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A global approach for investigating resilience in inland navigation network dealing with climate change context

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Abstract

At the European scale, inland navigation waterway transport is considered as a competitive and environment friendly alternative to road and rail transport. This transport mode is promoting in north of France thanks to the building of the Canal Seine-Nord. The number of boats and the navigation scheduling will increase significantly. A big raise of the required water volume is waited. Overcoming this future navigation demand will be particularly challenging in a climate change context. Hence, a crucial step consists in investigating the resilience of the inland navigation networks considering the future navigation demand and the climate change impacts. The main objective of this paper is to present the tools dedicated to the resilience determination that is required to design adaptive management strategies of these networks. An integrated model is proposed to model the network and to identify and quantify water supplies and water intakes. Then, a generalized flow-based network is used to model the water volume dispatching. The water dispatching has to be optimized according to the network resilience against the increase of navigation demand, and against the decrease of available water resource particularly during drought periods. Due to the complex structure of the networks, uncertainties that are linked to the daily number of boat and to the available water resource, an interesting approach will consist in defining a distributed problem. Local virtual agents will be designed to manage each waterway section, and a global coordination process will guarantee the efficient management of the network. The tools are designed and tested considering the inland navigation network in north of France.

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1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) expects an increase of the global temperature of more than 4°C by the end of the century if no effort will be achieved to reduce greenhouse gas emissions generated by

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human activity [10]. IPCC proposes 4 RCP scenarios (*Representative Concentration Pathways*) based on the forecasted greenhouse gas emissions. According to RCP scenarios, projections on temperature and rain over the earth have been proposed by several laboratories and searchers. The frequency and intensity of future flood and drought periods should be dramatically increased in a close future [2, 5]. Recently, studies on flood [22] and drought [20] have been proposed in the literature. Some authors used RCP 8.5 scenario to forecast the frequency, duration and intensity of drought events in several areas in China [13] and Korea [19]. These events should impact hydrographical networks and more precisely inland waterways [11, 21]. Indeed, inland navigation networks are semi-artificial systems that need a big volume of water to accommodate the navigation. Moreover, due to their competitive and environment friendly advantages compared to road and rail transport modes, and due to a great political commitment, it is expected that the navigation demand will increase.

In a climate change context with an increase of the navigation demand, it is thus necessary to study the resilience of the inland navigation networks. Then, adaptive management strategies have to be designed to improve this resilience. To achieve these aims a global approach is proposed in this paper. It is based on the integrated model and flow graph that are proposed in [15], and on a software that has been developed in Mines-Douai. Compared to software SIC² and MIKE11³ that allow the simulation of free-surface hydraulic systems, this software is dedicated to the resilience study and to the design of optimal water management strategies of inland navigation networks. It is more comparable to the software *Inland waterways simulation*⁴, with the advantage to be able to optimize the water management. In this paper, the resilience concept and its adaptation for the case of waterways systems are given in section 2. Section 3 is dedicated to the description of the flow graph and the management optimization approach based on Constraints Satisfaction Problem (CSP). Then, the presentation of the developed software by considering an example of an inland navigation network is given. Section 4 presents first concepts of a distributed problem using local virtual agents to deal with the uncertainties linked to the navigation demand and climate events.

2. Resilience

2.1. General concept

It is increasingly a question of resilience study phenomena in several areas, hence the use of this term in several scientific articles. What some may see as a "fashion effect" while for others is a simple consequence of current events. Moreover, authors in [8] made a bibliometric review that reveals the extent of propagation of the concept of resilience in what they called Industrial Ecology (IE). But authors also noted that the concept of resilience in its two forms static or dynamic is not restricted to IE. This has resulted in the emergence of several research communities under different themes [8, 9]. This diversity has given rise to different "definitions" of the term resilience according to the application areas, as detailed by [9], and sometimes as pointed out by [6], in some fields this term has been technically used in a narrow sense to refer to the return rate to equilibrium upon a perturbation (called engineering resilience by Holling in 1996).

Holling in 1973 defined resilience as part of his study of ecosystems in order to understand their behavior in the presence of disturbing factors [3, 14], even though he was the first to introduce the general concept of resilience. Besides, he considers that a resource management approach based on this concept “*would emphasize the need to keep options open, the need to view events in a regional rather than a local context, and the need to emphasize heterogeneity. Flowing from this would be not the presumption of sufficient knowledge, but the recognition of our ignorance; not the assumption that future events are expected, but that they will be unexpected*” [8].

The thinking over this definition led to distinguish, according to Holling’s work in 1996, two different perspectives on what resilience emphasizes, engineering and ecological resilience within complex systems [14]. These perspectives are gathered and illustrated in the “social-ecological systems” (SES) framework. This framework is the intrinsic dimension of the relationship between humans and nature, because the issues raised are not social or ecological but rather interdependent and from a philosophical standpoint existential. In their work [6], the authors citing the example of the Holocene era to assert that the separation of social and ecological, is no longer on the agenda if not irrational.

² <http://www.canari.free.fr/sic/sicfr.htm>

³ <https://www.mikepoweredbydhi.com/products/mike-11>

⁴ http://www.systemsnavigator.com/sn_website/inland_waterway

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