MODELS & INTERACTIVE SIMULATION FOR CIVIL MILITARY INTEROPERABILITY IN HUMANITARIAN AID AND CIVIL PROTECTION

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ABSTRACT

Modelling and Simulation based on innovative approaches and solutions could support training as well operational planning in humanitarian crisis management. Armed Forces could provide great expertise in Crisis Management to Civil Protection Agencies and, at the same time, need to be trained themselves to interoperate with civil organization in Humanitarian Support Operations. This paper describes on going researches devoted to develop innovative interoperable simulation models to enhance current capabilities in this field. Authors are focusing in particular on agent based simulation, human behavioral models and interoperability among different simulators to recreate complex crisis scenarios where the population represents the main critical target of any kind of Civil Protection operations. A specific attention is devoted to analyze simulation computational workload issues.

Keywords: Intelligent Agents Computer Generated Forces (IA_CGF), Human Behavioral Models, Interoperable Simulation Crisis Management, Simulation Computational Workload

1. INTRODUCTION

Our Armed Forces, based on current situation and international agreements, are more and more involved in Humanitarian Aid and Civil Protection operations for Natural and human-made Disasters in stabilization operations and to support and help population. Such involvement is focused, for every event, on providing personnel, means and vehicles and, in particular, to provide expertise in crisis management and coordination of "joint" coalitions (that is a further issue for Civil Military Interoperability, usually due to cultural differences).

Another critical issue in terms of military skills that Armed Forces could provide (with potentially huge benefits in the area of Humanitarian Aid and Civil Protection) is the personnel training and education at all the different hierarchical levels. In this area Armed Forces usually own consolidated methodologies and tools that could be brought to Civilian Agencies: Modelling & Simulation (M&S). M&S is a critical technology that could be used for Crisis Management training.

Nevertheless there are also several gaps that must be filled to provide a really breakthrough technology and an innovative methodology for training Civil Protection by using M&S.

In particular the research described in this paper focuses on how M&S, starting from the military experience in training, should be improved to be successfully used in Humanitarian Aid and Civil Protection considering some of the most critical factors that have to be improved in current simulations (Amico et al. 2000):

- Human Behaviour Modelling: the goal in this case is to recreate realistic complex scenarios where humans are the very real target of the operations. New models must be studied and developed to reproduce population behaviour and reactions to disasters and humanitarian relief operations (Bruzzone et al. 2011,2007).
- Models Interoperability: a crisis has to be regarded as a very complex scenario; the correct recreation of such scenarios by computer simulation models requires to consider several elements (i.e. the natural events, the economical impacts, the operative issues…); this clearly compel to develop real interoperable simulation where different federated simulators are in charge of reproducing different aspects of reality in the most complete, realistic way.
- Exercises repeatability and costs control: the goal in this case is to provide real benefits to both Military Commands and Civil Authorities in joint crisis management training therefore it is required to provide tools easy to be deployed with reasonable costs. In order to solve this problem (simulation based exercises reproducing extended complex scenarios, with thousands or million of

people involved in the crisis), this project proposes the use of Computer Generated Forces based on Intelligent Agents (IA_CGF) with autonomous behaviour to reduce the staffs number involved in CAX (Computer Assisted Exercise), preparation and management and, at the same time, to rapidly study and generate new scenarios and scripts to face different kind of events.

- Usability and Users engagement: the "serious game" approach for training is growing in diffusion in the military community and there are a lot of specific areas, during a crisis, that could be reproduced by a serious game to train specific personnel capabilities

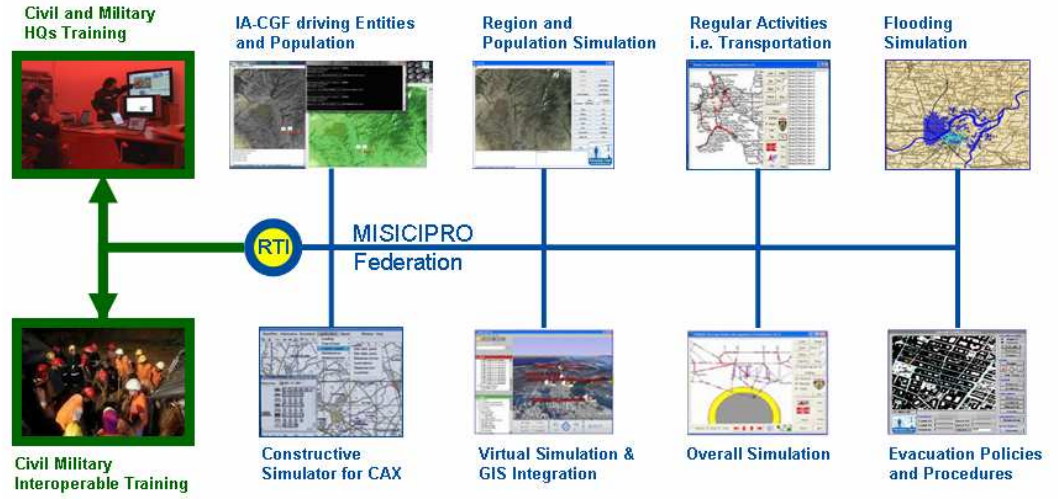

Figure 1: Sample of a Federation

There is a further area of development emerging from the results of the proposed research project: *innovative usage of M&S not only for training but also for operational planning and dynamic crisis management*. The researches described in this paper will pose the basis for the development of innovative models to be used for crisis management both in planning and execution phases. In fact we may suppose to provide different analytical supports for dynamic crisis management; in particular there are natural disasters where you can have a kind of "on-line" support from models to follow and analyze the event evolution over the time (i.e. flooding where decision makers have to predict the evolution of the scenario and to plan and coordinate interventions accordingly).

The general goal of this project is to provide a concrete support in disasters and crises management with the aim of developing a simulation that considers Civil-Military Interoperability and allows to demonstrate the results of the studies. To fulfill these goals a demonstrator will be developed during the activities. Another important concept is to create a virtual loop bringing to the Civil Protection Community the experience of the Military in Modeling and Simulation for training and to educate officers to co-operate with civilian considering the cultural and operative barriers that exits between the two communities. Accordingly to this another intent of the on-going researches described in this paper is to create a create a community involving military experts and Civil Protection personnel in training activities related to this context. This community could support in definition of innovative VV&A /Verification, Validation and Accreditation), a critical area where authors have several previous experiences (Bruzzone 2011, Tremori 2009).

2. PREVIOUS EXPERIENCES

The first step of this project is to overview the current state of the art above all in terms of ongoing research projects in other countries. Indeed we can cite several on-going activities at NATO level to explore Civil Military Interoperability. To mention one of the most important, we can cite the German experience where German Armed Forces and Federal Office of Civil Protection and Disaster Assistance (BBK) are jointly using the GESI constructive simulator (from CAE) in the BBK-owned Academy of Crisis Management, Emergency Planning and Civil Protection (AKNZ – Akademie für Krisenmanagement, Notfallplanung und Zivilschutz) in Bad Neuenahr. This project can be regarded as a good example to understand how to leverage on military experience and the starting point to provide innovative methodologies and solutions to enhance training and readiness of Civil Protection agencies.

For what concern the existing technological gap to Prof. Agostino Bruzzone's research team, in the last years, has worked on several projects to develop new computer generated forcers managed by intelligent agents (IA_CGF) (Bruzzone et al. 2011, 2010, 2009, 2008,2007) and based on human behavioral models to create complex simulated scenarios where agents act and react based on behavioral rules in an autonomous

way, considering the flowing of events and the perception of the events.

The first important project we can cite is PIOVRA (Polyfunctional Intelligent Operational Virtual Reality Agents), an European Defense Agency funded project. PIOVRA main goal was just to develop a new generation of CGF able to simulate "Intelligent" behavior. The final demonstrator based on the PIOVRA findings was used to recreate a urban scenario with civil disorders. From this project different research activities that represent solid base for the project described in this paper followed. Among the other it is necessary to cite another on-going project CAPRICORN (CIMIC And Planning Research In Complex Operational Realistic Network).

CAPRICORN project is going to be completed and it is providing final results and deliverables about the usage of agent driven simulation based on intelligent agents and Human Models to simulate Stability and Reconstruction operation, Civil Military Cooperation (CIMIC) and psychological operations (PSYOPS) where the clear final target is population and civilian.

Based on the researches in this area in 2010 the Authors worked with the US-Joint Force Command to re-create the Port O' Prince area during the 2010 Earthquake in Haiti. For that demonstration a IA_CGF Non Conventional Framework (IA_CGF NCF)developed by authors was federated with other systems (JTLS, JCATS, VBS2…) for representing the humanitarian support operation led by Coalition Forces in Haiti, and specifically in Port O'Prince. The IA_CGF NCF represented the 200.000 people population of the town before the disaster and after the operations, analyzing and representing evolution of human factors for every person in the area. The other simulators were used to re-create the different level of traditional operations, considering operative matters such as logistics or troops deployment, In this area authors have several experiences in the application of M&S also to the industrial sector and the described project could largely benefit from these works (Bruzzone 2004, Curcio&Longo 2009). This demonstrator is a very good sample of an HLA federation with different simulators specifically used to recreate different elements of the scenario and in particular with models based on Intelligent Agents to reproduce autonomous behavior of the population.

Authors have also specific competencies in modelling crisis scenarios. An important project was completed with Dartmouth College for the reproduction of a Katrina like scenario to demonstrate the possibility to model a national crisis and to simulate a wide emergency; the project successful demonstrated the simulation of an hurricane impact on the transportation layers of Louisiana state considering traffic cargo, evacuation activities, etc. Another project related to Crisis Management was PANDORA (PANdemic Dynamic Objects Reactive Agents) by a joint simulation project involving USA, European and Australian R&D Centers (DIPTEM, Dartmouth College, CRiCS).: it addressed the dynamics of the spreading of a Pandemic and experiments on H1N1 flu A virus. An evidence-based approach was used whereby statistical data (census) and ethnographic surveys were sources for the model and this was integrated with Human Factors representing the psychological and social parameters impact on people behaviors and their reaction to containment measures and policies. The models evaluated the efficacy and cost benefit of various mitigation strategies such as school closures, target anti-viral prophylaxis and other mitigation measures, level of absenteeism, and its impact on commerce, industry, economy and functioning of society as well as population attack rate, risks related to specific groups and on flows across State borders.

Another research project that should be mentioned is CIPROS (CIVIL Protection Simulator). As the name itself suggests CIPROS presented a a modular approach for Civil Protection that integrates GIS and Simulation. By the models developed during this project it was possible to generate Crisis Dynamic Web Sites for supporting training and information share. CIPROS included simulation of explosions, hazardous material fallout and flooding (Bruzzone et al. 1996).

3. THE PROJECT

To complete a general overview of this research we start from the innovative methodologies and technological enhancements the will be investigated and developed and in particular the three main pillars of the project described in this paper:

- Agent Driven Simulation and in particular based on Intelligent Agents Computer Generated Forces (IA_CGF)
- Human Behaviors Models: to provide a behavioral base for any models where the impact of humans is a critical element.
- Interoperable Simulation: and specifically such simulators will be federated under the IEEE 1516 High Level Architecture with the aim of creating a Federation of Simulators.

To provide evidence on the relevance of the approach proposed in this project, one of the first steps is the definition of the scenario to be modeled as a demonstration case study (see next paragraph). The successive step will be an accurate survey of the state of the art; the results of this survey will help in understanding which interoperable simulators from the Military area are available to support disasters and crises management with the aim of enhancing Civil-Military Interoperability. As additional step, it will be also possible to define also the demonstrators (simulators or serious games) to be developed in order to complete the above mentioned Federation. This simulator (or serious game) will provide an effective training environment with a realistic reproduction of the disaster scenario accordingly to the defined training targets.

By this project it is envisaged to provide a support to all the M&S related areas: from personnel training and education to operative analysis of different scenarios both for Defence for "Support Operations" and to support population through Civil Protection for disaster relief operations.

Needs to train such capabilities are reflected both in national standard policies for Peace Mission deployment and in specific Civil Protection Department operations. These policies will define conceptual references for the development of this project.

In particular specific operative capabilities that will be supported by this project are:

- Forecast: causes analysis to identify risks and critical areas
- Prevention: damages reduction and mitigation with a gradual improvement of population consciousness
- Relief: interventions aimed to ensure different types of assistance to populations
- Other Actions: different actions to remove obstacles and rubbles to restore normal life conditions;
- Personnel Training: military and/or civilian both collective and individual, in particular for procedures use;
- Procedures Development: development of innovative methodologies and techniques for the DMP (Decision making Process), crucial element for crisis management (Tremori 2011)

Accordingly to the above described capabilities to obtain an effective representation of complex scenarios (as required by the goal of this project), with involvement of military forces and civilians, it is required to define properly all the Political, Military, Economical, Social, Informatics and Infrastructural parameters (PMESII). Therefore models to be developed for this project shall include among the others the following characteristics:

- Entities for representing Civilian Population with related familiar and social networks
- Socio-Economic-Ethnic-Religious aspects for each entity
- Actions that could have an impact on population

4. SCENARIO AND COMPUTATIONAL ISSUES

In this paragraph we briefly summarize two of the possible scenarios that we are studying to provide an effective tool for training Civil Protection agencies and, at the same time, Armed Forces to interoperate in crisis management. A particular effort is done by authors to predict and face the different computational issues that emerge from complex scenarios where large amount of human beings are involved and, at the same time, specific incidents and all the related events has to be reproduced.

Based on previous experiences and on available simulators we could plan two kinds of exercise scenarios based on different kind of disasters: natural and manmade. In these two macro-categories we are planning to investigate and work on:

- Flooding and/or Earthquake in an highly populated area (see samples of existing models in Figure 2).
- Environmental Emergency with hazardous materials fallout.

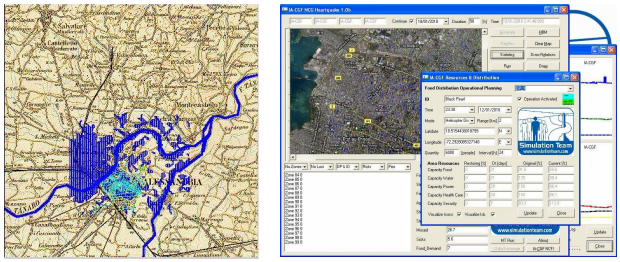

Figure 2: Sample s of existing models for Flooding and Earthquake disaster management

The above mentioned scenarios imply different problems for what concern simulators computational workload.

First of all there is the large number of people involved in the scenario and all the behavioral rules that must be considered to accurately reproduce the population. Among the different phenomena that must be considered to reproduce population behavior there are:

- The combination of Macro-Micro models to represent human behavior at social and single individual level and the combination of these two levels (Meso models).
- The parental and social relationships and networks that create counter-flow phenomena (i.e. if a family member is in the dangerous area you an agent will run towards the risky zone and against the general flow of entities running away).
- Leadership: in a group of people during any kind of event could emerge a leader: its leadership can be based on recognizable, official authority (i.e. a police officer) or on unofficial., single perception based authoritativeness (i.e. people know that on guy lives in the area and knows the places).
- Knowledge and perception of events that influence the decision of agents during the incident evolution

These and other phenomena must be consider at single agent level; in previous experiences (i.e. US Joint Force Command project for Haiti earthquake scenario) were simulated populations of over 200.000 units, considering all the relationships (parental and social), the perception and knowledge of the events, diffusion and sharing of information and other topics that influence single and, accordingly, population behavior.

For wider area, with higher number of people involved in scenario software engineering solutions will

be studied to face the exponential increasing of computational workload.

Another important kind of models that will be federated to realistically reproduce the different listed crisis scenarios are specific simulators to reproduce evolution or effects of the disaster. For the scenarios under evaluation at this stage we can see the following specific models to be federated:

- Diffusion and fall-out of hazardous materials: in previous projects such kind of simulators were developed by the authors to reproduce diffusion and fall-out over an area considering wind streams, terrain orography, buildings geometry.
- Flooding dynamics: accurate models must be developed to reproduce the evolution of a flooding and all the related effect on the terrain, transportation network, productive facilities…
- Earthquake Models: specific simulators must be used to appropriately model impact of an earthquake over a specific area. For instance are undergoing collaborations with the research centers (i.e. INGV - Istituto Nazionale di Geofisica e Vulcanologia) for federating different existing models to recreate an earthquake disaster scenario.

The above mentioned models imply severe issues for what concern computational workload there are, indeed, to be considered several elements (i.e. fluid-dynamic or structural) to obtain realistic results.

Finally we think it is important to be stressed that the above described issues imply increased complexity in time management in the Simulators HLA Federation: indeed we must consider that different models, representing different level of complexity run with different time rules (i.e. fast-time for constructive system at theater level, real-time for virtual systems and slow-time for CFD, structural or fluido-dynamic simulators).

5. PROJECT OBJECTIVES

As already highlighted in the introduction, the models developed in this project and the federation will be used, initially, for training, with the perspective to become in a further step the base to start new developments for operational planning purposes. In both cases, models and federation will have a positive impact in terms of:

- Support to Decision Makers that usually have access to partial or insufficient information.
- Reduction of time for decision making (time is usually very limited during the disaster management).
- Better use of the available resources (also resources are usually limited during the disaster management).
- Capability of considering multi-dimensional Problems involving population.
- Study and solve Simulation Computational Workload issues related to the large number of autonomous agents (i.e. population) and the characteristics and dynamics of the simulated incidents.

It is important also to underline models interoperability via the IEEE HLA standard for distributed simulation. As already mentioned disasters can be considered as very complex scenarios; the HLA choice can provide multiple benefits not only in terms of simulators interoperability, re-usability and composability but also in terms of future possible integrations (additional models to be integrated within the federation for investigating specific scenarios or recreating particular phenomena). This is the case, for instance, of flooding where specific models could be part of the HLA federation.

Furthermore, the use of interoperable simulation based on HLA provides the users with simulation available on-demand, easy share of resources among different agencies and involved offices in the Exercises or in operations planning.

6. CONCLUSIONS

We can conclude that the aim of the researches described in this paper will be to rapidly recreate different scenarios able to reproduce the constrains and the complexity of the different and elements of the scenario it self, this in terms of population behavior and impacts and evolutions of the specific simulated incident to prepare Civil and Military agencies to Crisis Management. This kind of joint training will be fundamental also considering all the cultural constraints of Civil-Military Interoperability. Furthermore the use of distributed simulation based on HLA combined with Computer Generated Forces with autonomous behavior and Intelligent Agents will allow the development of innovative solutions at reasonable costs with the proper attention to realism and fidelity.

REFERENCES

Amico Vince, Guha R., Bruzzone A.G. (2000) "Critical Issues in Simulation", Proceedings of SCSC, Vancouver, July

Avalle L, A.G. Bruzzone, F. Copello, A. Guerci, P.Bartoletti (1999) "Epidemic Diffusion Simulation Relative to Movements of a Population that Acts on the Territory: Bio-Dynamic Comments and Evaluations", Proc. of WMC99, San Francisco, January

Bocca E., Pierfederici, B.E. (2007) “Intelligent agents for moving and operating Computer Generated Forces”, Proc.of SCSC, San Diego July

Bruzzone A.G., Massei M. Tremori A., Bocca E., Madeo F., Tarone F, (2011) “CAPRICORN: Using Intelligent Agents and Interoperable Simulation for Supporting Country Reconstruction”, Proceedings of DHSS2011, Rome, Italy, September 12 -14

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., Massei M., Tremori A., Bocca E., Madeo F. (2010) "Advanced Models for Simulation of CIMIC Operations: Opportunities & Critical Issues Provided by Intelligent Agents", Proceedings of DIFESA2010, Rome, Italy, April

Bruzzone A., (2010) “Human Behaviour Modelling as a Challenge for Future Simulation R&D: Methodologies and Case Studies”, invited speech at Eurosim 2010, Prague

Bruzzone A.G., Massei M. (2010) "Intelligent Agents for Modelling Country Reconstruction Operation", Proceedings of AfricaMS 2010, Gaborone, Botswana, September 6-8

Bruzzone A., Madeo F., Tarone F., (2010) “Modelling Country Reconstruction based on Civil Military Cooperation”, Proc. of I3M2010, Fez, Oct.

Bruzzone A.G., Massei M., Tremori A., Bocca E., Madeo F. (2010) "Advanced Models for Simulation of CIMIC Operations: Opportunities & Critical Issues Provided by Intelligent Agents", Proceedings of DIFESA2010, Rome, Italy, April

Bruzzone A.G., Reverberi A., Cianci R., Bocca E., Fumagalli M.S, Ambra R. (2009) "Modeling Human Modifier Diffusion in Social Networks", Proceedings of I/ITSEC2009, Orlando, Nov-Dec

Bruzzone A.G., Frydman C., Cantice G., Massei M., Poggi S., Turi M. (2009) "Development of Advanced Models for CIMIC for Supporting Operational Planners", Proc. of I/ITSEC2009, Orlando, November 30-December 4

Bruzzone A.G., Frydman C., Tremori A. (2009) "CAPRICORN: CIMIC And Planning Research In Complex Operational Realistic Network" MISS DIPTEM Technical Report, Genoa

Bruzzone A.G., A. Tremori, M. Massei (2008) "HLA AND HUMAN BEHAVIOR MODELS" Proceedings Of MMS2008, April 14 - 17, 2008, Ottawa, Canada

Bruzzone A.G. (2008) "Intelligent Agents for Computer Generated Forces", Invited Speech at Gesi User Workshop, Wien, Italy, October 16-17

Bruzzone A.G., Scavotti A., Massei M., Tremori A. (2008) "Metamodelling for Analyzing Scenarios of Urban Crisis and Area Stabilization by Applying Intelligent Agents", Proceedings of EMSS2008, September 17-19, Campora San Giovanni (CS),Italy

Bruzzone A.G., Massei M. (2007) "Polyfunctional Intelligent Operational Virtual Reality Agent: PIOVRA Final Report", EDA Technical Report

Bruzzone A.G., Brano E., Bocca E., Massei M. (2007). Evaluation of the impact of different human factor models on industrial and business processes". SIMULATION MODELING PRACTICE AND THEORY, vol. 15, p. 199-218, ISSN: 1569-190X

Bruzzone A. G et al. (2004) "Poly-Functional Intelligent Agents For Computer Generated Forces", Proceedings of the 2004 Winter Simulation Conference Washington D.C., December

Bruzzone A.G., (2004). Preface to modeling and simulation methodologies for logistics and manufacturing optimization . SIMULATION, vol. 80 , p. 119-120 , ISSN: 0037-5497, doi: 10.1177/0037549704045812

Bruzzone A.G., Giribone P., Mosca R. (1996). Simulation of Hazardous Material Fallout for Emergency Management During Accidents. SIMULATION, vol. 66 (.6), p. 343-355, ISSN: 0037-5497Caussanel J., Frydman C., Giambiasi N., Mosca R. (2007) “State of art and future trend on CGF” Proceedings of EUROSIW2007, Santa Margherita, Italy, June

Curcio D, Longo F (2009). Inventory and Internal Logistics Management as Critical Factors Affecting the Supply Chain Performances. INTERNATIONAL JOURNAL OF SIMULATION & PROCESS MODELLING, vol. 5(4), p. 278-288, ISSN: 1740-2123

Fletcher M., (2006) “A Cognitive Agent-based Approach to Varying Behaviours in Computer Generated Forces Systems to Model Scenarios like Coalitions”, Proceedings of the IEEE Workshop on Distributed Intelligent Systems: Collective Intelligence and its Applications,

Kallmeier V., Henderson S., McGuinness B., Tuson P., Harper R., Price S. Storr J. (2001) "Towards Better Knowledge: A Fusion of Information, Technology, and Human Aspects of Command and Control", Journal of Battlefield Technology, Volume 4 Number 1.

Lichtblau, D., et al., (2004) “Influencing Ontology,” ex-tended abstract in Behavior Representation in Modeling and Simulation Conference

Rietjens S.J.H., M. Bollen, (2008) “Managing Civil-Military Cooperation”, Military Strategy and Operational Art

Nacer A., Taylor A., Parkinson G. (2007) “Comparative Analysis of Computer Generated Forces” Artificial Intelligence, Ottawa

Rehse P., (2004) “CIMIC : Concepts, Definitions and Practice”, Heft 136, Hamburg, June

Thagard, P., (2000) Coherence in Thought and Action, Cambridge, MA: MIT Press

Tremori A., Baisini C., Enkvist T., Bruzzone A.G., Nyce J. M. (2012), “Intelligent Agents and Serious Games for the development of Contextual Sensitivity”, Proceedings of AHFE 2012, San Francisco, US, July

Tremori A., Bocca E., Tarone F., Longo F., Poggi S. (2009)"Early Testing Procedures For Supporting Validation Of Intelligent Agents For Simulating Human Behavior In Urban Riots", Proceedings of MAS2009, Tenerife, September