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Modeling Crisis Management Scenarios: Simulating Behaviors in Case of Marine Flooding

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Keywords

Multi-agent simulation, submersion, behaviour, GIS (Geographic Information System), natural risk.

Abstract

This research is being conducted as part of a PhD in geography and geomatics, which began in October 2023. The aim of this project is to simulate human behaviors in the event of a marine submersion crisis. In the context of climate change, rising sea levels are a central issue in management and planning, and marine submersions are critical concerns. Marine submersions are defined as the flooding of land by the sea caused by meteorological phenomena. Human behaviors can have a significant impact during such crises. Therefore, to model all these parameters, multi-agent simulations are used, allowing us to represent these phenomena as realistically as possible. Our research environment spans numerous disciplines. The geographical approach is essential for representing and analyzing the studied areas. To this end, we have chosen to use ArcGIS and QGIS, combined with databases from the IGN. These tools enable us to set up physical simulations of marine submersions based on past events (such as Xynthia in 2010) and future phenomena. The most pessimistic scenarios from the Pays de la Loire IPCC in France will be exploited and modeled to evaluate the impact of such crises on structures (buildings, roads, etc.) in two French municipalities: Batz-sur-Mer and L'Aiguillon-la-Présqu'île. The mapping of this environment then allows us to use multi-agent simulations, closely representing the behavior of residents in coastal communities. Each agent is assigned the driving skill and can travel from point A to point B by following roadways. Specific behaviors are also assigned to the agents. For this, the model relies on the BEN (Behavior with Emotions and Norms) architecture, allowing us to integrate emotions more specifically panic behaviors into our agents. The modeling of these behaviors is extensively studied with social psychology. A questionnaire has been developed to accurately represent the behaviors and lifestyles of the residents. The use of GAMA is beneficial due to its ability to integrate such multiple disciplines: physical model while representing agent behaviors. This methodology enables us to identify different typical profiles that may be more or less sensitive to a crisis. Each of these profiles is fed with different behaviours from the literature and then modelled. The next phase of this work will focus on implementing the agents' behaviors based on the results of the questionnaire, thereby creating the most reliable population profiles possible. Once these behaviors are integrated into the architecture, we will be able to identify problematic areas (areas below sea level, potential dike breaches, etc...) and behaviors during a crisis (panic, unconsciousness, associability, etc...). The models will also incorporate interactions between agents (such as mutual aid and the arrival of emergency services), which may provide new insights into understanding population reactions. In the subsequent stages of the project, the reliability of the model will be assessed and validated. To achieve this, we will rely on global sensitivity analysis tools to examine the significance of the model's inputs and their interactions.

Additional material

- Link to the daily movement simulation for the population of Batz-sur-Mer: [Click here](#)
- Link to the marine submersion simulation in GAMA : [Click here](#)
- Link to the poster of the project: [Click here](#)

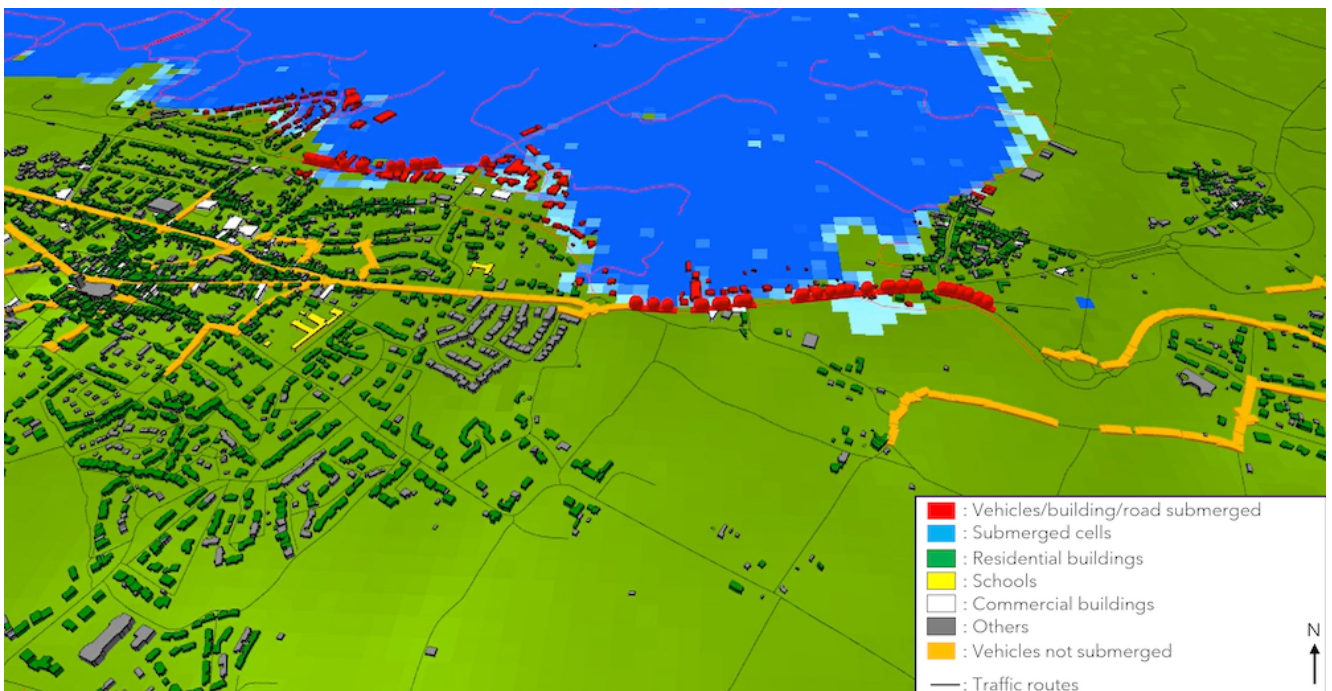


Figure 1: This screenshot illustrates the arrival of a marine submersion in the town of Batz-sur-Mer (Loire-Atlantique, France) simulated within the GAMA software. An evacuation was initiated one hour before the submersion's arrival, leading to congestion on the road network. Certain roads were quickly flooded and transitioned to a submerged state (marked in red), as did affected vehicles and buildings, rendering them unusable. As a result, agents became stranded and isolated, complicating rescue operations. This simulation was conducted using the IPCC scenario 8.5 for the Pays de la Loire region, corresponding to a water level of 4.96 meters.