System for the optimization of irrigation water intended for gardens from its Digital Twin

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1 Introduction

The implementation of smart irrigation systems allows the user to better manage the volume of water used for landscape irrigation, which translates into potential water savings [1]. However, there are cities that do not have smart irrigation systems (based on specialized sensors) due to their high installation and maintenance costs.

In this context, the need was detected to develop an urban irrigation management system capable of estimating the optimal irrigation allocation required by urban green areas or gardens, without the need to install sensors or any type of specialized equipment, thus reducing installation and maintenance costs, as well as the risks associated with the deterioration that such equipment may suffer.

The overall objective is to develop a novel, easily replicable garden water management system that, without the use of in-situ sensors, is able to I) predict the water requirements of all garden species; II) establish the optimal garden irrigation based on a local optimization algorithm; and III) provide a system for managing and analyzing the water status of the species that can be visualized in geographic information systems (GIS).

2 Methods

The methodology to be applied to carry out this research and obtain the desired results is based on the following milestones:

- Generate a database of the garden coefficients of the most representative species of trees, shrubs and flowers.
- Develop a system that allows estimating the water needs of vegetation without the use of sensors installed in-situ, and with high accuracy.

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- Develop an urban solar radiation model that allows considering the diffuse, direct and reflected fractions and the shadows generated by the environment on the gardens.
- Develop a Neural Network to automatically identify species in order to automatically assign species coefficients to any analyzed garden.
- Develop a local optimization algorithm to manage irrigation with high efficiency, taking into account different garden, surface and soil factors.
- Assembly of the system to obtain a prototype and validation of the system in relevant environments.

It is noted that the achievement of all objectives requires the collaboration of several multidisciplinary aspects: in the field of remote sensing and image recognition techniques for the development of the algorithms in charge of obtaining climatic variables from multispectral images, classifying species by processing visible and hyperspectral spectrum images, increasing image resolution; in addition to that, for the field of the development of the Digital Twin in charge of predicting the water needs of the garden, and estimating the reflected solar radiation from a 3D model; and finally, for the estimation of species coefficients.

3 Results

The result obtained will be a system for the efficient management of irrigation in urban gardens in real time, which will estimate the values of evapotranspiration (ET) and soil moisture (%w) without the need to implement any type of sensor. The system will be composed of a Digital Garden Twin, which will use satellite information of precipitation, wind speed, atmospheric humidity and solar radiation as its main input to reproduce the existing physical conditions of any garden.

The proposed Digital Twin will be able to obtain the irrigation needs of any garden within an urban environment considering: the hydrological conditions of the terrain, the local climatic conditions and the specific water requirements of the vegetation [2]. The Digital Twin will be integrated by the following components.

I) Satellite climatic information: which allows estimating variables such as precipitation, air temperature, atmospheric humidity, wind speed and net solar radiation.

II) Urban solar radiation model [3], [4]: which will be able to automatically obtain the fraction corresponding to direct, diffuse and reflected radiation in the gardens on an hourly scale. This will be done from an initial 3D mapping campaign of the environment, in conjunction with global solar radiation models in order to estimate the effects of shadows and reflections of the urban topography on evapotranspiration.

III) Garden Evapotranspiration (ETj): By considering the garden coefficient (Kj), the calculation of ETj will allow a more accurate estimation of the water needs of the gardens, making the system more similar to reality. The calculation of the garden coefficient contemplates the estimation of three coefficients (species, density and microclimate) [5], which will depend on the outputs generated from the solar radiation and climate models, as well as from an initial classification campaign of species and grouping densities.

$$ET_j = K_e \cdot K_d \cdot K_{mc} \cdot ET_0 = K_j \cdot ET_0$$

Equation 1

Where:

- ETj = Garden evapotranspiration.
- Ke = Species coefficient
- Kd = Density coefficient
- Kmc = Coefficient of microclimate.
- Kj = Garden coefficient
- ET_0 = Reference evapotranspiration.

IV) Hydrological model [6]: which will be able to perform a water balance for gardens, considering precipitation data (coming from the climate model), previous irrigation allocations, garden evapotranspiration and physical parameters of the garden soil.

Thus, by integrating the components mentioned above, the Digital Twin will be able to reproduce the physical conditions of each garden and generate management strategies for the optimization of irrigation water.

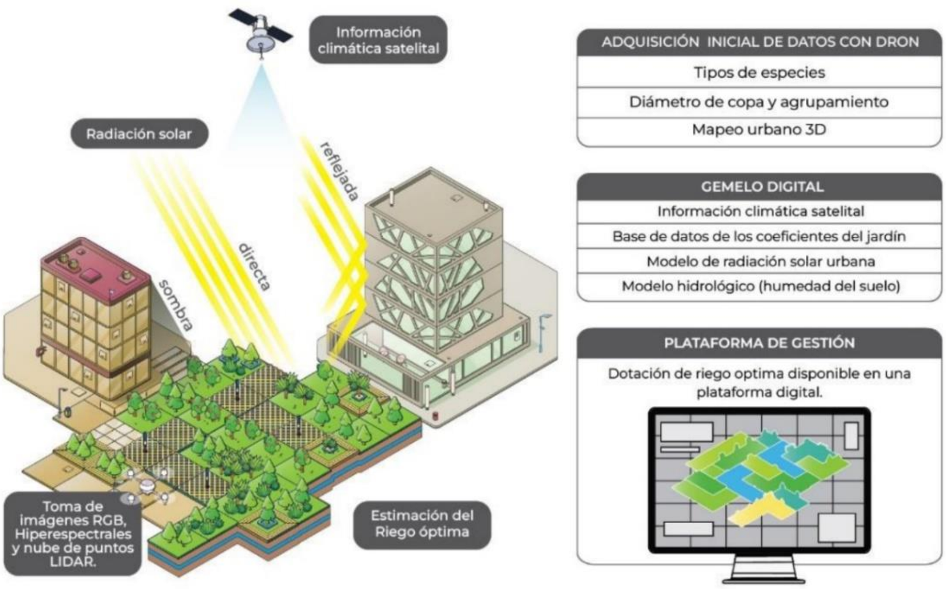

Figure 1. System process flow diagram.

4 Conclusions

Currently, the state of the art in urban landscape irrigation management is associated with Intelligent Automated Irrigation Systems (SIRA). These systems manage irrigation by performing a water balance based on measurements of soil moisture percentage (through sensors) and the calculation of reference evapotranspiration, which is calculated through general formulations considering variables such as air temperature, atmospheric humidity, solar radiation and wind speed.

The performance of the current systems offered by the market depends directly on the availability and accuracy of the sources of information from which to estimate soil moisture, precipitation and evapotranspiration. These sources are: a) sensors installed in-situ; and/or b) meteorological stations.

For this reason, this system will be a fundamental innovation for the reduction of costs of acquisition, operation and maintenance of gardens and the generation of a management system that can be easily replicated in any location. In addition, it will be necessary to develop a system that allows considering the specific characteristics of each garden, without depending on any type of hardware.

References

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