#7660 A REINFORCEMENT LEARNING BASED APPROACH FOR EFFICIENT IRRIGATION WATER MANAGEMENT

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ABSTRACT

Due to population growth and the effects of climate change, most of the world's regions are threatened by water scarcity, especially in Africa and Mediterranean region. In Morocco, the agriculture consumes more than 85% of available water. Thus, to preserve water resources, the rational management of irrigation water is necessary. In this context, recent technological progress and the emergence of artificial intelligence could provide an effective decision support tool for the rational and sustainable use of this resource. In this paper, we propose an approach based on reinforcement learning, a type of machine learning that uses trial-and-error principle to learn how to best fit situation to action in a highly dynamic, stochastic environment. In this proposed approach, a Farmer Agent learns to choose the optimal cropping pattern defined by the type of crop, area to cultivate, sowing date and irrigation plan depending on the water availability at the beginning of the agricultural season. Each agent interacts with the environment which is composed of environmental and socio-economic modules containing different processes to provide the Farmer Agent with the information he needs to learn. The use of reinforcement learning in this complex system will certainly change the traditional irrigation water management mode and bring more intelligence into the system. This approach will be generalized in future work to cover the entire agricultural sector and study the behavior of many Farmer Agents. This will be used then, for the design and implementation of a decision support system platform that can be used at the beginning of the agricultural season to make informed decisions.

Keywords: water resources management, irrigation water management, reinforcement learning, precision agriculture, machine learning, cropping pattern optimization.

INTRODUCTION

Water resources are already under pressure [1]. Most regions of the world are experiencing water stress. This is due to several factors such as population growth, rising living standards, and climate change which intensifies dangerous phenomena such as heavy rains in some areas and drought in others due to the disruption of the normal water cycle. The latter represents the supply of water to the environment. Water resources problems arise at demand levels. In Morocco, 15% of water resources are used by industry for the cooling of machines and for production, or tourism which uses it for swimming pools, and irrigation of golf fields and for domestic use. The remaining 85% is used by the agricultural sector mainly for irrigation activities [2]. In addition, over 76% of irrigation in Morocco is gravity-fed and uses non-optimal methods and techniques.

Having a better combination of crop choice, optimal area to cultivate, sowing dates, and profitability is a real problem for farmers. It is currently done in a non-optimal way. Thus, we propose in this paper an approach that uses reinforcement learning to address this optimization problem.

LITERATURE REVIEW

Several studies have tried to solve the problem of efficient irrigation water management with different approaches. Roque et al. [3] used supervised learning with the objective of reproducing the behavior of an expert agronomist by regressing the amount of water to be pumped into the local basin at the following week. They used different types of data collected from sensors installed in orchards and meteorological data. Meanwhile, Evangelos et al. [4] have proposed a method for optimal management of irrigation water in the city of Athena. This method is divided into two phases. The phase of training during which a neural network learns based on historical weather data and the constraints associated with each reservoir of the city. And an application phase during which the system will be able to perform optimal operations for each new state. With such approaches, the performance of the model will be linked directly to the data annotation process which depends on annotator reasoning. It can therefore never exceed the level of expertise of the agronomist who annotated the data for the first case and the environmental characteristics for the second case. In recent years, reinforcement learning has shown promising results as an optimization method. Most of their applications are only in games such as Elhadji et al. [5] where Deep Reinforcement Learning was applied in the Pong game, testing whether two agents can dynamically learn to divide their area of responsibility and avoid collisions in front of a hard-coded adversary. Elhadji et al used several architectures, namely DQN, DQN with double Q-learning, and Dueling network architectures.

We propose in this paper to apply the Reinforcement Learning to a real-world problem, where an agent learns to maximize his objective function independently of a supervisor.

PROPOSED METHOD

Our approach is based on reinforcement learning where a Farmer Agent learns from its environment through actions and feedbacks. Each time he observes the situation, selects an action and gets feedback (reward/punishment) (Figure 1).

The environment is characterized by a state belonging to S, the set of states. This environment changes depending on the interaction with the Farmer Agent. It provides him with observations (O_t) at each instant t. These observations represent the current state of the environment.

Then, the Farmer Agent decides based on these observations. And the environment will be affected by that decision and provides him with a reward (R_t) in case of a positive results (increasing the profit), or a punishment otherwise (exceed the amount of allocated water, deficit). This repetitive process will enable the Farmer Agent to evaluate his actions according to his final objective.

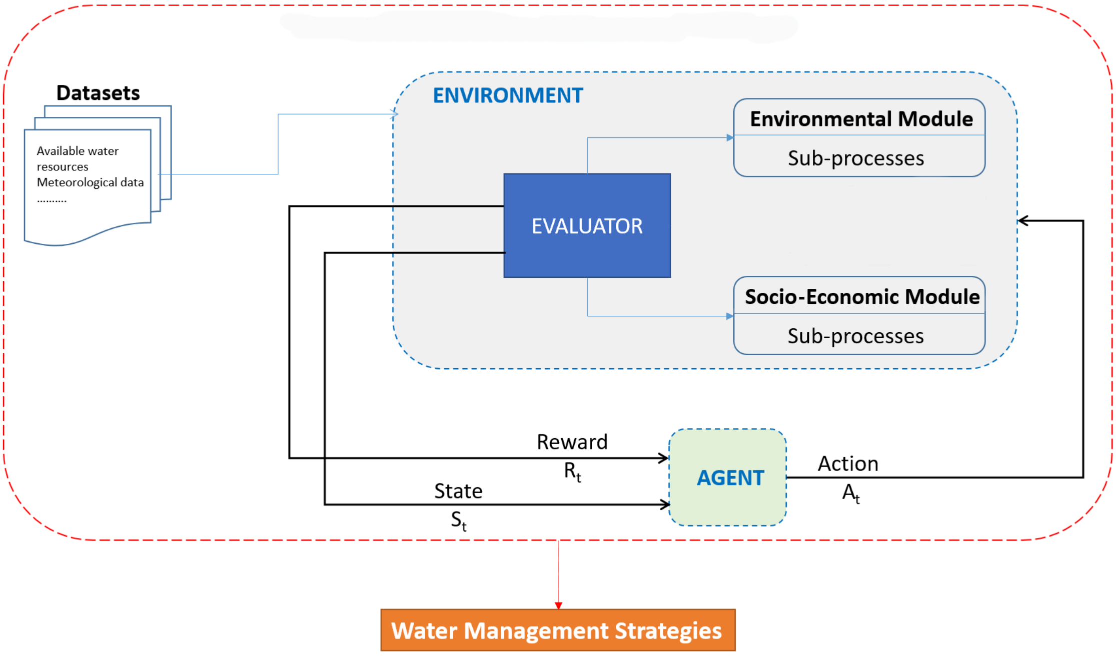

Figure 1. The proposed model architecture

The environment is composed of two modules: the environmental module which is responsible for managing meteorological data, water availability and soil information, and the socio-economic module that provides the agent with all information needed such as crops water needs, growth phases durations, seed prices, and fertilizers prices. It also allows the agent to calculate his incomes at the end of the agricultural season. After the training phase, the Farmer Agent will be able to choose an optimal cropping pattern defined by the type of crop, the area to be cultivated, the sowing date, and the irrigation plan depending on the amount of available water and initial constraints (Figure 2).

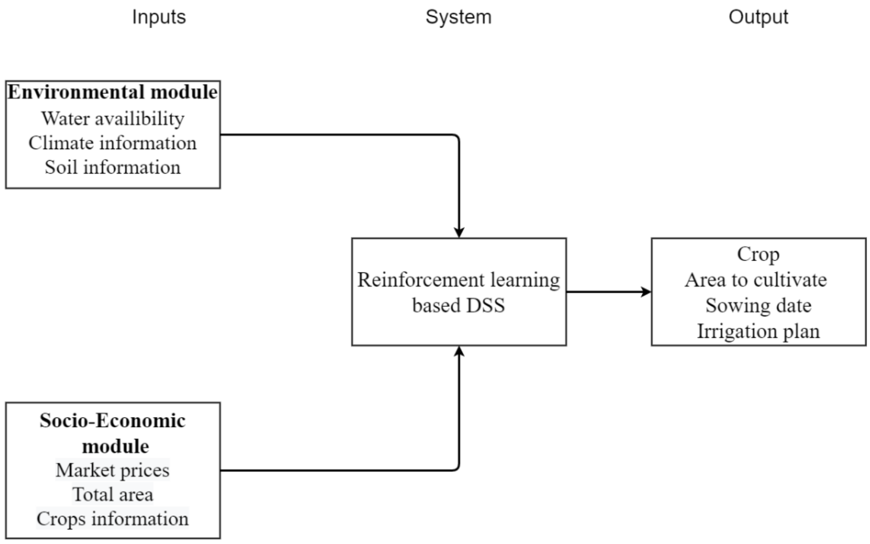

Figure 2. Inputs and outputs of the final system

The mathematical modeling of our problem uses the Markov Decision Process [6], which represents the basis of reinforcement learning. The goal of solving MDP is to find an optimal policy that will maximize the sum of the expected rewards (Equation 1). The Bellman equation (Equation 1) is called the value function. It is decomposed into two parts: an immediate reward R(s, a), and a discounted value of the successor state.

$$V(s) = max_a \left(R(s,a) + \gamma \sum_{s'} P(s,a,s')V(s') \right)$$

Equation 1. Bellman equation

Where:

S: the set of states which is water availability and environment's constraints (Figure 2),

A: the set of actions (a combination of a crop type, area to cultivate, sowing date and irrigation plan),

P: the set of transition's probabilities,

R: A reward in case of a positive income, and a punishment in case of exceeding water availability or initial constraints.

λ: discount factor.

CONCLUSIONS

In this paper, we have proposed an approach based on reinforcement learning for the agricultural sector at the crop field level. It will provide farmers with the best cropping pattern, defined by the type of crop, area to cultivate, sowing date, and irrigation plan depending on the water availability at the beginning of the agricultural season and initial constraints. This work will form the basis for developing a decision support platform to help farmers make informed decisions about their agricultural practices. The next phase will be at the level of the entire agricultural sector where we will generalize and study the interactions between many agents with different objectives.

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