Estimation of the Best Measuring Time for the Environmental Parameters of a Low-Cost Meteorology Monitoring System

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Abstract. Meteorology monitoring is crucial for implementing smart agriculture systems. These systems should employ as few power as possible in order to avoid workers going to the fields to replace batteries. Thus, the collection and forwarding of data should be reduced as much as possible. However, the time interval to be employed should be large enough for the data to be accurate and so as to avoid data loss. In this paper, we examine different time intervals for data acquisition utilizing our proposed algorithm for our low-cost meteorology monitoring system. Real data has been analyzed with time intervals from 5 to 60 minutes. Results that the best time interval is 25 minutes for temperature, 45 minutes for humidity and 5 minutes for light.

Keywords: Precision agriculture · ESP32 · Algorithm · Low-cost · Decision making

1 Introduction

The predictions related to the world population, presented by different international organizations, suggest that there will be a large and constant increase in population in the coming years. Organizations such as the United Nations [1] predict that the world population will reach 8.5 billion people by 2030, and 9.7 billion by 2050. This increase in population brings with it the need for a very important increase in food production. But given this need, there are great difficulties to increase current production, among other reasons due to the important changes that are taking place

over the last few years in meteorology, water resources are becoming increasingly scarce every day.
Due to the causes previously exposed, it is necessary that agriculture advances in the future and becomes an intelligent agriculture. Smart agriculture is achieved by applying Information and Communication Technologies to traditional agriculture [2]. Thanks to their employment, farmers and engineers can use smart tools [3], through which they can be more efficient and consume smaller amounts of natural resources. Implementing this type of solutions can optimize the moments to temporize vital actions in the harvests, like the irrigation, sowing or the moment to add fertilizers to the terrain. In addition, through Artificial Intelligence, patterns can be determined, which can be used to generate intelligent systems that are very useful when making decisions.
In smart agriculture, it's vital to have information about multiple parameters that allow us to establish precision agriculture [4]. Among others, we can highlight as fundamental the obtaining of information in real time about temperature, humidity, precipitation or light.
Our proposal presents the evaluation of different time intervals to be applied to monitor meteorological parameters while reducing the amount of data gathered and transmitted by the system while maintaining the necessary information for decision making. We also present the results of real measurements obtained in an area of Mediterranean climate. This work is part of the implementation of our proposed smart irrigation systems [5].
The rest of the paper is organized as follows. Section 2 presents the related work. The system description is depicted in Section 3. The results are discussed in Section 4. Finally, the conclusion and future work is presented in Section 5.

2 Related Work

The Related work on low-cost meteorological monitoring systems and energy-saving algorithms is going to be presented in this section.
Due to the importance of meteorology monitoring, researchers have developed several meteorology monitoring systems. F. J. Mesas Carrascosa et al presented in [6] an environmental monitoring system for precision agriculture. The system is comprised of the Arduino ATMega2560 microcontroller, analogue and digital temperature and humidity sensors, a light sensor that detects the presence and absence of light, a clock, a Bluetooth module, an SD card module and a photovoltaic panel. The system was able to forward the data to a database for further processing. Real measurements were performed in a farm located in the Spanish city of Cordoba. The price of their proposal is below 100 € and results were similar to those of a real meteorological station Furthermore, a wireless weather station that included a web interface for users was developed by Hardeep Saini et al in [7]. The system was able to monitor temperature, humidity, pressure, wind direction and wind speed. Zigbee was employed for data transmission and alerts were generated according to the measured parameters. Results showed the accuracy of the proposed system.

These systems need to be deployed outdoors, thus the use of energy-efficient algorithms is necessary. Thar Baker et al. presented in [8] an energy-aware algorithm for IoT applications based on cloud called (E2C2). The algorithm allows utilizing the least possible number of services needed to complete the requirement. The proposed algorithm was compared to four other existing proposals. Results showed a better performance of the proposed algorithm regarding energy efficiency and least number of services used to complete a task in an optimal manner. Moreover, Ali Hassan Sodhro et al. developed in [9] an energy-efficient algorithm for e-health electrocardiogram wearable devices. The proposed algorithm called ETPC is then compared to other transmission power control algorithms. Results showed energy savings of 35.5% compared to those of other TPC solutions. However, the resulting packet loss was slightly higher than other TCP algorithms.
In this paper, an energy saving algorithm is going to be applied for our developed meteorology monitoring system. As opposed to other existing systems, our meteorology monitoring system is able to determine the amount of light measured in lux as well as temperature, humidity and the presence of rain. The algorithm has been applied to real measures obtained from a Mediterranean climate.

3 System Description

In this section, the description of the meteorological monitoring system for agriculture is going to be presented.
There are several environmental parameters whose knowledge is important to farmers and the development of a comprehensive system for precision agriculture. Temperature is one of the most important factors that affect plants. The correct growth of plants, blooming, photosynthesis or water and nutrient absorption are some of the aspects that depend on the temperature of the environment. To measure temperature, on this prototype the DHT11 sensor has been utilized. This sensor has been utilized to measure humidity as well. Humidity affects plant transpiration, its photosynthesis and its growth. Low levels of humidity are related to withered plants, small sized leaves or burnt or dried leave tips. High humidity levels are related to higher root and leave diseases, nutrient deficiencies or weak growth. The rain determines whether the irrigation should be activated or not. Furthermore, high amounts of rain should be accompanied of the implementation of proper drainage so as to avoid the excess of humidity in the soil. A rain sensor was utilized so as to determine the presence or absence of rain. Lastly, the amount of light is related to the photosynthesis process of the plants and may affect the constitution of the fruit.
Apart from the sensors described previously, the system is comprised of an ESP32 Devkit V1 microcontroller [10]. Furthermore, an SD card is incorporated to the prototype so as to store the information in case of the malfunction of the wireless connection or he server and the power is provided through a 12V solar panel and a set of batteries. The system is presented in Figure 1. The DHT11 sensor is located inside a protective plastic with open spaces to let the air flow. The open spaces are protected with a net to avoid the incursion of insects. The other sensors are located on the bigger encapsulation. The solar panel is supported by an aluminum structure and the rest of

the circuit and the microcontroller is located inside the encapsulation.
The algorithm of the system is presented in Figure 2. Firstly, the thresholds of the parameters are set. Then the initial values are measured and used as reference values. The counter and variables of the different metrics are initialized afterwards. The system starts taking measures and calculates the averages of temperature and humidity and the maximum value for luminosity. Then, when the counter reaches the dt time, if there have been changes, the data is forwarded to the database and the reference values are reset. If there have not been any changes, the previous values are maintained.

4 Results

The results of the simulation of applying our previously proposed algorithm to the meteorological monitoring system are presented in this section. To determine the best *dt* for each parameter, the followed approach has been to evaluate the accumulate relative error (ARE) of the data in the database (DB) for 15 hours. The data is real environmental data gathered by our environmental monitoring system presented in the previous section. This 15-hour period includes two time lapses with big changes at the beginning and at the end of the experiment (sunset and sunrise), and a long time lapse with minor changes (the night). We consider that the best *dt* is the highest one that allows to have an ARE lower than 5%. Therefore, we minimize the number of packets and keep a good data accuracy in the DB.
First, the data about temperature when different *dt* are utilized in the algorithm is presented. The values of temperature in de DB with different dt are presented in Fig. 3. We can see that, at the beginning, of the data set the data values of temperature are decreasing slowly due to the sunset. During the night the temperature still decreases more leisurely. At the end of the experiment, after the sunrise, the temperature starts to increase. When different dt are used, the values of temperature in the DB change, and some fluctuations are lost. For example, for the *dt* of 50, 55 and 60 min, the minimum temperature (7ºC) are not recorded in the DB, and the increment of temperature during the sunrise is not correctly gathered with *dt* higher than 25min.
Regarding the ARE in temperature values of the DB, see Fig. 4, we can affirm that, ARE increases dramatically when the *dt* is higher than 25 min. ARE for *dt* between 30 and 55 min are almost the same and increases again with *dt* of 60 min. Therefore, considering the ARE during this experiment and the aforementioned information in Fig 4, the best *dt* for temperature sensing, according to our data, is 25 min.

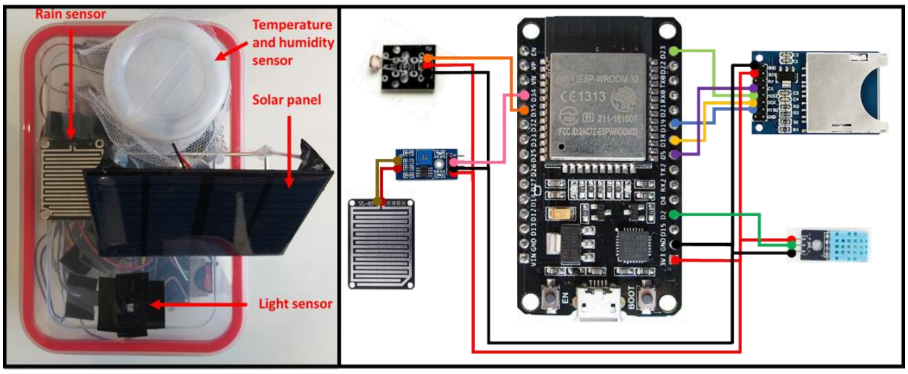

Fig. 1. Connection of the elements of the system.

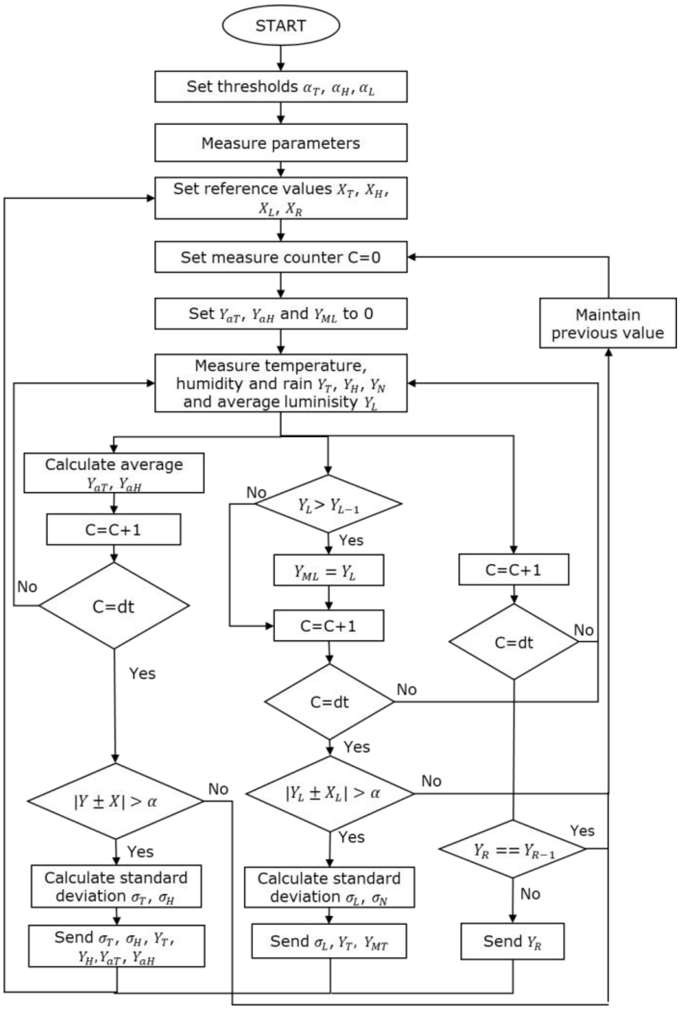

Fig. 2. Algorithm of the system.

Following, the data stored in the DB that is gathered by the Humidity sensor is shown, see Fig. 5. During the sunset and the first hours of the night, the humidity increases. Then, after the sunrise, the humidity decreases due to the increase of temperature. As the changes in humidity are slower than in the case of temperature, no big differences can be seen in the values of the DB with the different *dt* beyond a delay on the notification of the changes. The maximum and minimum values are gathered with all the *dt* and a good representation of data variability is archived in all the cases.
In terms of ARE of humidity data, see Fig. 6, it increases almost constantly as the *dt* upsurges. The only *dt* that overtakes the limit of 5% is the *dt* = 60 min. Nonetheless, the *dt* of 50 and 55 min are close to reaching 5%. Therefore, we can say that to ensure that ARE do not exceeds the 5%, it is better to use a *dt* of 45 min for the data of humidity.
Finally, we focus on the data of illumination, see Fig. 7. This data presents the highest

changing rate in sunrise and sunset. Consequently, we expect to have high mismatches in the data when high *dt* are used. In this case, the dt higher than 5 (the original data) are not able to record the maximum light value. Moreover, the dt higher than 15 min cannot gather properly the abrupt changes in the sunrise and the sunset. Thus, according to the capability to record the maximum, minimum values and the variations in the data, the maximum acceptable *dt* is 15 min, as seen in Fig. 8.

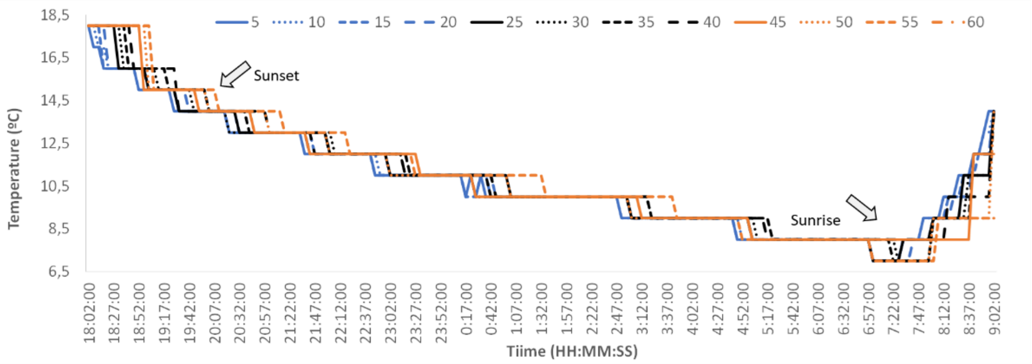

Fig. 3. Value of Temperature in the DB with different *dt* in algorithm X.

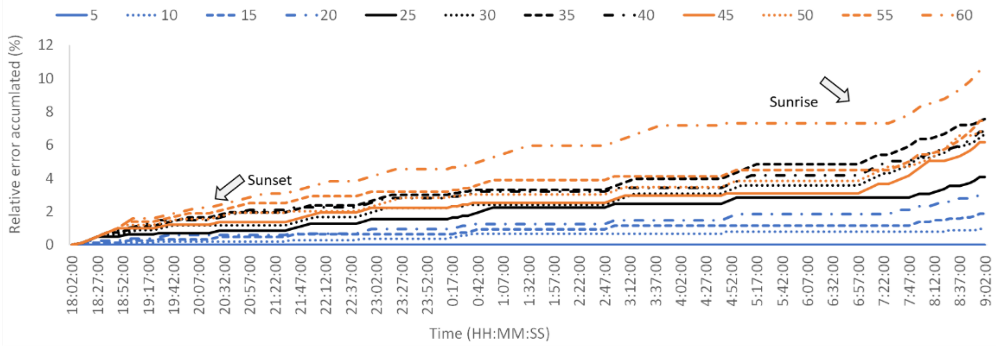

Fig. 4. ARE of Temperature in the DB with different *dt* in algorithm X.

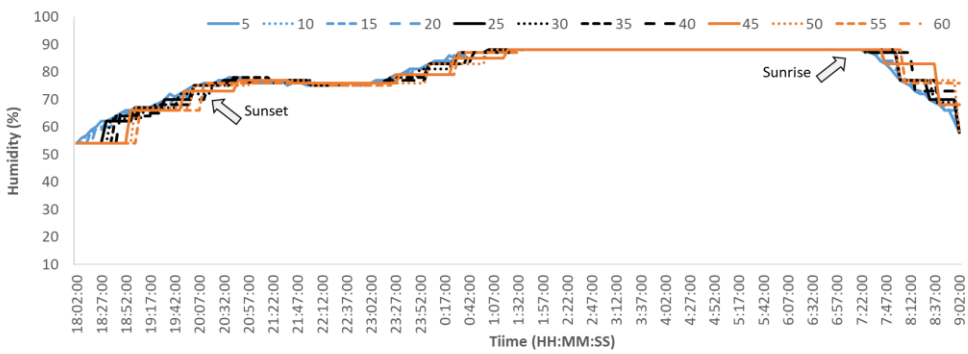

Fig. 5. Value of Humidity in the DB with different *dt* in algorithm X.

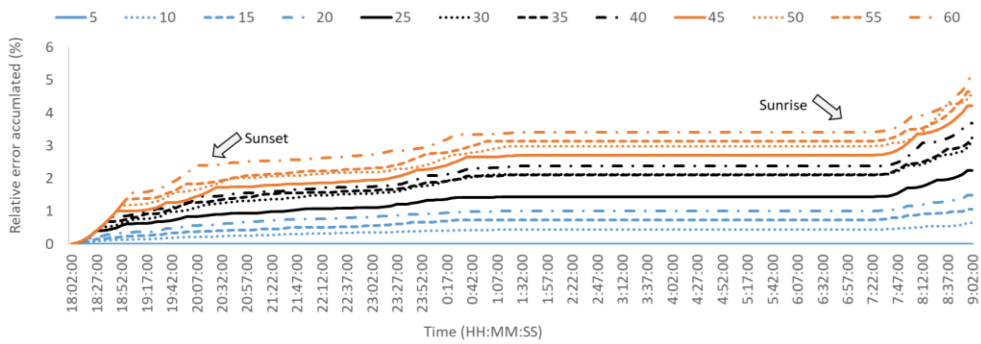

Fig. 6. ARE of Humidity in the DB with different *dt* in algorithm X.

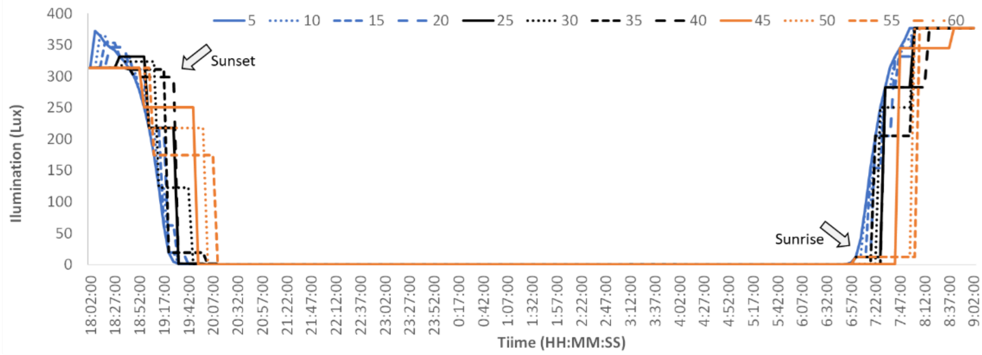

Fig. 7. Value of Illumination in the DB with different *dt* in algorithm X.

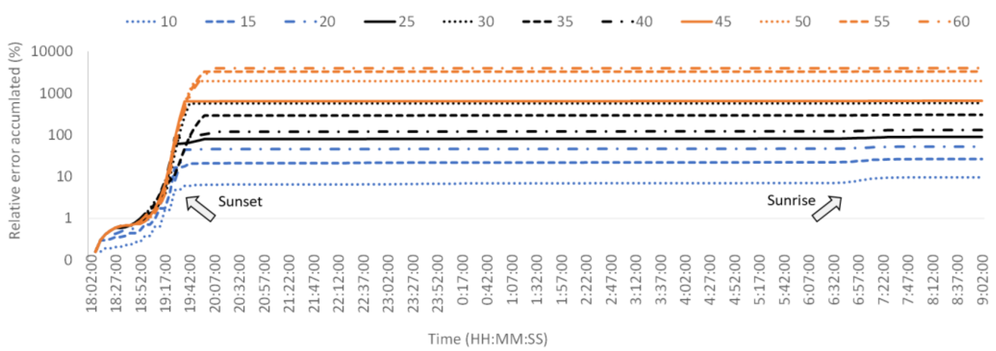

Fig. 8. ARE of Illumination in the DB with different *dt* in algorithm X.

As it can be seen, the obtained results vary from 45 minutes to 5 minutes depending on the parameter. Other environmental monitoring systems such as [6], perform a measure each hour. The selected time period must serve the required purpose. Our results indicate the best time period for each parameter in the Spanish Mediterranean weather in order to preserve the information of the changes in the weather. However, other climates may require different settings and other applications may not need much accuracy.

5 Conclusion and Future Work

In this paper, we have examined different time interval configurations for the algorithm of our presented meteorology monitoring system so as to determine the shortest time period that allows maintaining the required information. The results show that each parameter has a different dt that ensures a good representation of data in the DB: *dt* = 25 min for temperature, *dt* = 45 min for humidity and *dt* = 5 min for illumination. However, as the smallest dt forces to the system to send the data each 5 min, it will be necessary to evaluate the possibility of using a variable dt which can change according to the events. Having a shorter dt during sunrise and sunset, larger dt during the day and night and allow to the system to decide which dt should be used according to the data gathered and their changes.
For future work we are going to develop a low-cost soil monitoring device for the soil monitoring activities that are actually performed by costly commercial solutions. We will apply this algorithm to the soil monitoring system as well.

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