Smart Seed

Smart Irrigation & Weed Detection

Precision Agriculture Solution

Students:
Sara Messara, Mohamed Sammad, Abdel-Malek Atchi, Mosaab Derbal

Abstract – The *IoT is applied in many remote monitoring applications in vast domains, from healthcare to smart factories, and including smart homes, smart cities and smart farming. Some of the benefits of the IoT is that it can be used to improve the quality of the services for automated and remote farming systems. However, Internet instability or limited coverage in remote areas still presents several challenges for cloud-centric IoT architectures. Edge computing can help to overcome some limitations of these traditional cloud-centric IoT systems. In our project, we propose a prototype of a smart irrigation and weed detection system based on Edge AI computing. The first system will use a Wireless Sensor Network (WSN) for real time data gathering, an AI Algorithm will then process this data to make optimal prediction for water flow and irrigation frequency for each part of the farm. The second system will use a camera for image sampling, an implemented algorithm will detect weed presence and will notify the farmer to take action. A mobile application will provide a friendly user interface to the farmer, for real time monitoring and remote control.*

Keywords **–** Edge AI, IoT, Smart Irrigation, weed detection, Image Processing, Precision farming

1. Introduction

1.1. Background

Traditional irrigation practices are dominant in Algeria. They use uniform applications (only one rate all over the field) of agricultural inputs such as irrigation, herbicides and pesticides within fields.
However, these practices are inefficient because they do not take into account the within-field and crop variability.
The worldwide tendency to overcome similar problems is the use of modern strategies and technologies, known as "precision farming". But when it comes to the Algerian context, we are facing many factors that hurdle the adaptation of such strategies. We will talk more about these challenges and other issues which have stimulated our motivation in the next point.

1.2. Motivations

Social context: Demography growth rate of 1.85% per year, a rate that adds over 800,000 people to the population every year [1], exacerbated with expansion of urban areas at the expense of fertile lands, became the new challenge of the Algerian water resource sufficiency and food security.
Ecological context: Issues related to Climate Change as drought and desertification (20 million of hectares of soils in High Plains are highly exposed and vulnerable to desertification [2]), are constantly impacting Water Reserves. Non moderate use of herbicide also causes water and soil contamination, which decreases the quality and fertility of the soil and thus the production rate.
Technological context: The agricultural sector in Algeria relays exclusively on traditional techniques and small-scale farming that have proven their outcome limitations. Another challenge is the low internet coverage, especially in the countryside.
Academic context: Algerian universities are far away from interdisciplinary cooperation needed to respond effectively to modern challenges the country is facing. Moreover, there still is a gap between universities studies and research projects, and real field application, specifically in the agricultural sector.

1.3. Objectives

"Smart Seed" addresses 3 major agricultural challenges:

- *Water resources waste:* This solution tempts to reduce the water footprint, as the agricultural field will pump by 2050 70% of world water resources with a waste rate estimated at 60%. [3]
- *Weed invasion and herbicides toxicity:* Random spread of herbicides induces ecological disasters either on soil, water tables or crops.
- *Efficient harvesting:* Smart Seed promotes Precision Agriculture paradigm that implements the 5R concept that is Right input, in the Right amount, to the Right place, at the Right time, and in the Right manner and thus increased harvest productivity with optimized resources. [4]

2. Project description

"Smart Seed" is a precision agriculture [5] solution that gives birth to a new vision of farming paradigm, by proposing an innovative smart farm model, **the 1st in its kind in Algeria.**

"Smart Seed" is an Edge-AI - IoT based solution conceived to address 2 major challenges in a cornerstone domain: Agriculture. This smart solution tackles: "water irrigation inefficiency" and "weed invasion of crops" problems, by proposing the 2 following systems:

- *A smart crop irrigation system:* A precise control of 2 irrigation parameters: The "irrigation occurrence (frequency)" and the "water flow (quantity) per irrigation". The Edge-AI solution is real time, and based on an in-farm monitoring network that senses the RT farming conditions (soil conditions, weather conditions, geographical conditions) and outputs the irrigation parameters to control the water valves opening rate.
- *A weed detection system:* The 2nd part of the solution detects undesirable plants (Weeds) that parasite useful crops. This solution is UAV (drone) based, integrating RT aerial imagery of the field, that will be processed then fed to our AI model for a real time detection and localization of weeds.

The smart farm concept will make use of these 2 AI models in the decision making at the microprocessor level. Our model of a real scale smart farm will be composed of:

- A Wireless Sensors Network placed strategically in the operating farm.
- A UAV (drone) equipped with an RGB camera for the aerial imagery sampling of the field.
- A data processing unit at the farm level (no cloud computing, all Edge-AI) for monitored data storage and model implementation, to output RT targeted data.
- A friendly user interface dedicated to the farmer, for RT farm condition monitoring.
- Automatic irrigation system integrating solenoid valves connected to the data processing unit through switches and relays.

This study presents a small-scale smart farm prototype making use of the development kit provided by AIMX, using one CPU board (Jetson nano board), one camera (Raspberry Pi Camera Module V2) and one co-processor (Intel Neural Compute stick 2). However, we will demonstrate to the jury the high scalability of this revolutionary solution in the next sections.

3. Originality of the project

The ingenuity and originality of the "Smart Seed" solution resides in its relevance regarding the global and specially the Algerian context as it addresses real field challenges in a cornerstone domain that is agriculture. It is highly scalable, affordable and achievable. It makes an ingenious use of Edge-AI combined with IoT. The solution implements 3 learning algorithms: 2 major types of *Supervised Learning* algorithms which are *Regression* (for irrigation prediction) and *Classification* (for weed detection), besides an *Unsupervised Learning* algorithm (for UAV image samples labilisation). It also introduces a whole new product and concept to the Algerian market which is "smart farm model" and will revolutionize and tremendously impact a highly sensitive and full stacks sector , in all aspects; socially, economically and ecologically that is **agriculture**.

4. Technical specifications

4.1. Irrigation system

4.1.1. Data for Training and testing:

We set 2 options, the choice will depend on the availability and the exploitability of the found database:

- *Algerian Data:* Needed data can be provided by ENSA (Ecole Nationale Supérieure d'Agriculture), CDTA (Centre de Développement des Technologies Avancées), Algeria Open Data For Africa, ENSH (Ecole Nationale Supérieure d'Hydraulique)

Note: As we contacted all these institutions and got no reply back yet.

- *Foreign Data:* In the case where no exploitable Algerian data is found, the best alternative is using a foreign country database. One of them is the Canal Del Zujar Irrigation District of southwest Spain (CZID) [6]. CZID is made up of ten independent hydraulic sectors and covers a total irrigated area of 21,141 ha. Sector II of the CZID covers an irrigated area of 2,691 ha where the main crops are tomato, maize, grapevine and rice. It has a telemetry system with flow meters that record hourly flow rates at hydrant level. For the 2015 irrigation season, hourly records were aggregated at daily level. In addition, information is also available about crop types and sizes of the farms irrigated by each hydrant. Daily climate data are obtained from a weather station located in the irrigation sector.

4.1.2. Monitored data

Irrigation control employs *Proximal Sensing* technique [5]; Sensors are in direct contact with the target (crops) at the soil level. The following sensors will be used: Temperature sensor (Thermocouple k type probe/ PT100 probe), Humidity sensor (DHT 22), Wind speed sensor (3 Cups Anemometer), Light level detection (BPW 34), Rainfall sensors and Soil moisture sensor.

For a real scale farm, each sensor will be a node among a Wireless Sensor Network (WSN). Systems such as MESH network [7] offer a backup solution. If any of the nodes stops transmitting or receiving, or even if signal pathways become blocked, the operating software reconfigures signal routes to maintain data acquisition from the network. Besides Proximal sensing, the model needs *farm specific data* that include the soil humus, farm area and type of crops being cultivated.

These data are fed to the model algorithm, computed locally in the *Jatson Nano Developer kit*, accelerated by the *Intel Neural ComputeStick 2*, which makes it Edge-AI compatible.

4.1.3. Data Mining

Data cleaning: this includes treating the missing values (by using for example zeros or median values), significant row (correlations) and column (bayesian ascent, Chauvenet principle), data labelization, seasonality and aggregation analysis, dummy variables generation.

Algorithm: One of the best AI algorithms used for irrigation parameters prediction is the ANFIS algorithm that stands for Adaptive Neural Network Fuzzy Inference System. ANFIS combines 3 major algorithms of artificial intelligence which are: Neural Networks, Fuzzy Logic and Genetic Algorithms The typical structure of an ANFIS is composed of five layers network, where the adaptive nodes represent different values depending on the input variables and the fixed nodes develop the same function independently of the input variables. The number of nodes in the different layers depends on the number of fuzzy rules considered. [6]

4.2. Weed detection

4.2.1. Data for Training and testing

Many web open-source databases are offered for UAV weed detection such as senseFly. [8]

4.2.2. Monitored Data

Weed detection employs *Remote Sensing* monitoring technique [6] that relies on Unmanned Aerial Vehicles (UAV). For simplicity and affordability, we propose the use of a drone equipped with the provided *Raspberry Pi Camera Module* (8 MegaPixels). The drone will take regular image samples of the field surface and store them in a local memory. The data will be then collected and transferred to the computing unit (*The Jetson Nano Developer Kit*) accelerated by the *Intel Neural ComputeStick 2* for faster computations.

4.2.3. Data Mining

Image processing: The Raspberry Pi camera module provides RGB image samples that need to be processed and labeled before being fed to the model. One method consists of converting the RGB images into binary ones using unsupervised learning methods to create the database. We first process the skeleton filtering, then we apply Hough Transform for line detection (this suggests implicitly that the farm presents a row crops dist), finally, we implement an unsupervised 2-classes classification algorithm for labelization, most used one being SLIC (Simple Linear Iterative Clustering) using Superpixel segmentation. [9]

Algorithm: We will implement a supervised learning algorithm. One that provides best results is the SVM (Support Vector Machine). [10]

4.3. Mobile Application (user interface)

The app provides the farmer with monitored data, irrigation parameters and weed level and localization.

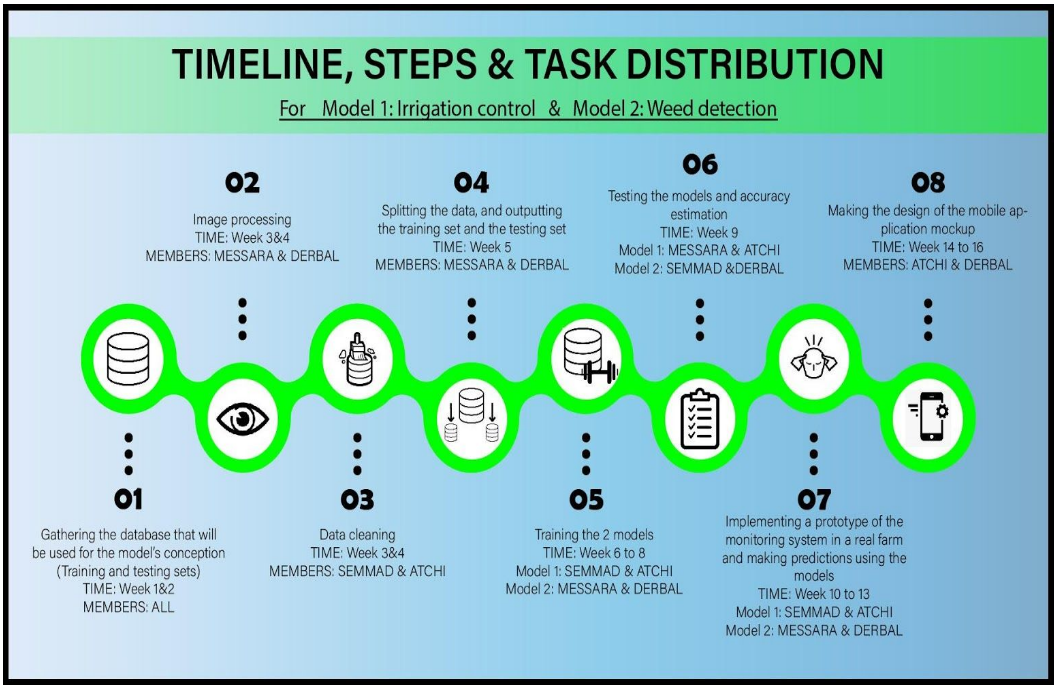
4.4. Development Kit integration Review

NVIDIA Jetson Nano Developer Kit: This is the processing unit. All sensors are connected to this module (wireless or wire connections) to provide data. Jetson nano provides a 4GB LPDDR as data storage. The 64 ARM CPU and 128-core GPU allow the computation of the data within the implemented models (irrigation control model and weed detection model). The output data will be displayed to the farmer through the mobile app for a manual control of the farm, or will be directly transferred to the actuator (solenoid valves) in case of a fully automatic control. Since the computation of the AI algorithms occurs on this unit and not in the cloud, this makes our solution fully Edge AI.

Raspberry Pi Camera Module V2: This unit is the vision sensing module. It offers a resolution of 8 MP, and RGB 10-bit data format. Mounted on a UAV (drone), the camera allows the continuous image sampling of the field used for the weed detection algorithm.

Intel Neural Compute Stick 2: This module is a task accelerator unit also known as a coprocessor used for Edge AI solutions. It is powered by an advanced VPU, integrating 16 SHAVE cores and an OpenVINO distribution. It enables AI development without cloud computing (EDGE AI), and is easily ported to vision modules. It will be used for faster computation performances, and thus real time response.

5. **Project outline (TimeLine, Steps & Task distribution)**



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