Multiagent System and Rainfall-Runoff Model in Hydrological Problems

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Typically, hydrological problems require approaches capable of describing and simulating part of the hydrological system, or the environmental consequences of natural or anthropic actions. Tools such as Multiagent System (MAS) and Rainfall-Runoff Model (RRM) can help researchers to develop and better understand water systems.

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1. Introduction

Hydrology is the area of study of the natural phenomena of the hydrological cycle, which considers the dynamics from the origins to the destinations of water on the planet [1]. A significant increase in hydrological problems has been occurring due to environmental changes carried out by natural or anthropic actions. As a consequence, serious risks to human life, the environment, and economic development can occur [2].

Some methods have been coupling social and water systems. One of them is integrated water resources management, which since the early 1990s has been providing interdisciplinary, quantitative, and qualitative methods, which assist decision-makers in water resources management [3]. Another approach, defined as a science called socio-hydrology, considers the coevolution of hydrological and social systems, aiming to analyze the consequences of decision-making, individual or collective, on water systems [4].

Computational hydrological models are widely used to describe the behavior of hydrological processes in a simplified form of reality [5]. Particularly, the rainfall-runoff models (RRM) aims at calculating and accurately describing the flow, based on hydrological processes at different spatial and temporal scales [6]. Researchers have developed and refined these models to better understand the hydrological physical processes involved in real water systems [7]. In addition, many studies investigate decision-making regarding the management of water resources, to analyze the environmental consequences of water use [8].

Besides that, artificial intelligence (AI) tools are often used to assist in the research of water systems [9]. Multiagent systems (MAS) are one of the AI tools and can serve to simulate complex adaptive systems through the behavior of emerging systems [10]. MAS is composed of a set of autonomous agents that interact with each other and with the environment in which they are inserted, generating consequences for each action within the system [11]. In this way, MAS is considered a bottom-up approach, the local instructions of the agents generate an adaptive behavior that results in the dynamism of the system [2].

Seeing that the joint use of RRM and MAS tools can be a coupled social and hydrological model, it is possible to solve specific problems of water systems. Furthermore, as it is a hybrid method, the results tend to be better in terms of precision, time and scale [12]. In this sense, it is intended to develop a tool that integrates the RRM and the MAS in order to support the management of water resources.

2. MAS and RRM Techniques

Among some of the difficulties to generating a coupled social and hydrological modeling, reference [13] mentions the process of determining the main interactions between the systems, and it must be objective and well defined. The authors of [14] mention that a common problem is the low quantity and quality of hydrological data available, which often interfere directly in the calibration and validation of the model. The authors of [15] affirm that the complexity due to the integration of different models is great, and often generates results with low precision.

Regarding the objectives, and integration of data and tools, the three works show different methodologies and approaches. The authors of [13] analyzed the land use change induced by anthropic actions, based on three coupled models. The authors of [14] developed a homogeneous MAS for water resource management using the eWater Source and SMDBRM models. The authors of [15] developed the OARES platform, to integrate a MAS, a calibration tool, and data from the region to model and simulate the rainfall-runoff process and soil erosion. In this sense, it can be observed that different hydrological problems can be explored using the integration of MAS and RRM.

The data needed to develop and integrate the models depended on the objectives and needs of each work. Data from the study region proved to be important input and validation data for the models, such as meteorological and hydrological data. The authors of [13] used an RRM to model the system and input the data into the MAS. The authors of [14] used an automatic calibration process although the SMDBRM model, where RRM was used to generate unmeasured flow in some regions of the study area. In the work of [15], the necessary parameters for the model are generated before being inserted in the MAS. In this way, the calibration processes were executed independently, and in order to generate hydrological responses for the respective MAS.

Furthermore, there are problems that should be explored in the future, so that the coupled modeling between MAS and RRM is more efficient and precise. **Table 1** lists the strengths and research points that were identified.

Table 1. Strengths and research detected in the coupled modeling process.

Strong Points	Research Points
Coupling of several different systems	Interaction between models
Analysis from different perspectives	Stability
Direct contribution between models	Coupling direction

Strong Points	Research Points
Better visualization of processes	Processing
Reduced complexity due to the use of MAS	Validation

This also generates other positive point, which is the direct contribution that occurs between the systems. When considering more than one system, the responses from each of them can have several implications. For example, decisions about water resources in a social system impact a hydrological region, and it generates changes in hydrological processes. On the other hand, changes in the hydrological region must cause changes in the decision-making of social systems. Thus, in addition to being possible to understand the aspects of a system, it is possible to analyze decisions about it and, consequently, the benefits and risks that they may entail.

From the coupled modeling process using MAS and RRM, other positive point is the MAS simulation. A MAS must be simulated on a specific platform for this type of model so that it is possible to visualize the simulation in each step. In this way, the change in the environment is directly perceived. In hydrological systems, it is possible to analyze the impact of each action in a region, which favors better forecasts and analyzes of the use of water resources. Furthermore, the use of MAS can generate models with less complexity, due to the flexibility that these systems have.

Regarding the points that still need to be explored, one of them is the difficulty in the integration process between the models. In this case, the relationship and language between the models must be carefully established. Moreover, compatibility between systems is very important. Spatial and temporal scales directly influence the stability of the model.

In addition to choosing the model, it is necessary to have a good knowledge of the study region and the available hydrological data. Furthermore, the impacts of environmental changes occur due to different factors and characteristics of the study region. In the process of coupling RRM and MAS, spatial and temporal scales that adjust to the mechanism of the models involved must be considered. Otherwise, the processing of spatial data and the accuracy of the coupled model may be impaired.

Another important point is the direction of coupling. The question is how to develop a coupled model in which the models involved mutually generate inputs and outputs. In this case, it should be considered that the responses of each system generate changes in the coupled model.

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