INTELLIGENT AGENTS & INTEROPERABLE SIMULATION FOR STRATEGIC DECISION MAKING ON MULTICOALITION JOINT OPERATIONS

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ABSTRACT

This paper proposes an innovative interoperable federation developed for addressing strategic decision making on multi-coalition operations. The proposed architecture integrates several different simulators in HLA and is open to be operated in different modes from stand alone basic installation to fully integrated with entity based simulations. The simulator uses Intelligent Agents to reproduce human behavior and human factors as well as discrete event simulation paradigm into virtual and constructive environment.
The paper describes the models as well as the approach to address the problem; some experimental results related a realistic scenario are proposed as well as the different a solutions adopted to support Commander engagement in using this kind of simulation.

Keywords: *Intelligent Agents, Human Factors, High Level Architecture, Multi-coalitions, Joint Operations*

INTRODUCTION

Currently most of existing humanitarian and normalization operations are carried out by international organization; in facts today most of the military operations carried out overseas have to face interaction with civilians in different roles, such as refugees, immigrants, internally displaced persons, etc. (Main 2009; Bruzzone, Sokolowski 2012); the dimension of the situations to be addressed as well as the socio cultural economic context are normally so big that it is pretty common to operate by multi coalition with specific goals and interests that interact in the same area by involving entities such as United Nations, NATO, EU, Nations (e.g. Russia, China), Red Cross, Red Crescent Moon etc.
In these context the human factors are often the main aspects as happen in recent scenarios such as Lybia, Afghanistan, Syria (Johnson et al. 2008, Bellamy & Williams 2011; Dewachi et al. 2014). For instance the HBM (Human behavior modifiers) that include fear, fatigue, stress, aggressiveness as well as need for food, water, health care and security strongly influence the behavior of both military forces (including also opposing force) and population both locally and domestically (Gartner & Segura 2008; Kreps 2010; Bruzzone et al. 2013b). The rational and emotional behavior of the people within the scenario is another crucial (Bruzzone et al. 2011a). Examples from operations in different cases from piracy to CIMIC, from country reconstruction to Disaster Relief confirms that the use of simulation integrated with human behavioral models is key issues for proper decision making (Bruzzone et al.2010, 2011b). Simulation Team developed since 2001 intelligent agents to be used to address these issues; in particular IA-CGF (Intelligent Agents Computer Generated Forces) has been successfully applied over a wide spectrum of applications and tailored for different socio-cultural frameworks (Bruzzone 2013a). So they have been used just to address specifically multi-coalition joint operation and to create an interoperable simulation over this mission environment as done for other cases (Bruzzone et al. 2012).
Due to these reason the creation of interoperable simulation integrating all these elements represents an important achievements for supporting decision making on issues related to human factors withincomplex scenarios.
The authors propose here these models in relation to project devoted to create a simulator for immersing a Commander in a comprehensive scenario where human factors are decisive (Bruzzone et al. 2014a).
The research is related to SIMCJOH (Simulation of Multi Coalition Joint Operations involving Human Modeling) project that was developed under coordination of Simulation Team, DIME, Genoa University in cooperation with CAE, Cal-Tek, MAST, MSC-LES University of Calabria and Selex (Bruzzone et al. 2014a).

Fig. 1 SIMCJOH_VIS Main Window. Presents the situation and the events to the User and all major commands

This paper focuses on the SIMCJOH federation and in particular on SIMCJOH VIS (Virtual Interoperable Simulator) and SIMCJOH VIC (Virtual Interoperable Commander) that are the two main simulator developed by simulation team for directing the simulation and managing the human factors.

1. DEALING WITH OPERATIONS AFFECTED BY HUMAN FACTORS: SIMULATION AS ENABLING SOLUTION

To model complex operations involving population and human factors is a challenge and requires the tailoring of HBM for the specific scenario; indeed in this case the mission environment is related to SIMCJOH project; therefore the authors had experience in modeling M&S in many different regions as well as in Middle East context already (Bruzzone et al. 2014a); SIMCJOH was devoted to carry out R&D activities with the aim of understanding at which extent interoperable simulators are effective and efficient within a multi-coalition context for supporting the Commander and his Staff to in addressing and solving specific problems strongly dependent on human factors.
Indeed Modeling & Simulation (M&S) makes possible recreating complex scenarios and carrying out what-if analyses with the aim of evaluating the effectiveness of several alternatives (Course of Actions, COAs). By this approach it is possible to develop training aids and even briefing supports able to immerse the Commander and his Staff into a virtual scenario driven by the Intelligent Agents (IA) that evolves dynamically and react to the decisions and actions in real time or fast time.
For this purpose SIMCJOH was developed as an interoperable Federation able to operates in multiple modes; for instance SIMCJOH could run in stand-alone mode for being used simply and quickly by the Commander on his own laptop to improve effectiveness of briefings when he is assigned to a new command and/or in a new geopolitical area. As alternative SIMCJOH could be fully federated through HLA (High Level Architecture) integrating entity level simulation, scenario generators, communication networks, C2; in this case SIMCJOH could be a dynamic element of a CAX (Computer Assisted Exercise) and introduce strategic issues and human factors within a large scenario. SIMCJOH adopt the innovative paradigm MS2G (Modeling, interoperable Simulation and Serious Game) for guarantee easy distribution of the simulator; indeed in this case the main simulator is able to interact through the web and it could even run within a browser (Bruzzone et al.2014b).
Such concepts benefit of previous experiences in web based simulation (Bruzzone et al. 2008, 2009a, 2009b); these SIMCJOH_VIC indeed is a serious game devoted to immerse the Commander into a 3D environment synchronized with SIMCJOH_VIS Scenario evolution and able to provide also video stream from drone point of view; this approach allows to overpass traditional serious games and to adopt new uses for these applications such as crowdsourcing and virtual experiencing complex systems (Rayburn 2012; Tremori et al. 2014)

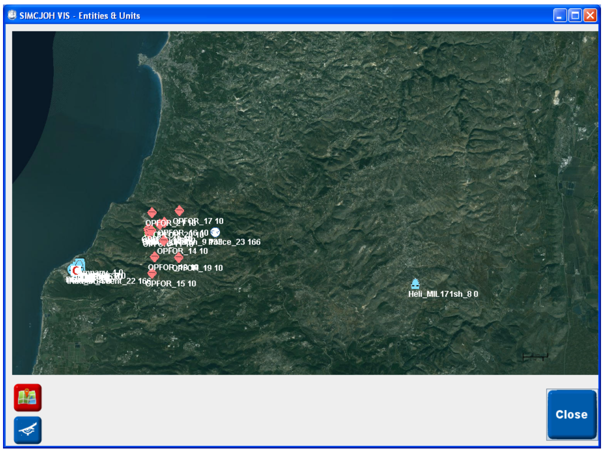

Fig. 2: SIMCJOH VIS Tactical Representation Window

2. VIRTUAL INTEROPERABLE SIMULATOR

The authors developed, for the above described application case, an innovative model defined SIMCJOH_VIS (Virtual Interoperable Simulator) which adopts stochastic discrete event simulation to generate simulation events, human behavior models, population reactions, unity actions and conditions that are shared over SIMCJOH federation.
SIMCJOH_VIS simulator in a specific NCF (Non Conventional Framework) of IA-CGF (Intelligent Agent –Computer Generated Forces) which drives the units and active entities within SIMCJOH federation. This simulator is in charge of reproducing emotional, rational and social behaviors of entities and units and, even, to interact with the Virtual Assistants that are reproducing virtually his staff. Indeed the Virtual Assistants are proactive IA proposing to the Commander problems and open issues, as well as possible solutions in terms of alternative COA; these IA execute Commander's decision; in addition to that they actively react to Commander requests.

Fig. 3: SIMCJOH_VIS Popup

These processes are simulated considering stochastic time and resources required to identify the problem, prepare the alternatives and present them to the Commander as well as to assign operational orders.
Most of the events generated and managed by SIMCJOH_VIS are presented by other federates (e.g. tactical situation, C2 representation, virtual immersive 3D environment), therefore to support easy quick stand alone mode SIMCJOH_VIS proposes also its own intuitive dynamic graphics (see figure 1); in this case the crisis representation as well as boundary conditions (e.g. daylight, sensor view, population status) as well all the events are proposed; events are represented as pop up while also a sequential storyline is generated stochastically in consistency by the simulator during the evolutions of the events.

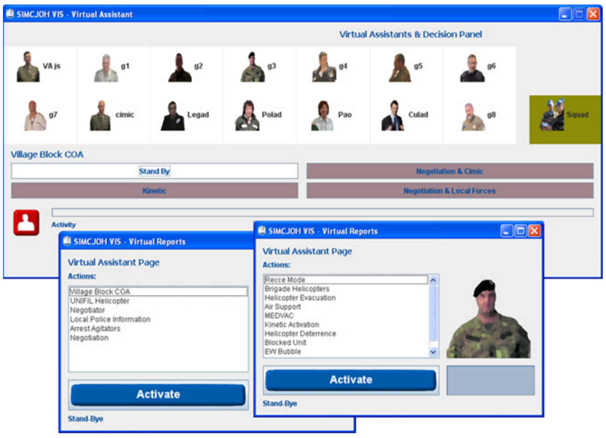

Fig. 4: SIMCJOH_VIS Virtual Assistants

3. SIMCJOH_VIS FEATURES

SIMCJOH_VIS includes Entity Simulation Models and it allows to simulate different kind of entities and units; these entities could be represented over a very basic tactical framework within SIMCJOH_VIS even if tactical and virtual representations are supported by other simulators federated within SIMCJOH Federation in HLA. SIMCJOH_VIS considers the use of entities for many different assignments including “force to force” actions; therefore these agents drives also other entities such as paramilitary units, ambulance and NGO, demonstrations etc. The simulated entities are characterized by several information including among the others. Indeed Figure 2 presents a very basic tactical representation of the on-going situation.

Fig. 5: Graphic Dynamic Representation

In figure 3 are reported examples of two Pop-up generated dynamically by SIMCJOH_VIS during the Simulation (corresponding to info distributed over HLA).
In figure 4 is shown the Virtual Assistant. It is possible to interact with the VA through the SIMCJOH_VIS Virtual Report and then, eventually, to decide about any current issue.

4. HUMAN BEHAVIOR MODIFIERS

As shown in figure 5, SIMCJOH_VIS proposes the dynamic evolution of HBM (Human Behavior Modifiers) along each simulation run; these objects proposed corresponds to the main human factors and how they are controlled by IA-CGF; similar events are proposing also decisions, actions and emerging behaviors.
In figure 6 in the upper part the graph proposes the different variables as ball elements; these include from left to right:
Fatigue - Fear - Stress - Aggressiveness - Hostility - Deterrence - Local Trustiness - Domestic Opinion - Demonstration Size

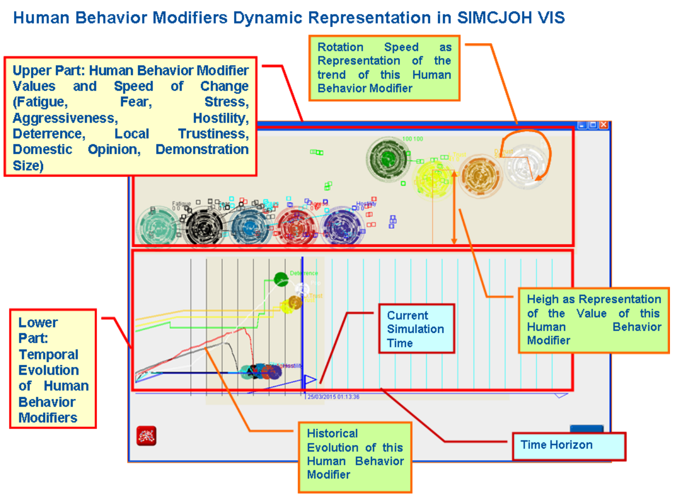

Fig. 6: HBM Dynamic Representation

Each ball element rotates based on their change rate and moves up and down based on their intensity; the value are pure numbers corresponding to a relative scale going from zero to 100 for Fatigue, Fear, Stress, Aggressiveness, Hostility; the relative scale used moves from minus 100 to plus 100 for Deterrence, Local Trustiness, Domestic Opinion in terms of positive and negative deterrence respect opposite size; Demonstration Size is scaled between zero to 1000 people.
Small Squares are generated and moved, in this figure, toward these different Human Behavior Modifiers (e.g. stress, fatigue, etc); each of this square represents an event or action that is increasing/decrease these modifiers. Vice versa, in the lower part of the window the graph presents the same factors as balls, but it reproduce their behavior in terms of temporal evolution along simulation time horizon as well as their trends; this support the users in understanding the situation evolution as well as in identifying the critical changes in population behavior corresponding to crucial events and effects of decisions. Temporal evolution of target function is also available (ASCII file in format CSM).

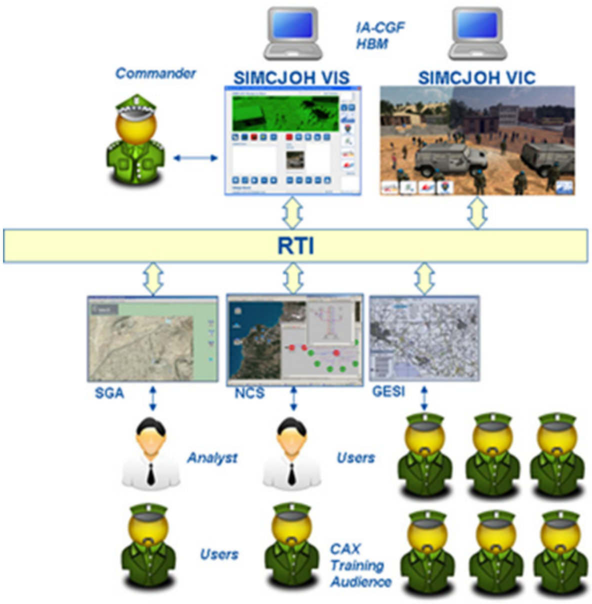

Fig. 7a: SIMCJOH Federation in full operative mode for CAX

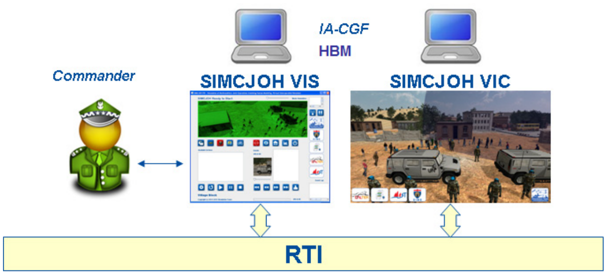

Fig. 7b: SIMCJOH VIS and VIC federated locally (e.g. same machine)

5. HIGH LEVEL ARCHITECTURE

SIMCJOH_VIS operates as main element of SIMCJOH Federation and drives the whole scenario evolution; currently it was tested operating with Pitch and Mak, but also portico was tested; SIMCJOH_VIS is operating mostly in Windows environments even if testing were conducted on Linux and Mac. The SIMCJOH architecture is proposed in figures 7a and 7b.
The propose simulator allows to change the configuration to allow proper initial setting in reference to eventual limitation of other federates,
HLA Configuration for this simulator includes:

- Federate Name
- Federation Name to Join
- RTI Engine to be used, currently supporting Mäk, Pitch and Portico
- IP Address
- Port Number
- Synchronization Point Mode and Number of Federates to wait as well as Synchronization Object Name
- Date and Time to use as offset for Simulation in HLA mode

In order to guarantee the interoperability amond the different simulators, it was introduced a specific interaction defined as PlayerMessage to be made available in SIMCJOH format and in JSON (JavaScript Object Notation) format.
Both formats could be activated concurrently generating in HLA multiple messages for same event.
SIMCJOH_VIS includes other possible elements devoted to change Simulation Setup through the following variables:

- Duration of the Simulation [h]
- Offset that represent the starting time and date for the simulation in standalone mode.

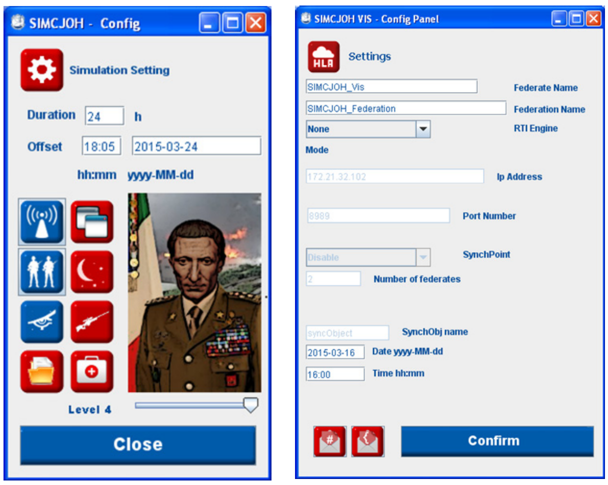

Fig. 8: Simulation Setup and HLA Configuration

6. SCENARIO

The context for testing SIMCJOH is identified in Middle East area over an hypothetical country named Eblanon where United Nation (UN) are active by a multi-coalition mission; the case study address the Commander of an Italian army Brigade that is responsible an area; the scenario includes events that, despite their small entity, have strategic relevance for the contingent and the multicoalitions; in this paper is proposed the case that a squad is blocked into a village and requested by civilians to surrender their weapons; considering the UN mandate and ROE it is evident the critical impact of such decision; the simulator regulates this scenario adding many possible elements such as presence of domestic or local media, mobile coordination, presence under coverage of insurgents and or snipes, possibility to access the area by helicoters, previous CIMIC in the village and their success, etc.
Baseed on this scenario and on available resources the Commander could decide different courses of actions , eventually tailoring them, while the IA driving his staff (e.g. J2, J3, CULAD, POLAD, PAO etc.) support his decisions and direct the simulation evolution as well as the IA ruling other parties (e.g. population, local authority, religious authorities, bordering countries, insurgents, etc.). The nature of this area of Middle East is pretty interesting considering the large difference of ethnics, religion, social status, education, etc. In addition to these elements the presence of different players (e.g. Local Authorities, Health Care, Red Crescent Moon, Other Coalition Partners having specific equipment, etc) forces the Commander to understand the correlations among different actotrs.

7. EXPERIMENTAL ANALISYS

SIMCJOH_VIS was subjected to formal, informal and dynamic VV&T (Verification, Validation and Testing); the model was presented and discussed with military experts involved in the specific scenario used for the experimentation; in addition the data collected by multiple simulation runs were used within ANOVA (Analysis of Variance) by applying Design of Experiments (Montgomery 2008). In facts, the SIMCJOH experimentation is focusing on identifying the behaviors of target functions mapped by the simulator; this analysis represent an example of how Design of Experiments and Sensitivity Analysis allows to evaluate the impact of the independent variables on the target functions.
Concerning with the experimentation execution and the simulation results, an example of techniques and methodologies to be used for studying results consistency has been provided. In particular Mean Square pure and Sensitivity Analysis are carried out for the different alternatives..
The analysis of MSpE (Mean Square pure Error) is a consolidate techniques supporting ANOVA both in terminating and steady state simulations; indeed MSpE measures the variance of the target functions among replicated runs over the same boundary conditions; by this approach it becomes possible to identify the number of replications and the simulation duration able to guarantee a desired level of precision; MSpE values in correspondence of these experimental parameters determines the amplitude of the related confidence bands. Vice versa Sensitivity Analysis allows to identify the influence of different parameters or choices respect specific target functions; for sensitivity analysis hereafter are synthetized the main alternative COAs:

- ***Stand By***: The Commander requests to wait for further evolution
- ***Negotiation & CIMIC***: Using CIMIC and previous activities in the area to negotiate with locals about stopping the crisis
- ***Kinetic***: The Commander request to prepare military units in stand by and to force the demonstrator to desist by applying controlled deterrence
- ***Negotiation and Local Forces***: The Commander requires support from Local Police Authorities for negotiating with the population and solving the problem.

$$MSpE\ (t,\ n_0) = \frac{\sum_{i=1}^{n_0} x_i(t) - \bar{x}(t)}{n_0} \qquad \bar{x}(t) = \frac{\sum_{i=1}^{n_0} x_i(t)}{n_0}$$

t simulation time
no number of replications with same boundary conditions and different random seeds
MspE (t,no,) Mean Square pure Error at t time

In fact the MSpE allows to quantify the experimental error due to influence of the stochastic components respect the required replications or durations for obtaining a stabilization; so by this approach it becomes possible to estimate the confidence bands on the different target functions. For instance, considering the Aggressiveness Level of Population related to the 4 different commander decisions, the MSpE (Mean Square pure Error) was computed by carrying out replicated runs over the same boundary conditions.

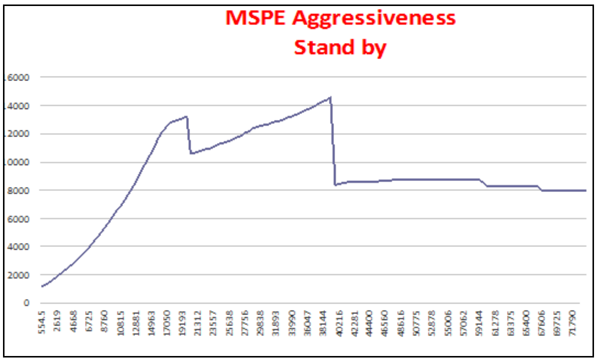

Fig. 9: Decision to Stand By during the Crisis– Stand By

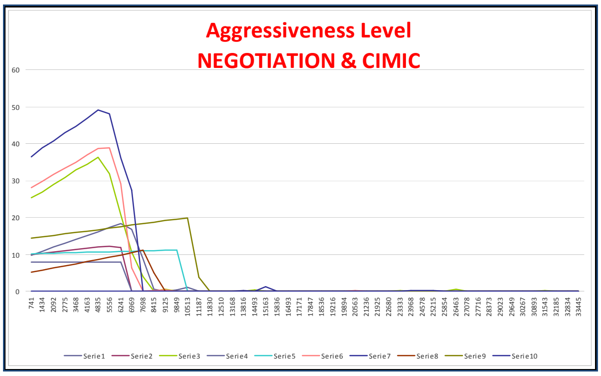

Fig.10: Option 1 – Negotiation & CIMIC: Results of Different Runs

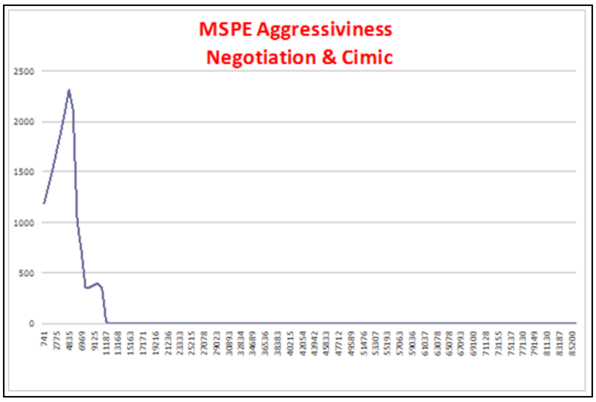

Fig. 11: Option 1 – Negotiation & CIMIC - MSpE

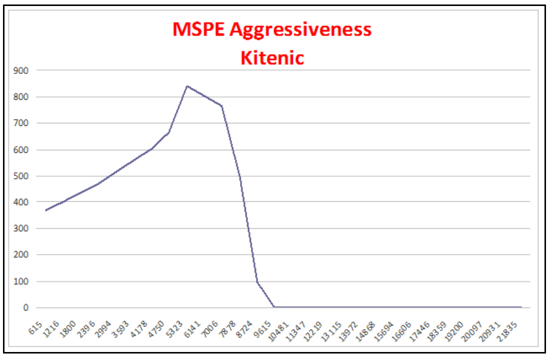

Fig. 12: Option 2 – Kinetic MSpE

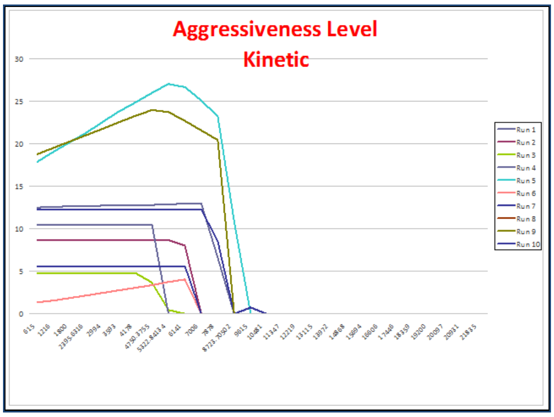

Fig. 13: Option 2 – Kinetic Replicated Runs

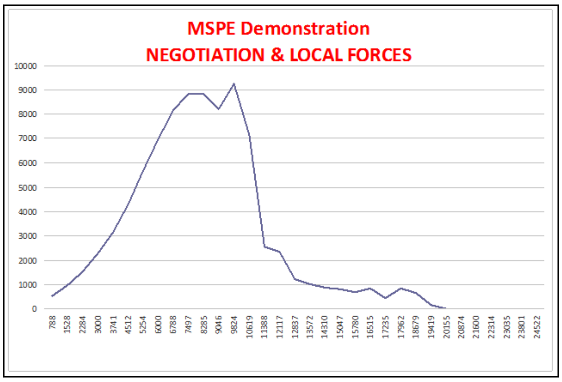

Fig. 14: Option 3 – Negotiation & Local Forces MSpE

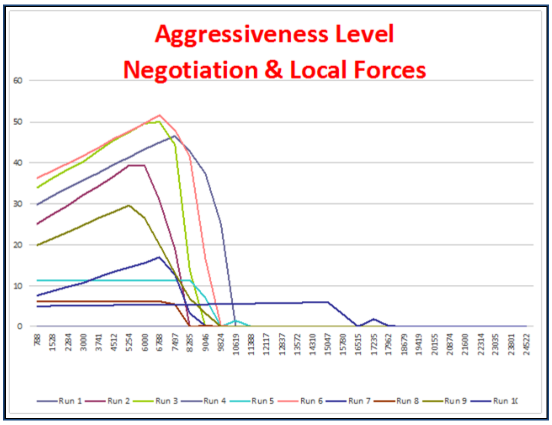

Fig.15: Option 3 – Negotiation & Local Forces Replicated Runs

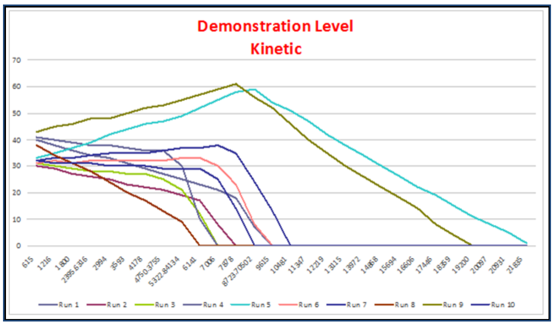

Fig. 16: Option 2 - Kinetics different End States - Number of Demonstration

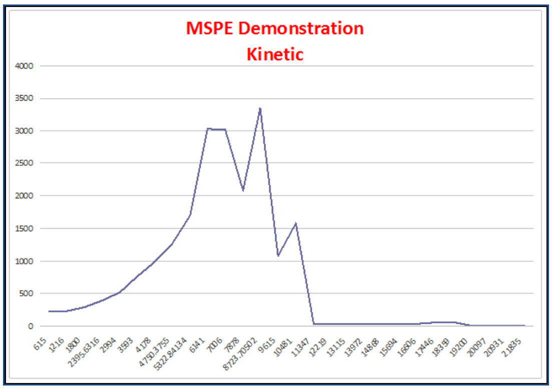

Fig. 17: Option 2 - MSpE among Converging Runs

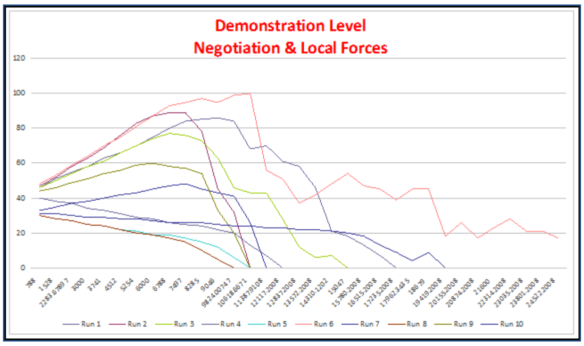

Fig. 18: Option 3 - Negotiation and Local Forces - Number of Demonstration

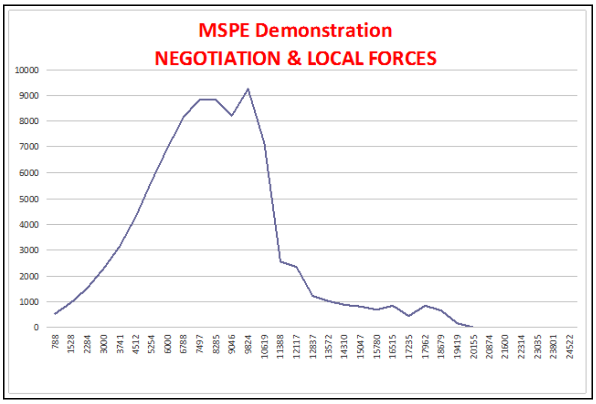

Fig.19: Option 3 - Negotiation & Local Forces - Number of Demonstration MSpE

In following figures multiple runs are compared for the different evolution of this scenario; different end states could be approached during the simulation due to stochastic components therefore final achievements results consistent based on MSpE.
A further analysis has been conducted by measuring the Number of demonstrators during the simulation considering the four different possible Commander decision respect the main COA to be adopted during the game. The result of the MSpE considering 10 replicated runs is proposed into the attached figures.
By applying Design of Experiments it was completed a set of experimental tests for evaluating the influence of the independent variables respect the target functions; this Sensitivity Analysis is synthesized in last figures 20a and 20b where the main alternative COAs are compared respect target function.
SIMCJOH_VIS was extensively tested federated with SIMCJOH_VIC and with other HLA Federates within SIMCJOH Federation including among the others: GESI, SGA, SC and its overall target functions are proposed in terms of temporal as reported (see fig 7)

CONCLUSION

SIMCJOH_VIS (Interoperable Virtual Simulator) represents an important opportunity to create new dynamic scenarios for different applications: preparation and briefings related to new environmental conditions (immersion in new scenarios), training on the comprehensive approach, training, etc.

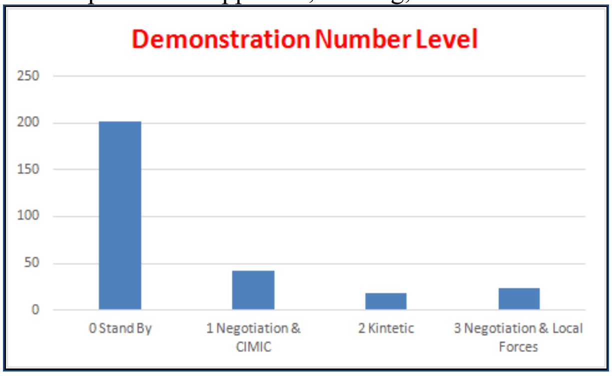

Fig.20a: Sensitivity of the Main Decision on Demonstration Average Size

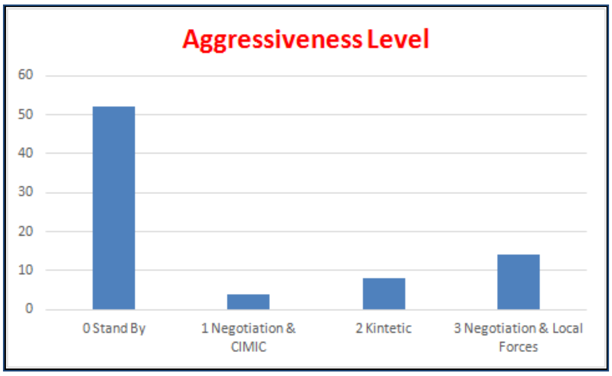

Fig.20b: Sensitivity of the Main Decision on Aggressiveness Level

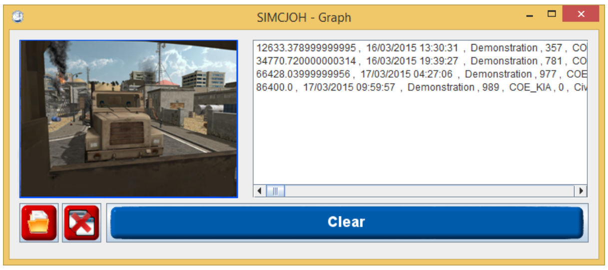

Fig. 21: Target Function Report

The human models of SIMCJOH_VIS could be integrated with other scenarios, missions and operations where these aspects are important and may interact with other models and simulators. In fact the SIMCHJOH_VIS is built for validating and experiencing the potential of a new generation of MS2G (modeling, simulation interoperable and Serious Games) able to use human behavioral patterns (HBM) and ensure interoperability with other simulators to recreate complex scenarios. Indeed SIMCJOH_VIS is also further developable to create a system for training able to reproduce case studies and to provide an interactive environment to understand reactions and human factors related to decisions and events. The authors re currently working to develop new actions and mission environments based on this approach and are planning to use SIMCJOH within existing CAX

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REFERENCES

Bellamy, A. J., & Williams, P. D. (2011). The new politics of protection? Côte d'Ivoire, Libya and the responsibility to protect. International Affairs, 87(4), 825-850

Bruzzone A.G., Tremori A., Cunha G. (2008) “Intelligence and Security as Framework for Applying Serious Games”, Proceedings of SeriGamex 2008, November, Rome

Bruzzone, A., Tremori, A., & Massei, M. (2009a). Serious games for training and education on defense against terrorism. Genoa Univ, Italy

Bruzzone A.G., Cunha G., Elfrey P., Tremori A. (2009b) "Simulation for education in resource management in homeland security", Proceedings of SCSC, Istabul, July.

Bruzzone, A. G., & Massei, M. (2010). Intelligent agents for modelling country reconstruction operation. In Proceedings of the Third IASTED African Conference (Vol. 685, No. 052, p. 34).

Bruzzone, A. G., Tremori, A., Tarone, F., & Madeo, F. (2011a). Intelligent agents driving computer generated forces for simulating human behaviour in urban riots. International Journal of Simulation and Process Modelling, 6(4), 308-316.

Bruzzone, A.G., Tremori, A., Massei, M., (2011b), “Adding Smart to the Mix,” Modeling, Simulation & Training: the International Defence Training Journal, 3, 25-27

Bruzzone A., Sokolowski J. (2012) "Internally Displaced Persons (IDPs), Refugees & Immigrants as Agents and Models for Simulation Scenarios", Proceedings of 7th NATO CAX Forum, Rome, Italy

Bruzzone A.G., Buck W,. Longo F., Sokolowski J., and Sottilare R. (2012).The International Defense and Homeland Security Simulation Workshop 2012, Vienna, Austria, September 19-21, DIPTEM Universita’ di Genova, 6-12

Bruzzone, A. G. (2013a). Intelligent agent-based simulation for supporting operational planning in country reconstruction. International Journal of Simulation and Process Modelling, 8(2-3), 145-159.

Bruzzone A.G., Tremori A., Sokolowski J., Banks C., Longo F., Casapietra A., Corso M., Ferrando A., Porro P., Dell’Acqua F (2013b) "Innovative Models for Multi-Coalition Management", Proceedings of WAMS, Buenos Aires, Argentina, November

Bruzzone A.G., Massei, M., Longo, F., Poggi, S., Agresta, M., Bartolucci, C., & Nicoletti, L. (2014a, April). Human behavior simulation for complex scenarios based on intelligent agents. In Proceedings of the 2014 Annual Simulation Symposium, SCS

Bruzzone A.G., Massei M., Tremori A., Longo F., Nicoletti L., Poggi S., Bartolucci C., Picco E., Poggio G. (2014b) "MS2G: simulation as a service for data mining and crowd sourcing in vulnerability reduction", Proceedings of WAMS, Istanbul, September

Dewachi, O., Skelton, M., Nguyen, V. K., Fouad, F. M., Sitta, G. A., Maasri, Z., & Giacaman, R. (2014). Changing therapeutic geographies of the Iraqi and Syrian wars. The Lancet, 383(9915), 449-457.

Gartner, S. S., & Segura, G. M. (2008). All politics are still local: The Iraq War and the 2006 midterm elections. PS: Political Science & Politics, 41(01), 95-100.

Johnson, T. H., & Mason, M. C. (2008). Understanding the Taliban and insurgency in Afghanistan. Orbis, 51(1), 71-89.

Kreps, S. (2010). Elite Consensus as a Determinant of Alliance Cohesion: Why Public Opinion Hardly Matters for NATO-led Operations in Afghanistan. Foreign policy analysis, 6(3), 191-215.

Main, F. S. (2009). Psychological operations support to strategic communications in Afghanistan. Army War Coll. Carlisle Barracks PA.

Montgomery, D. C. (2008). Design and analysis of experiments. John Wiley & Sons, NYC

Raybourn, E.M. 2012. Beyond serious games: Transmedia for more effective training & education, Proc. DHSS2012, Rome, Italy

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