HUMAN BEHAVIOR SIMULATION FOR SMART DECISION MAKING IN EMERGENCY PREVENTION AND MITIGATION WITHIN URBAN AND INDUSTRIAL ENVIRONMENTS

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ABSTRACT

The paper proposes an innovative use of intelligent agents and computer simulation to support decision making in industrial and urban reorganization for preventing and mitigating disasters. The use of intelligent agents is used to reproduce the population and their perception of the situation and of the actions on the territory as well as their reaction. The authors are proposing the methodology to use these tools integrated with new big data available in towns to improve the quality of life and safety and to crowdsource best solutions in complex problems.

Keywords: *Modeling & Simulation, Smart Government, Emergency Management, Human Behavior Modeling, Intelligent Agents.*

INTRODUCTION

The world is in the throes of a sweeping population shift from the countryside to the city. The global urban population is growing by 65 million annually. For the first time in history, in 2001 more than one half of the world's population was living in towns and cities. (Dobbs et.al, 2001)

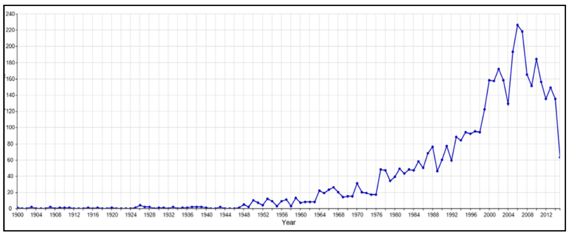

Figure 1: Number of Worldwide disasters due to floods (years 1900-2014) based on International Disaster Database

Since ancient times, people settled in strategic places, (i.e. on the coast, near rivers, in the at the foothills of mountains) first for defense reasons and later to develop trade.
This equilibrium between human and nature is always unstable; if fact in the past several cities were crippled

or even obliterated by natural disasters. (i.e. Pompei due to the volcanic eruption in 79 BCE, San Francisco in 1906 for Earthquake and Fire in 1906, and recently cities in Sumatra in 2004 for the earthquake and tsunami). Indeed the population growth, constructions, infrastructures and urbanization are overstressing the vulnerability of high density area as well as of the mega cities (Mtichell 1999; Brauch 2003; Hallegatte 2008).
Nowadays many experts agree on the fact that global warming and climate change are making natural disasters, like heavy rains, more frequent. It is essential to focus on disaster risk reduction in urban areas, as there is the highest density of population. (UN-Habitat, 2011); indeed the environment the climate change is expected to affect the statistics of natural disasters around the globe (Kahn 2005; Mills 2005; Van Aalst 2006).
Worldwide statistics reveal an increasing number of disasters and growing impacts of these events in the last three decades (Gencer E.A., 2013); whether the urbanization is going to be a driver of risk or mitigate risk levels in the future will also depend on decisions taken there (World Risk Report, 2014).
Public Administrators an constantly need to face strategic decisions that have a significant impact on the future of citizens and business.
In this context, the importance of good government is proved also by the number of studies. For example, Making Cities Resilient Report, 2012 defines some Risk reduction and Resilience factors:

- Institutional and Administrative Framework
- Financing
- Risk Assessment
- Infrastructure
- Schools and Hospitals
- Planning
- Training and Awareness
- Environment
- Preparedness
- Reconstruction

A critical element in reducing disaster impact in the future is the application of science and evidence of assessment of disaster risk, in order to anticipate and prepare for future hazards. (Government Office for Science, London, 2012).

1. MODELING & SIMULATION AND DISASTERS

So it is evident that the territory protection, respect disasters, results as a major issue becoming more and more important nowadays due to several reasons.
From this point of view it is evident the necessity to address the problem by activating preventive and mitigation projects on the territory (Burton 1997).
Modeling & Simulation (M&S) should be used as an effective support for decision makers for its capability to reproduce detailed elements and their complex interactions and to evaluate the different alternatives.
Due to these reason the authors propose the use of simulation for these needs, but by applying new paradigms that enable the integration with new available resources such as big data and mobile solutions; these aspects support the creation of a new generation of DSS (Decision Support Systems) that consider the population as an active part of the "problem", able to propose their own solutions, to validate proposals and obtain support on their implementation by achieving accreditation.
Indeed the simulator, proposed in this case, is based on stochastic discrete event simulation embedded within an interoperable simulation supporting the possibility to federate different models for covering the different aspects.
In facts, this simulator should be devoted to support strategic decision for decision makers reproducing urban context and industrial areas; these models should become a resource, available on the cloud, to generate quantitative analysis respect the impact of different alternative for prevention/mitigation of disasters; the simulation analysis over different possible scenarios could be used to spread the information among the citizens and to collect their feedback.
The idea is to create a quantitative computer simulation able to evaluate and quantify the effect of the different choices and related risks with benefits of new data available made available by open data and data farms respect urban environments (Kitchin 2014).
Indeed the simulator's interoperable architecture guarantees the possibility to integrate different systems within a dynamic distributed framework (Bruzzone, Massei 2010).
Obviously it is fundamental to consider the critical issues of developing models for this context (Amico et al.); traditionally major obstacles in developind DSS in this context include among others:

Data and Model are often not Available
Very often there are many tools already available, but they are not collated by the different offices and authorities that own them: it can be really hard to gather them to produce a single useable source.
Some data are available only in part, or other times in an aggregated format; privacy, data protection and security issues might affect many elements such as health or electoral data.
A large amount of data is important to predict a realistic future scenario and the so we have to see how

the European Union and national institutions will promote the concept of “Open Data”, and we will have to consider other big sources like social networks.

Missing Data Certification and Model VV&A
Verification, Validation an Accreditation of the Models as well as of the Data Certification are often partial or missed; sometime these issues are even addressed resulting in severe inconsistencies among database and unknown fidelity for existing models, leading to credibility losses toward decision makers

Obsolescence of Data and Models
The data available are often quite old and incomplete and it is difficult to use it as a trusted source. The urban and industrial data are subject to evolution and obsolescence and to use them it should be necessary to develop maintenance and updating procedures that often are not easy or possible to establish due to obsolete ICT infrastructure and limited resources.

Entry Barriers
Very often there are many tools available, in the different offices, but their use is limited because they require a license or because they need a skilled operator who may not be available.

Difficulty in understanding the Model
Many systems result extremely detailed and hard to understand; often they are equipped with difficult and non-intuitive interfaces, hard to use and not providing a clear picture of the whole model to the user.

Barriers against the publication of Results
The output of the complex simulation analysis doesn’t often give a clear map of the results; for instance data farming over large quantities of results proposed as static tables for the presentation of the outcomes result often as an obstacle for the use and acceptance of the model itself (Hofmann 2013).
Therefore, it is important to outline that recent developments in technologies and data resources are today mitigating these criticalities and that could support to overpass these criticalities; so new data sources and ICT infrastructures should be used in order to made available data and usability; in general this approach could improve the usability and impact of the proposed simulation including among the others: Internet of Things (IoT), Open Data, Data provided from Citizens, Social Networks as proposed in figure 2.

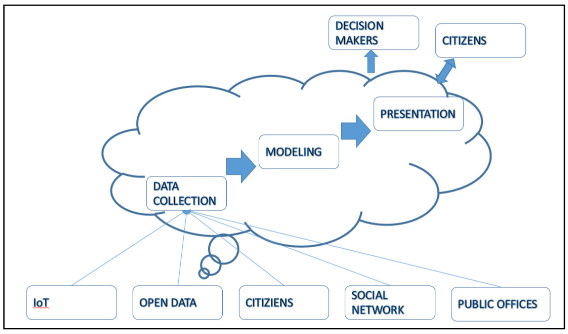

Figure 2: Combining Modeling and Simulation for Decision Makers and Citizen through Cloud Approach

2. POPULATION AS PROACTIVE ELEMENT IN PREVENTIVE AND MITIGATION ACTIONS THROUGH CROWDSOURCING

The authors propose to focus on a specific kind of disaster as starting point for the research corresponding to hydro-geological risk; so the simulator should support identification of best actions to be taken in order to prevent natural disasters (i.e. measure for consolidation, maintenance of rivers and sewers) by reducing risk of landslides, overflowing of rivers and flooding, reducing the risk of the creation of dangerous situation and consequent reduction in urban mobility.
Indeed the use of new simulation paradigms could allow population to understand the real risks and to perceive costs/benefits of Urban and Industrial reorganizations to deal with these kinds of disasters. By this approach it could be possible to achieve support and consensus; indeed due to the high degree of complexity, it is evident that people on the territory are usually a fundamental element to implement any solutions and crowdsourcing approach should provide interesting achievements as already investigated in urban context (Brabham 2009).
The authors already addressed the problem by proposing innovative MS2G (Modeling, interoperable Simulation and Serious Games) paradigm devoted to develop solutions combining game approach and interoperable simulation; these elements were applied to study the crowdsourcing applied to large town and Mega City (Bruzzone et al. 2014a).
In facts the recent experiences confirms that the dimension of the disasters could grow up to so large scale in terms of area and impact that it is fundamental to conduct actions to prevent and mitigate their effects; this fact is true both in case of man made and natural disasters (Xinhua 2010; Price 2013; Sudworth 2015).
The simulation provide the framework for crowdsourcing allowing the citizens to experience

interactively problems as well as potential solutions and to understand their costs/benefits; indeed crowdsourcing supported by MS2G supports population in:

- Understanding existing and potential threats as well as their risk and impact
- Estimating the costs/benefits of solution s proposed by authorities
- Understanding the sustainability of the possible alternatives
- Proposing their own solutions for being evaluated and compared with other ones
- Introducing additional critical issues to be addressed
- Increasing its level of collaboration with public authorities
- Receiving information and feedback about dangerous situations in the city
- Developing a mature political conscience and active participation in political decisions reinforcing positive consensus

In this context it is evident the challenge to identify and activate countermeasures through investments on the territory; the problem complexity, the financial resource required and the technological constraints make very difficult to implement effective solutions; by other point of view, most of these solutions could be very invasive of local population during their preparation (e.g. big constructions over intense populated areas, shortfalls in transportations) or when in place (e.g. additional taxes, relocation of productive and/or residential areas, loss of profit opportunities).
This context is really a complex system affected by emergent behaviors dealing with transportation, economics, politics etc.; so the use of crowdsourcing to extract solution extract solution is very promising (Bruzzone et al.2014b).
This approach could lead to develop a more mature and rational relationship between public authorities and population; so it could be developed a mutual trustiness based on understanding and *transparency* that could create capability to adopt courageous, but necessary decisions in this context.

3 M&S SUPPORTING STRATEGIC DECISION IN URBANIZATION AND INDUSTRIAL AREA

Among the different cases, it is evident that urbanized and industrialized areas are the main focus for this analysis; indeed the cities are getting more complex and much more urbanized along recent years creating very complex scenarios to apply preventive actions against disasters. In addition, the urbanization process leads to embedding large industrial areas and plants that affect the impact of the disasters and introduce additional constraints and challenges; all these elements could be addressed by applying M&S in analyzing the problem and supporting decisions (Bruzzone et al. 2011a; Bruzzone et al. 2014c).
Indeed, historically M&S has been largely used to support decision making in industry, even if the focus was strictly related to improve industry performances (e.g. Longo 2013; Del Rio Vilas et al. 2013; Bruzzone and Longo 2013). Instead, much more can be done in using M&S to support strategic decisions in preventing emergencies and disasters in urban and industrial areas.
Indeed, as anticipated, the natural disasters due to extreme meteorological events such as heavy rains happen more frequently due to climate change and global warming; this aspect is very significant in several areas and several Italian Urbanized areas are affected by this problem (Moromarco 2005)
Indeed the decision makers have limited resources: budget and time constraints, limited number of workers) and they need to keep maintain consensus among their citizens and guarantee safety in industrial town and industrial areas.
Indeed even if public administrators have a technical staff supporting them in the different tasks, they need to satisfy not only the complex technical aspects, but also the guarantee the quality of life of the population; this last element is usually strongly affected by their decisions; so consensus, quality of life and safety results result very strongly connected among themselves.
This is true obviously in relation to flooding phenomena, even if hydro-geological risk, obviously, is not the only challenge to be addressed: it is necessary to face many one day by day, e.g. crime, health, traffic, with different priorities; obviously the proposed approach, combined with other specific models, could be extended to the other areas.
In this context is necessary to simulate the effect of rational thinking respect each decision by quantitative models also taking into consideration the effects and reactions of the population.
Considering that simulation is the reproduction of reality by using computer models creating a Virtual Environment and running dynamic scenarios, it is evident the possibility to use it for analyzing and improving quality of life and safety (Mcleod 1999; Diaz et al. 2013); indeed traditionally M&S has been widely used in different applications both in military and in business domains. (Tremori et. al. 2015; Bruzzone et. Al. 2011a; Piera et. al 1996).
The authors propose here the use of Intelligent Agents (Bruzzone 2008) to allow the reproduction of complex behaviors among different entities affected by social relationships interacting with each other to consider the effect of population; indeed, it is proposed to reuse previous developed models focused on Country

Reconstruction, Urban Disorders, Civil Military Cooperation normally used for overseas scenario (Bruzzone et al. 2012).

Considering that all the actions needed to prevent flooding, often require a large amount of resources, both in terms of time and in term of money; so a virtuous administration should be able to schedule the activities for hydro-geological events according to the available resources in terms of time, money, and work; so these elements should be part of the model.

In general and as already outlined, an urbanized area is the result of the human presence in a natural environment; so it is evident that the model should address the different layers reproducing natural and urban systems summarized in table 1.

Natural systems reproduce the natural landscape of the city: the sky, the ground, the sea and the rivers; on the other side, the urbanized system reproduces all aspects connected with human activity.

System	Elements	Effect for the simulation
Natural System	Sky	Rain reproduction in the different zone of the city
	Ground	Simulating different ground permeability characteristics of the
	Sea	Simulating sea level fluctuation, and tsunamis
	rivers	Simulating the flooding due to high level of the water: Two different watercourses are considered: - Fluvial - Torrential
Urbanized system	Location of households	Simulating the more populated zones during the night
	Location of industries	Simulating the more populated zones during the day
	Mobility	Simulating the effect of natural events near the Hydrographic Basin of the river to roads, rail, and highways
	Location of points of interest	Schools, hospitals, stadiums are points of interest where there is a greater probability of high population density during certain hours of the day

Table 1: Different elements in the simulator

The interoperable approach allow to add to the simulation specific additional models based on the phenomena to be reproduced; for instance a model of rain could be developed by dividing the area into a grid, where each square has a given probability of showers. In this way it is possible to simulate heavy rains concentrating in certain part of the territory and town. The probability of rain could be estimated by the simulator, considering weather forecasts and historical data as well as update from the field. By this approach the simulated rain falls over the urban area surface and it is conveyed into the rivers and into the sewers increasing their flow based on terrain dbase. It is possible to consider different type of watercourse including fluvial and torrential ones. Torrential watercourses are usually more dangerous since they suddenly chance their behaviour, whilst fluvial ones change their behaviour gradually.

In this case the simulator could support decision makers in, evaluating respect different alternatives the impact of different preventive actions; all these estimations could be carried out virtually, before to undertake any specific decision and could be shared with population based on MS2G; in addition people could propose their solutions and evaluate the performance by same approach.

So this approach addresses the constant need to evaluate strategic decisions in order to prevent and mitigate the effect of potential natural disasters; indeed MS2G allows obtaining and sharing quantitative evaluations respect possible actions to be undertaken.

The authors propose as model for the urban and industrial areas including population reproduced by multilayer elements directed by Intelligent Agents (Bruzzone et al.2014d). By this approach it becomes possible to test different the scenario hypothesis facing not only budget, resources, and time constraints respect the impact of stochastic factors, but also reaction of people. Indeed Human Behavior Modeling & Simulation (HBM&S) is devoted to reproduce the people's actions within the simulation environment. In this simulator and according to the aim of this research, it is necessary to simulate different elements including emotions, psychology, rational thinking and social behavior. These different aspects characterize human behavior and generate often complex phenomena. Indeed, as anticipated different levels of complexity are defined: the first level is at the individual level, while the second one is at the population level, considering the different individual as a group.

There are several challenges in reproducing human behavior affecting these levels, indeed it is necessary to consider:

- **Rational Decision Making**
  - Intelligent Individual Behavior
  - Organization & Hierarchies
- **Emotion and Attributes**
  - Psychology, Culture, Social
  - Crowd Behavior
  - Social Networks

In the simulator proposed, the inhabitants of the city are simulated with single entities.

In this case the people objects represent human entities and are considered "intelligent" in applicative sense in terms of capacity to react to different stimuli as well as to their situation awareness.

In facts the HBM&S requires the capability to simulate the decision making process of the population even if in simplified way. (Gintis H. 2007)

In this case the use of Intelligent Agent is very important considering them as computer based entities with following characteristics (Wooldrige & Jennings, 1995):

- Autonomy: capability to operate without the direct action of humans, with some kind of control of their internal state.
- Social ability: capability to react with other agents (and possibly with humans) with a communication language
- Reactivity: ability to perceive their environment and respond to changes
- Proactiveness: capability to take the initiative

From this point of view, it is fundamental to focus the attention on modeling population behavior in terms of groups and individuals as well as respect their social networks; these elements allowed evaluating human factors over country reconstruction scenarios as well as on other and actions on the territory (Bruzzone, Massei 2010).
The proposed models reproduce humans as people objects, interest groups and entities. This multilayer approach uses people objects as element for representing individuals and/or small groups (e.g. a family), while interest groups correspond to aggregations of people objects (e.g. catholic people, rich people, farmers, inhabitants of a city quarter, teenagers, etc.). Obviously a people object belongs normally to multiple interest groups that are characterized by mutual relationships. Vice versa the entities are group of people that are aggregated or unites active on the terrain to carry out specific actions (e.g. a demonstration, a riot, a group of workers dealing with road reconstruction in some point of the map). The people objects are dynamically moving on the terrain based on their daily/weekly/yearly life cycle and on their characteristics; compatibility algorithms are used to define their aggregation and activities in consistency with their characteristics currently mapped by a set of parameters. People Objects are connected by social networks as well as interest groups by mutual relationships that dynamically evolve based on events and actions along simulation evolution (Bruzzone et al.2012).
Obviously the simulation should be tailored with specific data of the socio-cultural context to be studied; Intelligent Agents Computer Generated Forces (IA-CGF) have been developed as interoperable models, using IA and HLA (High Level Architecture), to simulate population behavior as well as its reactions to particular events that occur during the simulation (Bruzzone 2008). In facts Human Behavior modeling has been already applied both in military and in civil domain and examples on IA-CGF use are available for different cases including Haiti Earthquake (Bruzzone et.al 2010; Bruzzone et al. 2011b; Bruzzone et.al 2012) as proposed in figure 3.

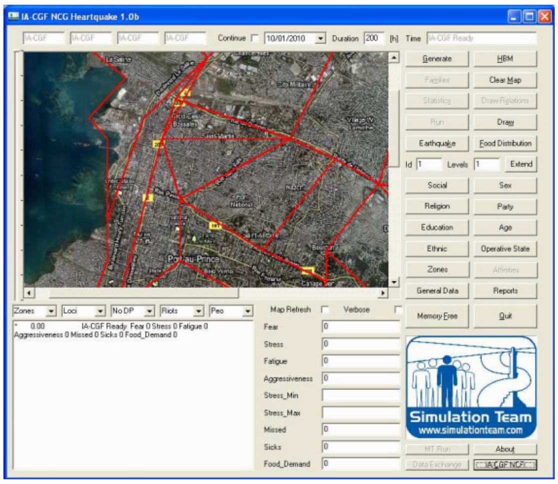

Fig 3: Example of Simulator interface applied to a large scale Disaster Relief Scenario

These previous researches represent the evolution on human behavior modeling in towns and regions to analyze urban unrest and emergency management along last 20 years (Bruzzone & Kerckhoff, 1996; Bruzzone et. al. 2014). Obviously the simulator should include the representation of urbanized area considering the location of households, and industry, in order to simulate the presence and the movement of the different individuals simulated by people objects and entities; in this representation the households and industries, together with other point of interest (like schools, stations, stadium, …) are attraction points for the people objects based on their characteristics.
In the proposed simulator, the setting of the scenario is based on the following scheme:

I) People Initialization:
In this phase people are created in the simulator, according with the number of inhabitants of the city

II) Setting local population characteristics
In this phase the local population characteristic are characterized in terms of statistical distribution, taking in account different parameters:

a. Gender
b. Health Condition
c. Age
d. Nationality
e. Marital status
f. Education level
g. Political Attitude
h. Residence District

Generation of the individual layer
In this phase the local population characteristics are generated randomly according with the available data and statistics of the local urban context.

III) Generation of the social Layer
After the generation of individual entities is possible to generate the social layer; this is generated by a stochastic aggregation of individual entities building families and social networks.

Simulating human modelling is critical from the point of view of verification and validation of the simulator, and the process of data collection and analysis is critical.
The emotional status of a single entity is simulated by taking in account different variables:

- level of stress
- level of fear
- level of trust
- level of political consensus

These parameters evolve thoughout the duration of the simulation and change both according to the internal relationship among the entities and the external actions set by the user.

CONCLUSION

The use of intelligent agents to reproduce population behavior in a large urban context provides a good research opportunity; the research underlines the conceptual framework of the simulator proposed.
Weather forecasting is possibly the most commonly accepted simulation as it is included in common decision making processes.
However, this approach, if properly applied, could allow developing a new generation of decision makers that consider simulation as an effective support for disaster prevention; this is not easy considering that in most of the case, current politicians prefer to spend 120 billions after a storm like Katrina than spend 20 to prevent the impact of the flooding.
Usually administrators are faced with openly hostile stakeholders that might even welcome a disaster. Including simulation in decision making systems relating to public safety takes vision, intelligence and political courage; the introducing of crowdsourcing and engagement of population could support the administration in developing such characteristics.
In facts there is also possibility to obtain additional support from insurance companies, major retailers and large industries interested in these issues

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