HUMAN FACTORS' SIMULATION MODELS MILITARY RELEVANCE

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ABSTRACT

Over the last two decades, military forces have been deployed to areas where the history, culture, language, religious and tribal or family dynamics have played a key role in shaping military operations. In 2010, the revision of NATO strategic concept triggered a new cycle of the NATO Defence Planning Process, which identified the need for an efficient co-ordination of the Human Environment activities as one of the most critical capability shortfall for every mission type.

This year, the University of Genoa (ITA) started, in conjunction with an industrial consortium and with the support of NATO M&S Centre of Excellence, a research programme aimed at developing for the Italian Defence new simulation models, that take into account human factors (i.e.: culture, jeopardy, fear, aggression, etc.) in order to support the military decision makers in Theater of Operations. This new tool should significantly contribute to fill in the NATO capability gap.

Keywords: human factor, NATO operations, joint communication, cross-cultural awareness

1. INTRODUCTION

The focus of this paper is the relevance of human factors in modern military operations. Subsequent sections describe the impact of human factors on the accomplishment of the overall mission in a military operation, the need to develop a capability to efficiently manage the Human Environment activities and a Modelling & Simulation research programme that can support this capability development.

The present paper compares the capability need identified by the military side with the technological support that Modelling & Simulation can provide, highlighting the existing supply/demand relationship in the Modelling & Simulation marketplace. Since this paper is produced with the contribution of the NATO Modelling & Simulation Centre of Excellence in Rome (ITA), the area of investigation is very wide and rises up to the NATO alliance perspective, taking into account also specific studies conducted by single Nations.

2. HUMAN FACTORS IN MILITARY OPERATIONS

After the fall of Berlin Wall, the use of the military shifted away from the conventional confrontation of the Cold War model towards the numerous humanitarian and peacekeeping interventions of the 1990s. In 1992, the Petersberg Declaration of the Council of Ministers of the Western European Union incorporated within the European Security and Defence Policy a list of military tasks having a humanitarian nature, formulated as:

- "humanitarian and rescue tasks;
- peacekeeping tasks;
- tasks of combat forces in crisis management, including peacemaking." (WEU 1992)

In 2001, "the events of a single day, September 11, altered the trajectory of the US and the way it used its military over the next decade. A national strategy that had focused on countering regional aggressors and sophisticated attacks using weapons of mass destruction (WMD) was now confronted by an enemy that attacked the homeland with low technology in asymmetric and unexpected ways—individuals armed with box-cutters using hijacked civilian aircraft.

In the decade following 9/11, it became evident that the Cold War model that had guided foreign policy for the previous 50 years no longer fit the emerging global environment.

Key changes included:

- A shift from US hegemony toward national pluralism
- The erosion of sovereignty and the impact of weak states
- The empowerment of small groups or individuals
- An increasing need to fight and win in the information domain

In the midst of these changes, the US employed its military in a wide range of operations to address perceived threats from both nation-state and terrorist groups; to strengthen partner nation militaries; to conduct humanitarian assistance operations; and to provide defense support of civil authorities in

catastrophic incidents such as Hurricane Katrina." (JCOA 2012)

It is therefore evident that, over the last two decades, both America and Europe changed their priorities and policies in the use of military, taking more in consideration the human aspects of military operations. The change of the geopolitical situation and the rise of new asymmetric threats triggered new military strategies that now have to understand the psychological, social and cultural reasons of a threat and vice versa the emotional impact of a military operation on civilians' perceptions.

This change on military strategies forced NATO to review its Strategic Concept in 2010. The new NATO Strategic Concept emphasizes the need to fight not only conventional threats, but also new ones like "extremism, terrorism, and trans-national illegal activities" and to foster security through the conflict prevention and crisis management. "The lessons learned from NATO operations, in particular in Afghanistan and the Western Balkans, make it clear that a comprehensive political, civilian and military approach is necessary for effective crisis management" (NATO Strategic Concept 2010). These statements triggered a new cycle of the NATO Defence Planning Process (NDPP) and posed the basis for new concepts like Comprehensive Approach, Cross-Cultural Awareness and Understand to Prevent.

Figure 1: NATO Defence Planning Process

3. CAPABILITY DEMAND

The NDPP is the five-step process – generally sequential and cyclical in nature – that NATO adopted since June 2008 in order to improve the necessary capabilities to initiate, sustain and successfully conclude its operations. Moving from the Strategic Concept, the NDPP establishes a single top level political guidance that provides objectives to be met by the Alliance planning. From the comparison between the capabilities needed to meet those objectives and the capabilities already existing, the process identifies the gaps that need to be filled in.

One of the most critical capability shortfall identified by the last cycle of the process is indeed the need for an efficient co-ordination of the Human Environment activities. To do that, first of all it is important to understand the human environment, and then to be able to efficiently engage it. "The operational environment encompasses not only the threat but also the physical, informational, social, cultural, religious, and economic elements of the environment. Each of these elements was important to understanding the root causes of conflicts, developing an appropriate approach, and anticipating second-order effects." (JCOA 2012) Examples of failure in understanding the human environment are: ignore early signs of an insurgency, ignore tribal and cultural historical preferences, "causing the population to lose trust in the coalition" "and allowing terrorist and criminal elements to thrive." (JCOA 2012). These failures, therefore, can affect the "effectiveness in countering asymmetric and irregular threats from insurgencies and mitigating terrorist and criminal influences." (JCOA 2012). This enforces the importance of the concept of Understand to Prevent in order to face the new threats identified by the NATO Strategic Concept. "Threats in this new environment become diffuse, abstract and uncertain. Their identification, isolation and suppression are increasingly complicated since adversaries blend into the population, which hampers countering the threat and preventing collateral damage or unsought effects. Therefore, in current operational environments the population (the human factor) becomes a key element to take into consideration as far as military planning and conduct of operations are concerned." (MNE 6)

"It is paramount to know and understand the local culture," "so as to comprehend the dynamics and causes of local behaviors, attitudes and emotions, to be ultimately able to predict further reactions. Moreover, in these contexts it is also crucial to be cognizant of how the Coalition Forces' culture is perceived by the local population/actors in Theatre." "Consequently, culture is to be analyzed and incorporated in the different elements and features in which it can be broken down", "such as the physical – geography, social dynamics, economy and political situation but putting special emphasis on those sensitive and touchy factors more operationally relevant depending on the scenario. Gender, honor and revenge are among them." (MNE 6)

So, understanding the human environment goes through the awareness of cultural differences. A multinational experiment, conducted by a group of NATO Nations led by Spain (Multinational Experiment 6), developed the Concept of Cross-Cultural Awareness (CCA), analyzing the culture from an anthropological point of view, studying the psychosocial and psychological factors of culture and showing the results of a research that "focused on the perceptions of the most conflicting cultural factors affecting the relations between the militaries and local populations" (MNE 6 2010). This resulted in a number of recommendations, methodologies and conclusions for the implementation of CCA with regards to military operations.


Figure 2: Perception of militaries in the local population

CCA seeks to apply the Comprehensive Approach to current operations. "According to this approach, military forces become a contributor (probably the most important one at some stages but in a supporting role at some others) in the resolution of a conflict along with national and multinational government agencies, international and intergovernmental organizations, non-governmental organizations and the private sector. Furthermore, particularly against irregular adversaries and non-compliant actors, local (host nation) authorities, traditional leaders, military and security forces are to be acknowledged as an essential component for success." (MNE 6 2010)
Understanding the human environment is a key element for an effective planning and conduct of military operations. An efficient co-ordination of the human environment activities and their effective engagement are strongly affected by the perceptions of the most conflicting cultural factors in the local population. The second important aspect of the identified capability shortfall is, therefore, the engagement of the human environment through actions that influence positively those perceptions. An important example is the strategic communication, the so called "battle for the narrative in achieving objectives at all levels" "by influencing perceptions on a local or global scale" (JCOA 2012). The correct use of strategic communication or the decision to take actions that might influence positively perceptions in the local population are key for the accomplishment of the overall mission in a military operation.

The next step of NDPP is to setup a course of actions aimed at developing the human factors' capability described above, according to the NATO requirements. The course of actions will be apportioned to Nations, either individually, multi-nationally or collectively, and targets assigned for capability development for the subsequent implementation.

A possible target might be set to develop a capability aimed at training or supporting decision makers in Theater of Operations through the Understanding of Human Factors to Prevent, the Cross-Cultural Awareness, the use of Comprehensive Approach. With this respect, there is a need for a tool able to train or support decision makers and shape operations in accordance to the capability demand depicted above. Modelling & Simulation can be a cost-effective provider of this tool, by the creation of a simulation model that takes into account also Human Factors in the simulation tool actually used for training, decision support and experimentation (Bruzzone et al. 2004; Bruzzone, Longo, Merkuryev, Piera 2007; Frydman et al. 2009).

4. MODELLING & SIMULATION SUPPLY

Agent Based and Human Behavior Models - State of Art

Modelling human behavior requires an extensively interdisciplinary approach with the involvement of psychologists, anthropologists, sociologists, economists, medics and, of course, engineers and M&S experts. Putting human beings at the center of simulated systems is really very challenging but very important since people are the key element in several situations to analyze industrial, safety, security, military issues and many others areas. For these reasons, in the last 15 years a huge bibliography of publications and research works have been produced and provided the basis for technologies to model human behavior, that can supply the capability demand depicted above.

The paper "Crowd Modelling and Simulation Technologies" written in 2010 (Chen et al.), provides an interesting assessment of the major existing technologies for crowd modeling and simulation. Authors propose a two-dimensional categorization mechanism to classify existing work depending on the size of crowds and the time-scale of the crowd phenomena of interest.

If we look at other researches in this areas and we apply the classification based on the number of modeled humans we can easily divide researches in three main areas:

1. modeling individual or small groups;
2. modeling crowd in a defined area (stadium, metro station…);
3. modeling populations over an area (village, town region).

Some interesting works we have found in the area of single humans or small groups are, for instance, "A study on modeling of human spatial behavior using multi-agent technique" written in 2011 (Authors Chen; Yee Ming; Wang Bo-Yuan) This research follows the design and implementation of an agent-based modeling environment written in Java program language on AnyLogic simulation platform to facilitate observing the human spatial behaviors of electric taxis and passengers. An interesting sample of application in the military field in 2010 focused on small groups and where a game engine was used for the simulator development is "Behavior representation and simulation for military operations on urbanized terrain" of Zhuoqian Shen and Suiping Zhou where authors present a work on the design of an artificial intelligence (Al) framework for the bots in military operations on urbanized terrain (MOUT) simulations.

Concerning the level of big groups or population, that is the level of aggregation related to the researches described in this paper, we cite first of all the work "Enhancing multi-agent based simulation with human-like decision making strategies" (Norling, E; Sonenberg, L; Ronnquist, R 2001) where authors explored the enhancement of models of agent behavior with more "human-like" decision making strategies. A work related to civilian modeling is "Application of parallel scenario description for RoboCupRescue

civilian agent" (Shinoda, K; Noda, I; Ohta, M; Kunifuji, S 2003) where authors propose an agent framework to describe behaviors of the general public in rescue simulations and implement an application for "Risk-Communication for disaster rescue".

We can also mention some works related to building design such as "Designing Buildings for Real Occupants: An Agent-Based Approach" (2011) (Authors Andrews Clinton J.; Yi Daniel; Krogmann Uta; Senick Jennifer; Wener Richard E.) or a very old work from Ozel in 1992 titled "Simulation modeling of human-behavior in buildings". For what concern crowd models we can cite "Integrating Information Theory in Agent-Based Crowd Simulation Behavior Models" where authors (Turkay, Cagatay; Koc, Emre; Balcisoy, Selim): it is an interesting work because proposes a novel behavioral model which builds analytical maps to control agents' behavior adaptively with agent-crowd interaction formulations.

Focusing on military and homeland security areas and on specific non conventional operations it is even more critical to consider human behavioral modifiers and mutual interactions for Computer Generated Forces (CGF). This area offers many solutions that have been developed over the years initially to solve basic issues (grouping and assigning joint basic commands) and subsequently to demonstrate intelligent capabilities. For instance, WARSIM is designed to train US Army command and staff. This constructive training simulation system can also be used to train commanders and battalion staff at the theatre level in joint and combined scenarios. The SAF Janus environment are of Semi-Automated Forces that was created in the Livermore laboratory (USA) in 1979 to model the effects of atomic weapons. In the 1990s it was modified and adopted by the Army as a standard model to teach Tactics at the small-unit level (squad/platoon/company). The software was adapted by France (until 1992) to the national norms prescribed by the Army operational and simulation research center (CROSAT).

"Spectrum" was designed in 1995 by the National Simulation Center in US as a command and control training simulation system, to address a deficiency in command and control training in Military Operations Other Than War (MOOTW), Stability and Support Operations (SASO) or again in complex contingency operations (CCO). It was designed while other military simulations were modelling force-on-force combat operations. Some CGFs are rather old but remain omnipresent in current M&S arena and still in use (i.e. Close Combat Tactical Training CCTT Saf). Another existing solution is OneSAF, a Constructive/Virtual and CGF (Computer Generated Forces) Simulation System that uses a high resolution terrain representation as well as an environment and scenario representation for stability and reconstruction operations, urban operations, support operations, etc. Recently updated, it is used for Concept Development and Experimetation (CD&E) and in international development and cooperation programs. With this regard, research projects have been designed to analyze how to create agents that can reproduce aspects to face such a kind of issues. For instance, Pythagoras (currently available at the SEED Naval Post Graduate School) is an agent-based environment originally developed in relation to the Albert Project, a USMC–international sponsored initiative that focused on human factors. In this context Pythagoras was designed to define and manage agents by assigning them behaviors based on motivators and detractors.

Researches lead by Raybourne in the area of emotional intelligence, transmedia and intercultural competence games (Raybourne 2009, 2011, 2012), must also be mentioned.

Moving to R&D projects developed by Prof. Bruzzone's research team, the first steps were made to apply behavioral models to process re-engineering in Industries: impact of human factors in companies strategies, ergonomic in complex conditions (company reorganization, off-shore platforms, crowd control, emergency management, etc.). In 2001, the research team presented a new research track for the development of new generation military CGF with "intelligent" autonomous behavior, especially focused on human factors. In 2003 PIOVRA (Polyfunctional Intelligent Operative Virtual Reality Agents), the first large project funded by the European Defence Agency in this area, was launched. From the very beginning, the idea was to create intelligent agents, interoperating in federations and able to direct units or to process tasks based on their specific perception and situation awareness; as a result, in 2007 PIOVRA interoperability within JMRM federation with JTLS by Rolands & Associates was demonstrated in several events in North America and Europe (Bruzzone et al.. 2006, 2007, 2008, 2011).

So far, several R&D activities on this subject have been developed and Prof. Bruzzone's Simulation Team currently applies IA_CGF (Intelligent Agents Computer Generated Forces) as elements and frameworks for introducing human behavioral models in simulation; IA_CGF was used for a demonstration in 2010 together with US JFCOM and presented during ITEC in London: in that event, after just three months from the real event, it was possible to create and simulate a complex scenario related to Haiti Earthquake where the Port au Prince population (over 2 millions) was modeled and analyzed in term of human factor evolution and behavior related to the crisis and the coalition food distribution operations. The presentation confirmed the effectiveness of bringing together many different simulators and tools, in that case JTLS, JCATS, IA_CGF, DI-GUY, VBS, Plexsys, etc, to support training (Bruzzone, Tremori, Massei 2011).

Now the research activities on this specific area are consolidated and focused on developing new IA_CGF modules as tiles to cover new areas over the wide spectrum of operations and scenarios that military forces are requested to face today (Bruzzone., Massei, Tremori, Bocca, Madeo, Tarone 2011).

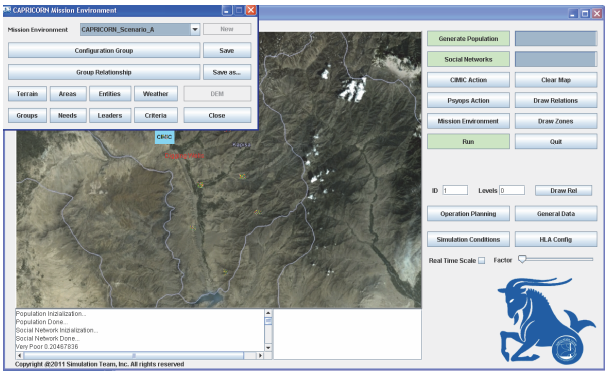

Figure 3: Capricorn and configuration of a CIMIC

CAPRICORN (CIMIC And Planning Research In Complex Operational Realistic Networks) is an EDA project devoted to develop new CGF representing not only military assets, but also regions, villages, parties and groups, moving forward to extend the use of these models from training purposes towards operational planning (Bruzzone, Tremori, Massei 2011). Another example of unclassified project is proposed by CGF-C4-IT, funded by the Italian MoD, where CGF are used in net-centric warfare to test the capabilities of different Command and Control (C2) architectures, maturity models and communication technologies in urban operations.

SIMCJOH Research Programme

The SIMCJOH (Simulation of Multi Coalition Joint Operations Involving Human Modelling) programme is a new research initiative of the University of Genoa (Italy). SIMCJOH Research Programme objectives are to study and develop new simulation models, in order to support the decision makers in Joint and Multi-Coalitions scenarios, considering a strong involvement of human factors with a particular focus on issues of refugees and civilians, natural disaster relief with presence of civilians in a theater of military operations; the initiative get benefits from innovative researches in population and human behavior modeling (Bruzzone, Bocca, Rocca 2006; Bruzzone & Massei 2007; Bruzzone, Tremori, Massei 2011; Bruzzone., Massei, Tremori, Bocca, Madeo, Tarone 2011; Mujica, and Piera 2012).

SIMCJOH Research Programme will lead to the creation of a simulator to be used in training, as a first step in experimentation phase, and later in operational planning in complex scenarios as described above.

The simulator will be realized federating via HLA (High Level Architecture) different models, according to technologies and standards state of art (Bruzzone et al. 1996; Kuhl et al. 1999; Massei et al. 2013). In SIMCJOH simulator federated models based on Intelligent CGF (Computer Generated Force) (such as IA_CGF), constructive simulators with different levels of aggregation (i.e. JTLS, JCATS etc.) and virtual simulators (i.e. VBS2, DI-GUY, ST_VP) will be integrated. For what concerns agents and the human behavioral models devoted to simulate population and civilians the effort of SIMCJOH research team will be focused on several critical issues, mainly summarized in the following elements:

- Models of human factors (i.e. stress, fatigue, food demand,…) to drive basic behavior of agents
- Models of social and parental networks for diffusion of information and perception of events by creating agents belonging to groups based on ethnic, political religious economics considering for instance mutual relationships between single agents and groups as proposed in Figure 4

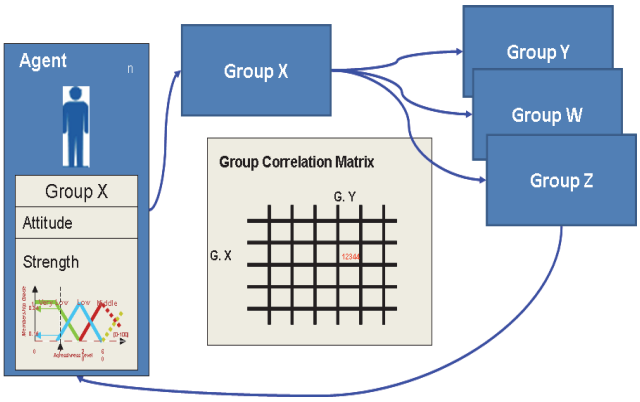

Figure 4: Sample of influence of correlation between groups based on Fuzzy Logic

The SIMCJOH federation will be executable and usable for different applications such as test & experimentation (or test & evaluation), training, operational planning. During the first phase of the Programme, the objectives to be achieved and the operational environment in which to run the new simulation models to be developed will be defined together with military users for field testing and validation (i.e. training). At this stage, the Concepts to be implemented (i.e.: Comprehensive Approach, Multicultural Awareness, Human Factor, Hybrid and non-conventional Threat, etc..) and the scenario (test case) in which the models will run (i.e.: Peacekeeping, Peace Enforcing, traditional conflicts, etc.) will be identified according to the state of art of the simulators and project constrains (budget and time). During the initial stages of SIMCJOH project authors are finalizing this aspect as well as the requirements for SIMCJOH federation and simulators to be integrated in. Based on the actual state of works preliminary conceptual models for defining proper Measures of Merits has been defined Such metrics are based on the impact of every single event considered in the scenario (i.e. number of casualties, number of rescued hostages…), on the impact of the 6 different PMESII effects (Political, Military, Economical, Infrastructural and Informative) and on the impact of the Countries analyzed and involved in the scenario and are summarized in the following formula.

$$\overline{MoM} = \sum_{i=1}^{n_e} I(t)_{e_i} f(t)_{PMESII_{e_i}} f(t)_{Country_{e_i}} H(t_{e_i} - t_o) H(t_f - t_{e_i})$$

Where

n_e = number of events considered

$$I(t)_{e_i} = \begin{cases} 0 \text{ if } t \le t_{e_i} \\ \text{Impact of event } i \text{ over time} \\ 0 \text{ if } t \ge t_{e_i} + \Delta t_{e_i} \end{cases}$$

And

$f(t)_{PMESII_{e_i}}$ impact of PMESII effects of event *i*

$f(t)_{Country_{e_i}}$ impact on different countries of event *i*

In a second time, military users will be identified for experimental phases.

Development phase for Federations and Models will be completed with the federation integration test and completion of statistical dynamic verification and validation phases based on execution of the federation. Finally, the simulation will be tested by military users during the accreditation phase to evaluate the effectiveness and efficiency and lead to the definition of requirements for an advanced system based on this study that could be deployed as an operational decision support system. Since the prototypal stage, SIMCJOH federation of simulators meets the expectation of an usable and useful tool, able to support the Defence Capability Demand and repay the investment. In fact, using this federation both the operational planners and the analysts will be able to conduct further experiments to evaluate different approaches to C2 in accordance with NATO Maturity Models (NATO NEC Maturity Models Command and Control - N2C2M2) (Bruzzone, Tremori et al. 2009). With this regard it should be noted that the Intelligent Agents Based Simulation will allow to add a new layer to complex scenarios, which takes into account the influence of human factors and the attitude for cooperation and coordination in multi-joint coalition operations. This will provide the opportunity to quickly test different alternatives based on quantitative data. Thanks to interoperability system based on SIMCJOH findings could reuse models and simulators developed for other operating environments and scenarios and will add functionality that will enable a considerable impact.

5. CONCLUSIONS

SIMCJOH Research Programme is a bottom-up initiative of a single Nation (Italy) that is trying to meet the military needs on capability development, identified through a top-down process. The expertise of University of Genova (ITA) together with the know-how of the Italian Industry and the excellence of NATO M&S CoE are proactively seeking for a tool that will support military operations in crisis management, where the human factor is the key for success. The relevance of this initiative resides in the inputs that can provide to the development of IA Based Simulation as well as the support to the transformational effort of NATO, contributing to fill the gap of the identified Capability Shortfall on Human Factors.

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Alberto TREMORI Phd is an Electrical Engineer with a PhD in M&S. He has extensive experience in technology transfer and management of R&D projects with a particular focus on modelling and simulation and serious games. He has participated in several International Conferences. He gained experience over the years working in major companies (IBM, Xerox, IDC…). He's a faculty member of MIPET (Master in Industrial Plants) at the University of Genoa. He has beenappointed from the Italian MoD to several NATO Research Groups. He's currently working at the University of Genoa, DIME as a researcher engineer, managing projects in M&S and acting as Technology Transfer Manager. He has authored several reports for the development of innovative applications of Serious Games (i.e. NATO ACT report -"Strategic Decision Making Training through Serious Games" and "Agile Intuition An innovative approach for educating Context Sensitive Coup d'Oeil"). He has also published several reports about human behavioral models (i.e. Phd thesis "Modelling Human Behavioral Models in Non-Conventional Operative Scenarios")