SIMULATION AS DECISION SUPPORT SYSTEM FOR DISASTER PREVENTION

Agostino G. Bruzzone [(a)], Matteo Agresta [(b)], Kirill Sinelshchikov [(c)]

[(a) (b) (c)] Simulation Team, DIME University of Genoa,

[(a)] agostino.bruzzone@simulationteam.com, [(b)] matteo.agresta@simulationteam.com,
[(c)] kirill.sinelshchikov@simulationteam.com,

[(a) (b) (c)] www.simulationteam.com

ABSTRACT

This paper describes the overall architecture of a simulator developed by Simulation Team and Genova University to address the problem of strategic decision making related to prevention and mitigation of natural disasters risks. The proposed approach combines a Decision Support System for supporting decision makers in strategic planning with interoperable simulation and serious games. The scenario used for the validation in this case focuses with a particular attention on hydrogeology and related risks within urban environments. The authors propose a multilevel and multi resolution simulation able to match the models of the flooding with that one of the population reproducing interest groups as well as single people. Indeed the population is simulated by intelligent agents (IAs) that include physiological, social and psychological parameters reproducing feelings and emotions that allow them to live and move inside the virtual city both in normal conditions as well as during the disasters.

In facts in normal conditions works devoted to serve as preventive actions devoted to prevent certain events and or mitigate their impact are carried out; vice versa during the crisis, decisions change addressing the identification of convenient operational planning and/or evacuation site. Each time, an action is undertaken by the decision makers, the IAs react dynamically by changing their feelings and their political consensus, so it becomes possible to plan the actions in an effective way by maintaining the consensus and support of the population.

Keywords: Flood Simulation, E-Government, Intelligent Agents, Decision Support Systems, Political Consensus, Social Networks

1 INTRODUCTION

Urban decision makers constantly need to face many challenges during their governance. Indeed they have often limited resources both in terms of time and money. Their governance last generally around 3-5 years and this is a short time compared to the completion time of certain big projects such as civil works such as floodways, dikes and other large infrastructures. The challenge for the local decision makers does not deal only with time constraints, in facts the central administration often reduce the annual budget of local municipalities that consequently have to limit their investments or have to rise local taxes to respect the annual budget.

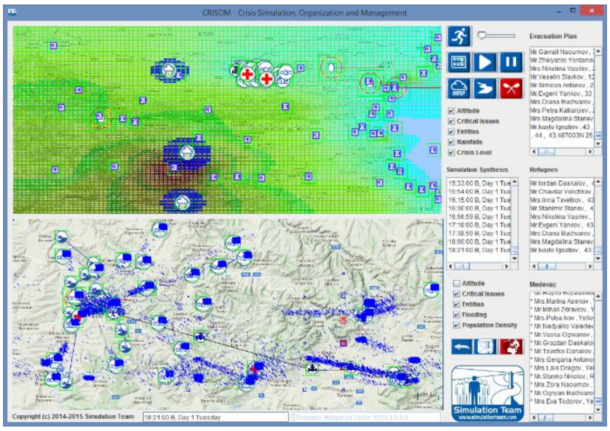

Figure 1: ST_CRISOM main interface

Today the impact of natural disasters is reinforced by several phenomena; for instance climate change increase frequency and intensity of these events as well as urbanization; in facts today more than 50% of world population is living in urban areas. These aspects increase the impact of flooding, hurricanes exponentially due to the high concentration of humans for square kilometer. One of the most recent and devastating confirmation of this problem is hurricane Harvey (Bromwich 2017).

For instance, urbanization amplifies the effect of flooding not only due to the increase of population density, but also as consequence of urban concreting; in facts this aspect requires a big attention from urban decision makers in planning the new constructions in order to respect local hydrogeology and avoid floods to be magnified by overbuilding (Jia et al. 2008; Lankao & Qin 2011). In the last decade several countries has experienced a number of unusually long-lasting rainfall events that produced severe floods and other extreme events such as big landslides (Schirmer et al. 2013; Howard & Israfilov 2012; Leichenko 2011). The importance of projects, addressing protection from risks related to hydrogeology, is often underestimate and many activities are postponed or reduced since they are extremely costly and the popularity is often "hidden" compared to other more popular and less costly investments. In addition politically opposing parties and different interest groups could act against the Decision Makers introducing delays and obstacles that compromise these project. In facts, the decision makers are political entities, and they need to keep constantly "an eye open" to citizen consensus during their mandate: each decision produces effects on the population.

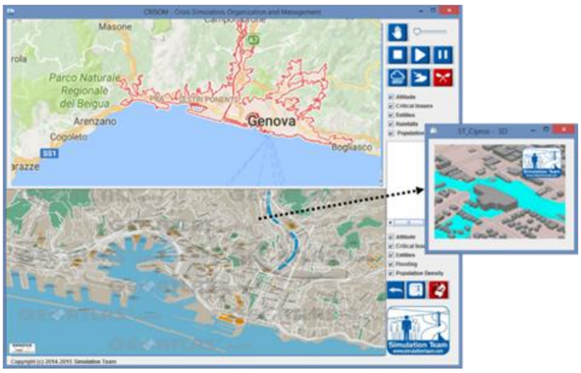

Figure 2:ST_CRISOM User Interface

Therefore popular & unpopular decisions influence statistically the average consensus and in some case, extreme situations, could lead also to the risk of delegitimization of current governance bringing unexpected early elections. (Rimlinger 1971).
The "art" of good governance is based on the capability of decision makers to address major issues based on priorities and in respect of available resources (e.g.money, time and people) by activating and completing projects and investments in different areas such as Environment, Economy, Welfare, Security, etc. (Bruzzone et al. 2014a). The set of all the possible investments and decisions is huge and there are several categories of potential investments, for example:

- Urgent/Non Urgent
- Long Realization Time/Short Realization Time
- Popular/Unpopular
- Cheap/Costly
- Useful/Not Useful
- Urgent/non Urgent

Each of this choice have a different specific impacts over multiple domains finance, environment, consensus, safety, etc. For example cleaning the river has a prompt results in population consensus and a medium economical cost; on the other side, a civil work such as rising the level of a bank in a particular point, or building a new floodway have an higher cost, and a longer time reaction time from population since it require more time; by the way sometime the works required to complete the project could be perceived in negative sense by the population for several issues (e.g. noise, impact on traffic, etc).
It is evident that most of this factors are affected by uncertainty and influenced by stochastic factors (e.g. weather working days, people perception, etc.).
These considerations underline the potential of simulation for supporting the decisions and for testing and evaluating the different hypotheses and even to underline emergent behaviors and situations (Ören and Longo, 2008) in different types of real world systems; in facts also the use of serious game could be pretty useful to provide a framework to share, through the web, multiple different proposals with the population. Indeed modern crowdsourcing concept based on this approach is very interesting beacuse it allows to collect active proposals and suggestions by people as well as for improving communications with citizens and building consensus (Rossetti et al.2013).

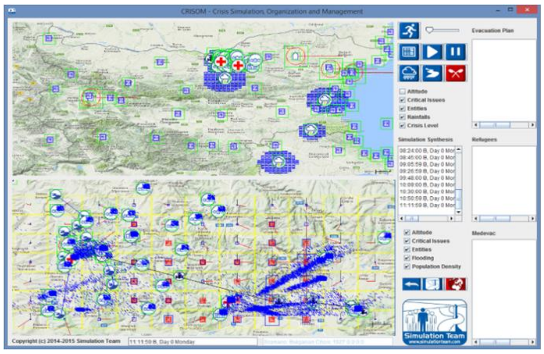

Figure 3: rain propagation in ST_CRISOM

2. E-GOVERNMENT, OPEN DATA AND THE IMPORTANCE OF COMMUNICATIONS

Nowadays Twitter, other Social Networks and Blogs are "massive" communication channels, often considered more effective compared to traditional ones (Baruah 2012; Trusov et al. 2009; Garton et al. 1997)
These resources represent an extremely powerful tool, indeed communication strategies have a great potential to support the establishment of good and effective governance (Heeks, 2001). In facts this consideration could be used by Public Administrators (PA) in order to create an effective E-Government system:

- From PA to Citizens: to publish information, results, alerts
- From Citizens to PA: to collect feedback and to "keep an eye" on the city by monitoring the situation based on citizen posts as well as on their web activity

In this way the citizen participation to local politics could be improved and their consensus could be monitored through social networks and web activities. Such kind of information is available to be fused with open data, statistics and census information becoming extremely powerful; indeed urban municipality have access to big data characterized by a big potential, that often are not used for supporting decision makers for several reasons such as:

- Availability of Data and Models: very often Public Administrations have some model or simulation tools as well as dataset, but usually the models are almost disconnected; for instance, frequently, the data require additional preprocessing to be transformed in the required formats and not trivial manual elaboration and/or filtering are necessary.
- Obsolescence: frequently the data are not updated constantly and their validity is expired. In similar way the models could turn obsolete or loose their fine tuning if not used frequently.
- Entry Barriers: databases and models are often used by analysts, in many cases they are not intuitive and require the advanced scientific and/or technical skills to be used. In addition, the models are not designed, usually to be used directly by decision makers, so it is missed such feedback to refine them.

Figure 4: CRISOM Map Editing Tool

- Organization Complexity: Public Authorities have a complex bureaucratic structure often with partial and not interconnected substructures such as local police, Civil Protection, Statistical Office, Mobility office etc all these entities often use their own local dataset missing the chance to share common information and models.
- Privacy: PA owns several information about its citizens, buildings, infrastructure etc. but often don't share such data due to privacy reasons (i.e. health and other sensitive information). Often the privacy concerns limit the data sharing much more respect the effective regulations due to the pusillanimous of some officers, vice versa such information would be extremely useful also in the form of aggregate data set. (Floridi, 2014).

Thanks to the Open Data, several PA are now publishing much more information about their municipalities and these are becoming more and more accessible. Accessibility often corresponds to reliability considering that the review by third party user of the database contents allows to identify errors and inconsistencies and to apply corrective actions (Kassen 2013).
These Open Data are available often to everyone, so they represent new opportunities for the e-government and for developing new tools for Decision Support Systems, Crowdsourcing and Serious games for improving communications with citizens and for collecting their feedbacks (Janssen et. al, 2012; Kitchin, 2014).
From this point of view the authors decided to develop a simulation approach devoted to benefits from the huge quantity of available open data from the web and ready to reproduce population by effective human behavior models.

3. ST_CRISOM

Simulation–Team Crisis Simulation Organization Management (ST_CRISOM) is a simulation framework, developed by Simulation Team and DIME University of Genova, with special attention to reproducing disasters and decision makers planning. Indeed ST_CRISOM is part of a "suite" of different simulators dedicated to Disaster Emergency Simulation that are adopting HLA (High Level Architecture) interoperability standard.
In facts, ST_CRISOM enables the possibility to generate and simulate disasters and to estimate the effectiveness of different actions carried out to prevent, mitigate and eventually manage the crisis. In facts this simulator reproduce both urban areas as well as country side and it could be federated with other tools by means of a Run Time Infrastructure (RTI).
ST_CRISOM is able to run real time and faster-than real time, so it could be used to check validity and robustness of different alternatives; in facts this allows to apply data farming and risk analysis for decision support over complex scenarios (Barry et al.2004). In addition ST_CRISOM has passed integration test within CRISOM HLA Federations, so it is available to interoperate with other simulators developed by DIME-Simulation Team; (i.e. IDRASS, DIEM-SSP, IA-CGF NCF NCF EQ, TRAMAS Katrina Like, DIES IRAE, SIMCJOH VIS & VIC, MARIA) that could further enhance its capabilities in complex scenarios (Bruzzone et al. 2011, 2015a; Massei et al. 2014).
ST_CRISOM is equipped by an intuitive interface for users that support a Multilevel and Scalable approach (tactical/operational/strategic level); originally this solution was including different simulation models for addressing multiple different crises:

- Explosions
- Hazardous Material Fallout
- Flooding

These simulation models are used to identify areas and to define items, objects, buildings, plants, infrastructure and people affected by such event.
ST_CRISOM have a multi-layer resolution that could be tuned by the users. Such capability allows to consider different layers and to overlap available information provided by different sources and to share them within the simulation through Geo-Referenced data.
In facts, ST_CRISOM consider different layers:

- Natural: Orography of the terrain as well as information on sea, woods, rivers, aquifers and Hydrographic basins
- Urbanized: households, buildings, industries, transport networks, point of attraction
- Infrastructures: pipelines, power grid, and point of interest (hospitals, schools, stadium etc.)
- Population: distribution in villages and quarters, individual life cycle, individual preferences, families and social networks
- Communications & Social Networks

ST_CRISOM allows to simulate humans from single entity (i.e. individual) up to aggregated level of the entire population of a city according to the users' needs and the data available. Hereafter some major different parts of the ST_CRISOM are described.

3.1 *Model of the Orography*

Simulation Team have developed an acquisition algorithm for importing the Digital Elevation Map of a given area from the web into ST_CRISOM databases. In particular ST_CRISOM is already able to import the Orography of a certain area by converting a shape file into a discrete surface composed by polygons. Such area have a variable resolution according to the level of details required by the simulation and according to the overall efficiency that is related to the extension of the area to be investigated.

3.2 *Rain Generation Model*

ST_CRISOM is equipped by a rain simulation model that allow to simulate the evolution of a perturbation. The model is stochastic in order to be more realistic and simulate the "uncertainty" affecting the decision makers. Rain probability and intensity (e.g. mm/hour) as well as cloud propagation are simulated considering the meteo-forecasts and potential deviations; indeed the available measures of wind speed & direction, humidity, temperature and other stochastic variables, concur to create a realistic propagation of the perturbations; therefore ST_CRISOM includes special algorithms devoted to spread these data in space, over the whole area, and in time, respect the whole temporal horizon, by applying the different conservation laws.

3.3 *Rain Absorption Model*

This model is needed for simulating the rain absorption from the terrain; indeed the water absorption factor of rain strongly depends on many parameters such as type, state (e.g. frozen ground), roughness and inclination and orientation of the terrain; that is the reason why setting the right coefficient it requires proper tuning techniques. In addition it is necessary to distinguish:

a) Urban areas where there is presence of drainage networks composed by roofs, roads and other man made items
b) Not-asphalted areas, where there are also different terrain typologies with different absorption behavior (i.e. rocks, clays, grit) and different conditions. Indeed if the terrain is already wet from the previous days the model should consider that its absorption will be lower.

3.4 *Hydraulic Models*

Hydraulic models reproduce in details the rivers and the hydrological basins. These models allow to simulate the water streams in the different section of the rivers and the local flooding phenomena due to the overcoming of the maximum water level. Such data can also be shared with other simulators through HLA and/or elaborated by ST_CIPROS VIC (Simulation Team Civil Protection Simulator - Virtual Interoperable Simulation) for reproducing the 3D flooding local model (Fig. 2). Indeed ST_CRISOM is HLA compliant and it can be federated by means of the RTI to other software in real time (Bruzzone et al. 1998, 2015b).

3.5 *Urban Mobility Mode*ls

These model represents the population movements in the city and between towns, plants and infrastructures located in the region of interest. The City is divided into zones and the people objects at their creation have assigned homes and working places based on their specifics characteristics; these correspond to zones that during simulation become attraction and generation points. The people objects by moving around allow to compute the distribution of the population and its activities based on their specific life cycle and their reactions to events. In this way the crowd change over the different zone of the city and according to several boundary conditions and events, including floods, such as hour of the day, meteorological conditions, day type (working day/holiday), other special events like fairs or football matches etc.

3.6 *Entities & Points of interest*

ST_CRISOM simulates several different Entities (e.g. ambulances, mobile command post) and Points of Interest (PoIs) such as schools, hospitals, industrial facilities, plants, pipelines and other "hot point" that are important in case of an emergency such as a flood.

3.7 *Damage Models*

Damage models match the flooding dynamics resulting from the simulation to the other layers, particularly with the population and Entities and PoIs; indeed ST_CRISOM calculates dynamically the list of the entities that are affected by the flooding over the different areas, providing their details (i.e. name, sex, age, health status etc). Such information are organized to support evacuation plans as well as support operation and could be visualized dynamically in disaggregate or aggregated according to the desired resolution for the virtual environment.

4. IA & POPULATION SIMULATION

ST_CRISOM is designed for being available through the web and to reproduce the town reactions to decisions as well as to crises; in this context it is fundamental to reproduce the population, so the Intelligent Agents (IAs) are used by ST_CRISOM to simulate the human behaviors considering complex aspects such as rational decision making, emotional and irrational behavior resulting from individual perception as well as social interactions. Indeed ST_CIPROS VIC reproduce individuals on different layers:

- People Objects (POs) representing entities devoted to cover the single individual as well as a small group or a family
- Interest Groups (IGs) representing groups of people with common characteristics and interests

People Objects are integrated into a social network connecting different entities due to family or friendship liaisons, while Interest Groups are interconnected by mutual relationship relationships; obviously each PO is connected also to multiple IGs representing the groups to what he belongs and, vice versa, IGs is linked to many POs representing its members.

These multi layer multi link social networks represent the population and all corresponding social interactions.

In facts, the familiar relations and social networks are simulated by IA-CGF (Intelligent Agent Computer Generated Forces) and have been developed by the Simulation Team during the years and applied in different context (Bruzzone et al. 2011).

ST_CRISOM simulates each single individual as an intelligent entity with several functions representing their emotions (e.g. fear, stress, aggressiveness, political consensus) that evolve during the simulation based on its perception of events. Indeed The ST_CRISOM is a stochastic, discrete event based simulation that adopt MS2G paradigm (Bruzzone et al.2014a).

4.1 Single Entity Layer

This is the basic layer where it is possible to recreate population based on open data. Here, the POs are created based on statistical distribution created by the available open data that feed the Configuration Objects defining the different element of the population (e.g. a Neighborhood of a city, the workers of a business sector, the followers of a leader). The following parameter are considered:

- Age
- Gender
- Living Zone
- Nationality
- Religion
- Marital Status
- Political Party
- Level of Instruction
- Individual Income
- District of residence
- District of work
- District for leisure activities

4.2 Family Aggregation Criteria

This elements represent the aggregation criteria for single individuals to become a family and are structured in terms of parameters considered for verifying the compatibility of a stochastic generated family: number of component, importance of social differences, average incomes, number and age of the children, etc.

4.3 Social Aggregation Criteria

This layer allow to connect each individual to other entities by reproducing their social relationships including among others: Friendship, Workplace connections and specific Social Networks. Such components are simulated by means of compatibility algorithms similar to that ones of the families and currently the authors are working on creating special models for Web Social Network Simulation to be used during training sessions and for educating the decision makers to take into account the feedbacks from these new media channels.

5. ST_CRISOM FUNCTIONALITIES

ST_CRISOM is designed in order to be accessible as web applications to be available on the cloud and it supports the following functionalities:

a) User registration: the registration page allows to keep record of the user data and supports different account type are configured:

a. PA Decision Maker
b. PA Analyst
c. Citizen

Such differentiation is important to preserve privacy of some data and other information that PA cannot or does not desire to share and publish. Such characteristics activate and deactivate some functionalities, for example only a Analyst is enable to change parameters of flooding model.

b) Loading the Common Interface - Geo-Map Tool

This tool is based on an open source map with several layers (topographic, political, etc.). Several Points of Interest (PoIs) are displayed, geo-referenced over the map, classified as macro-categories. ST_CRISOM includes the following basic classes, even if other classes could be added easily:

- School (e.g. Primary, Secondary, Comprehensive Institute, Universities, etc.)
- Hospital
- Museum
- Commercial Center
- Other big PoIs (i.e. aquarium, stadium, fair etc..)

c) Map Editing: ST_CRISOM map includes an editing tool that is devoted to add additional layers from existing maps (i.e. hydrological basin, flood risk map). PoIs could be also added easily by defining their type, coordinates and attributes.

d) Sensors and Cameras: this functionality is available only for PA users and it allows to visualize the following elements:

- The available camera in the city
- The available sensors in the city (i.e. rain gauges)

e) Prediction tools: these functionalities allow to create the future population in reference to a reference year in order to investigate its structure and related social networks. Indeed ST_CRISOM support data sets covering future population up to 2030.

f) Population Generation: ST_CRISOM reproduce population considering individuals, families, social network and interactions over the whole town. The generation process adopt Monte Carlo techniques based on Configuration Groups created through the data fusion of open data. The overall process is following

- ➢ Open Data Access: open data available from public sources are used to update ST_CRISOM databases
- ➢ Population Data Fusion: the open data could have different granularities, for instance it can be referred to different types of urban subdivisions; so it could be necessary to combine them in order to create a comprehensive and consistent set of

Configuration Groups able to define the whole population; for this purpose it should be necessary to design and implement tailored data fusion algorithms.

- Individual Generation: the single individuals are generated as people objects from the Configuration Groups applying Monte Carlo Technique, aggregation criteria and the compatibility algorithms on the zones. In this way the POs are located on the terrain, for instance, in terms of home and work place; in order to speed up the simulation, it is possible to aggregate the individual into similar entities such as family
- Interest Group (IG) Creation and Population: from the generated individuals are extracted the main groups and created the mutual links between IGs and POs.
- Social Network Generation: the social networks are created by applying compatibility algorithms and aggregation criteria among themselves; in this way families are create in consistency with general data of the area.
- Interest Group Network: the IGs are interconnected in the form of a dynamic graph considering mutual attitudes and connections based on general characterization of the area that could be fine tuned by analysts.

g) Urban Mobility Layer: the urban mobility layer allow to simulate the people movement inside the city. For the ST_CRISOM purposes, people move from their home zone to working zone of the city and back during working periods as well to relax areas in free time. Urban mobility layer is used to evaluate the dynamics of people object on the map. During crisis or when a PO perceive a risk, he reacts emotionally or rationally (based on a specific stochastic human factor model) by changing behavior and, potential, moving to some other place (Bruzzone et al.2011). Indeed it is possible to calculate Origin/Destination (O/D) Matrixes in order to provide the PA with data aggregated at the level of the finest statistical zone available; in facts these results could be very useful for Verification & Validation of Data available in terms of O/D Matrixes by PA. In facts ST_CRISOM calculates the O/D Matrix as result of the daily activity of people by recreating the dynamic human presence over the different areas of the range of analysis during the simulation.
Simulated O/D matrix consider each single zone as an attraction/generation point and allows to conduct analysis devoted to correlated key factors such as the expected number of people respect different parameters such as, for instance, the number of Jobs, Schools and Household in each different zone. Simulated time is stepped into hours to collect simulation results for conducting risk analysis over the daily evolution, including morning and afternoon traffic peaks in working days and along weekends and other special occasions that can vary the people destinations.

h) Indicators: ST_CRISOM provides the user with different indicators for having a continuously updated overview of population feelings during the simulation. Such individual feelings can be aggregated at different level for better understanding the situation evolution. At the moment, ST_CRISOM consider the following main functions:
- Consensus in the local governance
- Trustiness (in the Alert System for floods)
- Fear

Such functions provide a quantitative feedback of the citizens "status" and their reaction to the different political choices on the different time-scales:
- short term behavior (during the flooding and during mitigation phase)
- long term behavior (i.e. trustiness in local governance after that a new floodway is completed)

i) Communication panel: the communication panel is available for the PA user and it allows to analyze the communication activity from Public Authorities to citizens. This is an emulator of the real communication channels and allow to the user to publish the alert on the following communication channels:
- Website
- Twitter
- Facebook
- SMS service
- Apps
- Road information panels
- Display on the bus stops

Each one of these communication channels will reach a certain percentage of population changing their feeling and modifying their behavior.
In order to increase the realism, ST_CRISOM reproduce the "crying wolf" phenomena: if too much information or too many weather warning are produces a decrease into the level of trustiness, and more and more people ignore the next warning about weather alert without modifying its behavior.

j) Budget: ST_CRISOM player have a budget and it is consumed based on the decisions and performed actions. Simulation consider use of these resources both in terms of money, people and work-hours; in facts at each action it is associated a cost, the number of people to complete it and the time required. These parameters could depend, or not, on weather conditions and other factors (e.g. strikes, demonstrations).

k) Damage estimation models: these functions allow to estimate the damage of the flooding according to the level and intensity within a specific area to the people present in such area when the flood occurred as well as to PoIs and other objects or entities

l) Decision Panel: this panel allow the user to undertake a set of strategic actions during the simulation such as, for instance:
- Improving the maximum level of the dike in a certain zone
- Realizing a new floodway

- Increase the number of panels in the road and in the bus stop in order to improve the communication among citizens
- Increase the number of rain gauges and increase the number of IoT (Internet of Things) device, for instance for improving the pre-alert phase
- Move the pumps from the bottom to the top of Public Buildings (i.e. hospitals)

ST_CRISOM allows to simulate the decisions along year time horizon to check the costs/benefits ration and the impact on safety and on population trustiness.

6. CONCLUSION

ST_CRISOM is a simulation solution originally designed for Public Administration (politician and analysts), but it is available also to be used by citizens for improving their understanding and active participation to public strategic decisions. Currently the focus is on preventive actions respect floods, therefore it is evident that this approach could be generalized over many different sectors. ST_CRISOM supports decision makers in estimating the impact of strategic decisions related to the hydrogeology of an area as well as on protective actions and flooding prevention projects considering a multi layer and multi resolution simulation; this approach is based on complex algorithms able to reproduce human and social behavior through simulation and these models have been already used into several other application fields.

ST_CRISOM allows the user to test the counterintuitive effects of different decisions in different domains such as economics, politics and environment with a particular focus on providing a direct feedback on the impact of such choices in terms of citizens consensus.

Currently, the research team is ongoing for calibrating ST_CRISOM algorithms with the Open Data from Genova Municipality respect flooding.

Indeed the ST_CRISOM multi-layer approach is promising and innovative, especially considering the evolution of ICT; in facts, this simulator combines modern data sources, Open Data, GIS information, human behavior modeling and Social Networks in a common multi-layer solution able to support crowdsourcing and to reproduce the effect of political decisions on population.

This approach is expected to generate in future several solutions able to serve as effective instruments for PA in order to improve planning and strategic decision making capabilities and to create mutual trustiness among citizens and authorities.

REFERENCES

Barry P., Koehler M. (2004) “Simulation in context: using data farming for decision support”, Proc. of the 36th Winter Simulation Conference, Dec., pp. 814-819

Baruah, T. D. (2012). “Effectiveness of Social Media as a tool of communication and its potential for technology enabled connections: A micro-level study”, International Journal of Scientific and Research Publications, 2(5), 1-10

Bromwich J.E. (2017) “Port Arthur Faces Harvey Flooding Disaster: ‘Our Whole City Is Underwater’”, The New York Times, August 30

Bruzzone A.G. Tremori A., Massei M. (2011) "Adding Smart to the Mix", Modeling Simulation & Training: The International Defense Training Journal, 3, 25-27, 2011

Bruzzone A.G., Cirillo L., Longo F., Nicoletti L. 2015, Multi-disciplinary approach to disasters management in industrial plants. Simulation Series, pp. 139.

Bruzzone A.G., M. Massei, M. Agresta, S. Poggi, F. Camponeschi, M. Camponeschi (2014a). "Addressing Strategic Challenges on Mega Cities Through MS2G”. 13th International Conference on Modeling and Applied Simulation, MAS, University of Bordeaux, France Sept. 10-12

Bruzzone A.G., Massei M., Longo F., Nicoletti L., Di Matteo R., Maglione G., Agresta M., (2015). Intelligent agents & interoperable simulation for strategic decision making on multicoalition joint operations. 5th International Defense and Homeland Security Simulation Workshop, DHSS 2015, pp. 72.

Bruzzone, A. G., Manetti, E., Perletto, P. (1998) “Object-oriented documentation from simulation for civil protection & industrial plant accidents shared directly on the web”, Simulation Series, 30, pp.168-173

Floridi, L.(2014).“Open data, data protection, and group privacy”, Philosophy & Technology, 27(1), 1-3.

Garton, L., C. Haythornthwaite & B. Wellman (1997). Studying online social networks. Journal of Computer-Mediated Communication, 3(1)

Heeks, R. (2001) “Understanding e-governance for development”, Manchester: Institute for Development Policy and Management

Howard, K. W., Israfilov, R. G. (2012). “Current problems of hydrogeology in urban areas, urban agglomerates and industrial centres”, Vol. 8 Springer Science & Business Media

Janssen, M., Charalabidis, Y., Zuiderwijk, A. (2012). “Benefits, adoption barriers and myths of open data and open government. Information+ systems management”, Vol 29 (4), 258-268

Jia, J., D. Liu, J. Tang, W. Wu, S. Zhao (2008). “Lack of Urban Disaster Prevention Land and Disaster Prevention Green Field Construciton: from perspective of Wenchuan Earthquake”, City Planning Review, 7, 009

Kassen, M. (2013) “A promising phenomenon of open data: A case study of the Chicago open data project”, Government Information Quarterly, 30(4), 508-513

Kitchin, R. (2014). “The data revolution: Big data, open data, data infrastructures and their consequences”. Sage

Lankao, P. R., H. Qin, (2011). “Conceptualizing urban vulnerability to global climate and environmental change”, Current opinion in environmental sustainability, 3(3), 142-149

Leichenko, R. (2011) “Climate change and urban resilience”, Current opinion in environmental sustainability, 3(3), 164-168

Massei, M., S. Poggi, M. Agresta & A. Ferrando (2014). “Development planning based on interoperable agent driven simulation”. Journal of Computational Science, 5(3), 395-407.

Ören T., Longo F., (2008). Emergence, anticipation and multisimulation: Bases for conflict simulation. 20th European Modeling and Simulation Symposium, EMSS 2008, pp. 546.

Rimlinger, G. V. (1971) “Welfare policy and industrialization in Europe, America and Russia”, John Wiley & Sons, NYC

Rossetti, R. J., Almeida, J. E., Kokkinogenis, Z., Gonçalves, J. (2013) “Playing transportation seriously: Applications of serious games to artificial transportation systems”, IEEE Intelligent Systems, 28(4), 107-112

Schirmer, M., Leschik, S., Musolff, A. (2013). “Current research in urban hydrogeology–a review”, Advances in Water Resources, 51, 280-291

Trusov, M., R. E. Bucklin, K. Pauwels (2009). “Effects of word-of-mouth versus traditional marketing: findings from an internet social networking site”, Journal of marketing, 73(5), 90-102