for non-technical operators.

The final system is constituted by two main parts: the sensing modules collect environmental information about the vines and the vineyard status, while a server analyzes the collected data, computes the CWSI, and generates maps that can be used to monitor the current status of the vineyard in detail, as well as to make prediction about the future development of the grapes and the plants.

The sensing subsystem is composed of a series of fixed sensors along the rows of the vineyard measuring pressure, air temperature, air humidity, UV radiation, IR radiation and wind; while an autonomous drone equipped with different kinds of cameras, including a camera used for navigation purposes and a thermal camera, detects instead the canopy temperatures of the leaves of the plants. The collected data are transmitted to and stored in a server where ML algorithms fuse the information coming from all sensors correlating the water stress during each period of the year with the expected productivity and quality.

The design of the system has been tested with an on-field data collection session in the vineyard of *Azienda Agricola Balladore Pallieri* in Calosso (Asti, Italy). For the occasion, a prototype featuring an automatic data acquisition system mounted on a Rasperry Pi single-board computer connected to environmental sensors and managed by a Graphic User Interface has been assembled and tested. The acquired data have been processed and a CWSI heatmap of the vineyard has been produced offering a concrete perspective of the potentialities of the solution, confirming the validity of its concept and, at the same time, highlighting the areas of improvement of the design to further develop it.

Main bibliographic references

Anda, A. 2009. "Irrigation Timing in Maize by Using the Crop Water Stress Index (CWSI)." Cereal Research Communications 37 (4): 603–10.

Jackson, Ray D. 1982. "Canopy Temperature and Crop Water Stress." In , 43–85.

Spano, D, V. Mereu, V. Bacciu, S. Marras, A. Trabucco, M. Adinolfi, G. Barbato, et al. 2020. "Analisi Del Rischio I Cambiamenti Climatici in Italia." Fondazione CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici.