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EXTENDED REALITY, INTELLIGENT AGENTS AND SIMULATION TO IMPROVE EFFICIENCY, SAFETY AND SECURITY IN HARBORS AND PORT PLANTS

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ABSTRACT
The paper introduces a new project devoted to develop a simulation-based solution for improving emergency planning and crisis management in critical infrastructures such as seaports and related terminal. The research aims to investigate the use of Artificial Intelligence and Simulation jointly with Extended Reality in this framework.

Keywords: Modeling, Simulation, AI, Seaport safety

1 INTRODUCTION

Seaports are critical infrastructures and have significant impact on economy and people's life. Indeed, nowadays they manage huge flows of goods and passengers, create numerous work opportunity and are essential parts of economy of countries where they are located. Unfortunately, such environments are characterized also by high risk of accidents; for instance, handled materials could be dangerous (e.g. toxic products, explosives) while heavy, huge and cumbersome equipments and ships might collide each other or with goods and port structures.
In general, analyzing the statistical data, it is possible to conclude that number of accidents in seaports is constantly growing despite continuous improvements in safety procedures, even due to a constant increase in flows and operations; in facts this could be explained by continuous increasing sea traffic (Darbra & Casal, 2004). In the same time, frequency of domino effect accidents is decreasing, even if their occurrence is still quite high (Clini et al., 2010). In order to identify main safety issues in seaports, it is necessary to analyze existing situation as well as past events.

2 PAST CASES OF INTEREST

In the past many notable accidents in seaports occurred, which should be used to identify some of main issues related to safety, crisis prevention and management of emergencies in ports. Indeed, these examples provide insight in most important causes of casualties and economical damage, as well as some clues regarding how to mitigate them. Hereafter it is presented a brief analysis of some cases in chronological order.

Halifax Explosion

One of the most notable explosions of the beginning of the past century happened during WWI, in the port Halifax, Canada, 1917, where collision of two ships, one of which loaded of explosives, caused fire and subsequent explosion, which devastated a large area of the city killing circa 2000 persons (Lilley, 2013). The cause of explosion was a navigation error of the two ships; as proved during the investigation, a lot of safety regulations were "relaxed" due to the war, while only few persons of the port personnel were aware about explosives on board of one of the ships. Indeed, such event caused revision of handling procedures for dangerous materials as well as more strictly checks.

Chicago Port Disaster

During WWII, improper handling of ammunition by not qualified personnel caused explosion of almost 2000 tons of TNT in the port of Chicago (Allen, 1982). Similarly to the case of Halifax, personnel was not properly informed about properties of the cargo neither prepared enough to handle it.

Moby Prince Disaster

In 1991 in the harbor of Livorno, Moby Prince ferry collided with the Agip Abruzzo tanker, leaving only one survivor among passengers and crew aboard (Cigolini & Rossi, 2010). In this case, first several hours passed with almost no actions from the port management. This particular case shows how important is a proper emergencies management; indeed, according to some evidences, many passengers could have been saved with adequate interventions timing.

Chlorine Leak in Mumbai Port

Although explosions and fire cause typically the biggest damages, lack of containment is much more frequent accident (Darbra & Casal, 2004). Indeed, nowadays transportation of potentially dangerous materials in gaseous and liquid forms is very diffused, while in some cases related risks are not assessed properly and safety

procedures are not sufficiently applied. For instance, one of such cases happened in Mumbai in 2007, where old tanks with chlorine were abandoned and eventually leaked; due to negligence more than 100 people were hospitalized (Sharma et al, 2010).

Tianjin Explosion

One of the biggest explosion of the last years happened in the port of Tianjin, China, in 2015 and it caused many fatalities and injuries (Fu et al. 2016). Analyzing its details, several issues raise, mostly related to the crisis management as well as urban area planning. For instance, firefighters were not informed about presence of calcium carbide and tried to extinguish fire by water, which is considered as one of main cause of the explosion. Furthermore, distance between the storage of hazardous materials and nearby houses was less than one km, which caused additional casualties (Iyengar, 2015).

3 PROBLEM IDENTIFICATION & POSSIBLE SCENARIOS

Based on presented cases, it is evident that ports, especially that ones nearby residential areas, are potentially very dangerous. Considering the urbanization of coasts and increase of logistics flows this issue is expected to growth in terms of impact. Indeed, fire, explosions and leakage of materials might easily create casualties and severe economic damage. For instance, in case of release of contaminant agent and certain wind direction, big number of people could be at risk of poisoning in only a couple of minutes after leakage (Pastorino et al., 2014).

Analyzing historical data, it is possible to identify most frequent types of accidents in seaport as well as main causes (Darbra & Casal, 2004). Indeed, in the following are listed main types of accidents, in descendant order based on frequency of occurrence:

- Loss of containment;
- Fire;
- Explosion;
- Gas cloud.

Similarly, principal causes are the following:

- Impact;
- Mechanical malfunction;
- External factors;
- Human factors.

Obviously, this data are not complete and could be updated, but they provide an insight into the seaports safety situation.

After problem identification, it is possible to perform preliminary risk assessment and identify potential scenarios of interest, which could be used for developing a simulation-based solution. In this case, it should be considered possibility of multiple types of accidents (e.g. fire with subsequent explosion) and causes. In the same time, the model should take into account the external conditions, such as presence of personnel, proximity of residential areas, meteorological conditions and configuration of the port. Indeed, it is possible to develop different realistic scenarios which would include multiple interconnected causes and effects. As an example, possible scenario could include leakage of toxic material from tanks in the port while ferries are docked in proximity. In such case, analysis of the possible outcomes should include such factors as weather conditions (e.g. wind, fog, temperature, even time of the day) passengers' behavior (e.g. organized evacuation, panic) logic and actions of personnel and first responders (e.g. strategy, delays in decision making), impact on port structures and nearby urban zones (domino effect, evacuation of urban areas). Obviously, based on combination of such factors it is possible to observe completely different outcomes, from fast suppression of the cause of accident without any significant damage up to complete chaos and mass casualties; evaluation of possible outcomes in terms of probability of occurrence and impact could be very difficult.

4 SIMULATION FOR EMERGENCY MANAGEMENT

Modeling and Simulation reproduce reality in interactive virtual worlds. Indeed, simulation is a strategic science, capable to analyze existing or future complex systems through experimentation over models, which makes it a perfect tool to be applied to the context of interest (Bruzzone et al.2011a). In facts the interactions among different actors in ports and different concurrent operations represents a major challenge and issue in this context (Bruzzone et al.2008, 2012). Crisis management and prevention are very important tasks for administrators of complex systems. Indeed, a complex system such as a city or a seaport could be difficult to keep under control in regular conditions, while in case of emergency it is even harder to create good preventive and operational plans. In order to succeed in such critical tasks, it is essential to have proper support tools, which could be used to evaluate alternative solutions and foresee how decisions affect the scenario in different conditions (Bruzzone et al., 2018). In previous works, the authors developed multiple models devoted to emergency management, as well as crisis prevention and decision support (Bruzzone et al., 2000; Bruzzone et al., 2014; Bruzzone et al., 2019). Such models, based on Intelligent Agents (IA) are capable to reproduce human behavior and social interactions; this approach allows to extend model capabilities in predicting scenarios outcomes. Indeed, in the scenarios of interest, human factors might introduce even fear or aggressiveness, so that the scenario evolution being more realistic.

For example, Augmented Reality (AR) applications could be used to support such activities (see fig. 1). As shown, the 3D terrain and port infrastructure overlapping the real nautical map of the zone of interest; such technology allows to extend information provided by "hardcopy" map. In this example, it adds

information regarding hazardous materials, security systems and adjacent zones (Bruzzone et al.2011b, 2011c).

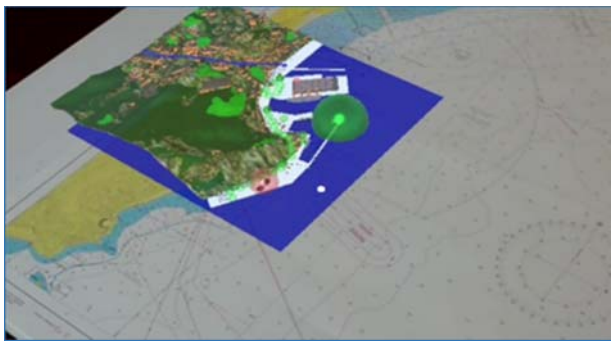

Figure 1: Augmented Reality demonstration

Hereafter, several interesting projects about simulation for critical events are presented.

T-REX: Critical Infrastructures Security

T-REX (Threat network simulation for REactive eXperience) is a simulator for evaluation of impact of different parameters on critical infrastructures. For instance, it allows to analyze consequences of hybrid attack on a port area including a Tank Farm, Oil Terminal, Power Plant and Desalination Facilities.

PONTUS: Urban Disaster Management

PONTUS (Population Behavior, social Networks, Transportations, Infrastructures and Industrial & Urban Simulation) is a city model, which simulates the entire population along with social activities and its behavior in case of critical events. For example, it allows to calculate flooding zones caused by rain (see fig. 2) and analyze impact of such dangerous situation on population in the areas at risk, with particular attention to the situation in the points of interest near to the seaport (e.g. schools, big shops, cinemas and malls).

Figure 2: PONTUS Flooding Simulation

5 CREATING A VIRTUAL LAB FOR PORTS

To address port safety, the authors propose innovative modeling & simulation solutions, capable of predicting outcome of different scenarios in various initial conditions. The idea is framed within an international project named ALACRES2 (Advanced Simulation Based Lab for Port Crisis and Emergency Management over Tyrrhenian Sea Area) carried out among different Universities and Institutions that foresees identification of scenarios of interest for port safety and their application to several ports of interest in order to create a virtual lab able to support definition of policies and guidelines as well as to turn into an efficient modern training equipment for managers, decision makers and operators (Bruzzone et al. 2010; Massei et al. 2011).

ALACRES is lead by Genoa University and it involves currently Cagliari and Pisa University, Italian Coast Guard, Chamber of Commerce of Var and of Bastia Haute Corse, Cagliari Fire Fighting Department and Liguria Environmental Agency

Indeed this consortium is sponsored by EU funds for regional development in order to develop a solution that could have a great impact in this sector. In facts, the Simulation makes possible to reproduce complex crisis evolution and impact on structures, systems, people and goods considering both the physical aspects and the domino effect. Furthermore, it is possible to test the effectiveness of new technological and infrastructural solutions to reduce vulnerability, mitigate damage and prevent emergencies. The simulation techniques adopt the new MS2G paradigm (Modeling, interoperable Simulation and Serious Games) to combine different models and guarantee a high level of fidelity and at the same time simplicity of use, intuitiveness and immersiveness of these simulations, that can even be distributed. In this way it becomes possible to recreate the emergency scenario using immersive virtual reality technologies, thus allowing the involved operators to take actions and simulate their work performance within scenarios that possibly reproduce, from the visual point of view and sound, the real emergency conditions and that guarantee to be involved in the crisis. ALACRES2 expects to involve both the technical partners to build the environments in virtual reality and to set up the laboratory tools, and the operational partners, in charge for the development of the emergency procedures and for the tests.

CONCLUSIONS

The objective of ALACRES2 is a permanent laboratory to identify, test and validate procedures for emergency management in the event of crises or significant accidents occurring during loading/unloading of goods and hazardous material in port areas. The project is at early stage and the alternative models to be used, paradigm to be adopted and general architecture are currently identified, while the survey on accidents and critical issues is finalizing scenario definition. Currently, the authors are investigating with the experts these situations for evaluating new behavioral protocols, more effective guidelines, new operating standards, new emergency monitoring procedures, new support technologies for infrastructure and on-board systems.

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