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The contribution of the complexity of virtual disaster scenarios in potential tools for crisis and risk management

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Abstract. The role of the analysis of disasters and crisis scenarios with growing degrees of complexity is focused, on the possible development of new tools aimed to enhance the awareness of rescuers, crisis managers and population, in case of high-impact events. The availability of computers with growing capacity, and the fast development of immersive reality devices, offer new possibilities to enhance the population's capacity-building in case of crisis and disasters, as well as the readiness of rescuers and risks operational managers. The present paper considers the complexity of a scenario describing an offshore event, and a scheme for applications to enhance risk-related awareness is proposed.

Key words. disaster scenarios, virtual scenarios, disasters complexity, risk awareness, crisis management

1. Introduction

The activities related to the Risk and Crisis situations management typically involves paradigmatic examples of complex systems, in which each part shows multiple connections with the other ones. Usually, within a defined geographical area, a specific event (such as an earthquake, flood, wildfire, environmental disaster, as well as a health crisis, an international conflict, a huge movement of migrants, and so on), locally triggers an immediate and necessary dialogue between responders, policy makers, technicians, victims, media, and so on, primarily. The necessary extension of the analysis of the of the event in time, both before and after the occurring of it, implies the involvement of further inter-connected components of the systems, such as infrastructures, territorial planning, education, scientific and historical research. As an example, a growing interest is dedicated in the recent EU funding programs to the psychological, sociological and historical aspects related to disasters and crisis[1]. In addition, social crisis with wider impact (such as pandemic, conflicts, economic crisis) and large-scale natural disasters may involve trans-national geographical areas, so that different management systems (institutional-administrative, technical-operational, and

[1] https://tinyurl.com/2p86725b

economic systems) will be further connected. It clearly results how the degree of complexity of the involved ecosystems may dramatically grow. The difficulties related to the management of this complexity can be recognized during the rescue operations, from the point of view of the crisis managers, who have the role to collect the overall information and to coordinate the first responders' activities. At the same time, the complexity of the disasters scenarios commonly takes shape directly to the rescuers, who operate on the ground. A lot of research and projects, based on virtual reality are currently under development to support both intervention planes (coordination and operational activities on the ground)(Lovreglio (2020); Bernardini et al. (2022)).

2. Complexity in virtual disaster scenarios

A great-impact event may deeply modify the real scenario in which the first responders are asked to operate, and in which the victims need to move, respect to its ordinary shape. In general, a substantial gap exists between what people could commonly expect from an impacting event and how it results in the real cases, due to the several variables concurring. This may be figured out by considering, as an example, the case of an offshore event, such as an earthquake (or the pouring of lava from a volcano into the sea), that causes a subsequent tzunami. An immediate representation of that, on the base of everyday life observation, may start from the image of a drop of water which, once dropped into a container filled with the same liquid, can generate a series of waves which propagate in the liquid, until they break against the walls of the container. Similarly, by firmly pushing up the bottom of the container, if not rigid. One could then simply translate this basic idea to the scale of the oceans. In terms of the simulation of the evolution of the event and therefore of the resulting scenarios, this would imply the physical description of few main phases: the "t0" event, typically a displacement occurred on the ocean floor; the resulting waves, that often propagate in a shallow-water regime (usually considered when $D : \lambda = 1 : 20$ at least, where D is the ocean depth, and λ is the wavelength), with a speed intensity, v, which is not dependent on the wavelength, but only depends on the ocean depth (which is usually uniform compared to the wavelength scale, when far from the shore),

$$v = \sqrt{gD},$$

where g is the gravitational acceleration, allowing them to proceed almost unaltered; and finally, the breaking of the waves on the coasts, where a reduction of the wavelength and an increase of wave amplitude is expected - refer to basic physic texts and (Stevenson (2005); Uy (2004)) - with the possibility to calculate the arrival times by the distances from the epicenter. What happens in the real cases may differ from the basic description above reported, due a to a series of local effects that influence the effective event propagation and the resulting scenarios. Since a further level of detail would go beyond the scope of this work, we can summarize some of the elements that can influence the final representation of the event, as follow: (i) the rupture speed, the raise time and the modification of the ocean floor, giving the initial profile of the waves, should be taken into account (Stevenson (2005); Mori (2012); Shigihara (2021)); (ii) the tidal corrections (Mori (2012)); (iii) local effects due to the interactions with coasts, lands, and islands, such as the enclosed bay amplification effects, diffraction and reflection effects (Stevenson (2005); Mori (2012); Shigihara (2021)). These effects contribute to increase the level of complexity of the phenomenon, as well as of the related numerical simulations (for example, when the nonlinear models equations are used, or when the coastal amplifications are fitted on the base of power more than linear laws[7]), and therefore of its virtual/immersive rendering. At the same time, an accurate knowledge of local phenomena increasing the complexity of the scenarios, their cataloging, and the possibility of gradually insert them into simulations and in their virtual renderings may represent an important tool to train rescuers and crisis managers. Furthermore, it may play an important role to enhance population's awareness too.

3. Methodology

The possibility to train rescuers to enhance their spatial cognition when operating in complex scenarios may substantially contribute to strengthen their capacities in all phases related to different kind of impacting events. A combination between methodologies used in different fields (such as psychology and neuroscience), the numerical simulations (and the physics in them) and the virtual/immersive reality is proposed as a scheme to develop useful tools to contribute to this aim. In Ref (Wallet (2009)), make use of virtual reality environment to investigate the quality of learning transfer from a virtual to a real environment for spatial cognition issues (meant as the capacity to move in an environment without getting lost), based on three knowledge steps (Landmark, Route, and Survey knowledge). In the case of the disaster scenario, this activity, enclosed in training sessions and also as an available digital tool, would be helpful for rescuers, crisis managers and would also help population, in case of crisis situations. The involved subjects would acquire the necessary landmarks of the the simulated scenarios in an immersive environment (and, where possible, also of the real situation, considered as a point-zero step). The subjects will improve their capacity to immediately set a sufficient number of the main reference points recognized in different possible scenarios. In a subsequent step, the subjects will be trained to learn routes between the marked points, in order to finally estimate distances and shortcuts. The tasks would be faced by the subjects at growing levels of complexity. To this aim, scenarios of different disasters will be simulated and gradually improved, based on the different elements that may influence their real evolution. The activity will be also useful for the victims of the disaster, and for vulnerable groups among them, such as people with disabilities. In the case of the victims, the final goal will be to safely and fast move inside, and escape from the proposed environment (differently from the rescuers, who need to reach it). Besides the typical indicators considered to test the efficiency of the tasks (such as errors in directions or hesitations), the possibility to identify ad hoc parameters (and dedicated software), specialized for the disaster cases considered, and for the target groups involved, will be taken into account. Furthermore, it would be interesting to introduce the distinction between tasks connected to the egocentric and to the exocentric referential (Wallet (2009)), also in the case of the disasters, where the first point of view would refer to the training of the crisis managers, while the second one should be proper of first responders and victims.

4. Conclusions

The use of virtual scenarios of disasters with growing level of complexity is focused, to improve the spatial cognition capacity of crisis managers, rescuers, and victims. Within a multidisciplinary approach, a scheme involving specific tasks to improve the recognition of the reference points and of the safer and faster paths to move in a disaster scenario, in order to reach the crisis areas or to leave them, is proposed. The possibility to develop specific numerical simulations that also consider the local effects that may influence the resulting scenarios, allows to gradually increase the level of complexity of the virtual environments in which the subjects are asked to move, starting from the simulations that best fit the natural phenomena involved.

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