METAMODELLING FOR ANALYZING SCENARIOS OF URBAN CRISIS AND AREA STABILIZATION BY APPLYING INTELLIGENT AGENTS

Agostino Bruzzone[(a)], Achille Scavotti [(b)], Marina Massei [(c)], Alberto Tremori[(d)]

[(a) (b)] McLeod Institute of Simulation Science
DIPTEM University of Genoa
Via Opera Pia, 15, Genoa, 16145, ITALY

[(c)]Liophant Simulation

[(d)] MAST s.r.l
Piazza Lerda, 1, Genoa, 16158, ITALY

[(a)] agostino@itim.unige.it, [(c)]marina.massei@liophant.org, [(d)]alberto.tremori@mastsrl.eu

ABSTRACT
The paper proposes an experimental analysis on a civil disorder scenario where innovative Computer Generated Forces (CGF) are tested. In paper is provided a description of the experimental design made for the definition of the metamodels to be applied in two different cases: urban demonstration and riots as well as the subsequent stabilization period; the two cases related to the same urban scenario are tested in experimental campaigns. In this case metamodels are developed by regression equations in each scenario. So are defined the different metamodels (5 per campaign) and from each one it is possible to apply response surface methodology (RSM) for target function analysis considering multiple independent variables.

Keywords: metamodelling, intelligent agents, urban crisis

1. INTRODUCTION
Metamodels can be used effectively in order to conduct analysis on the experimental results without request to run the simulator; so optimization analysis, quick investigation of specific areas, general criteria.

In a complex scenario involving CGF that introduce many human factors as well as very complex relations, it becomes critical to develop procedures to proper analyze a very wide spectrum of alternatives; the course of action in this context can results very different and in order to support the user the metamodelling approach could be pretty interesting; for these reason in the following the metamodelling analysis is proposed with a set of possible solutions demonstrating the use of this classical techniques in Scenario analysis where Intelligent CGF are used.

Considering the high number of parameters and configuration there are many possible sub-analysis; in the proposed case this is limited to two different configuration of the scenario, each one to be evaluated in term of multiple target functions and input variables; the set proposed is based on 5 input and 5 output specific for each configuration just as example concentrated on some of more interesting and significant parameters.

This paper is based on experimental results obtained using CGF developed in PIOVRA project (Poly-functional Intelligent Operational Virtual Reality Agents); this research was devoted to test an innovative Federation integrating wargaming systems and intelligent CGF and to analyze the potential of their combined used on complex scenarios. The techniques used for these test include Data Analysis, Design of Experiment, Simulations Runs, Statistical Techniques; in fact the results proposed in this paper has been obtained by applying ANOVA and Mean Square pure Error for estimating the impact of stochastic factors.

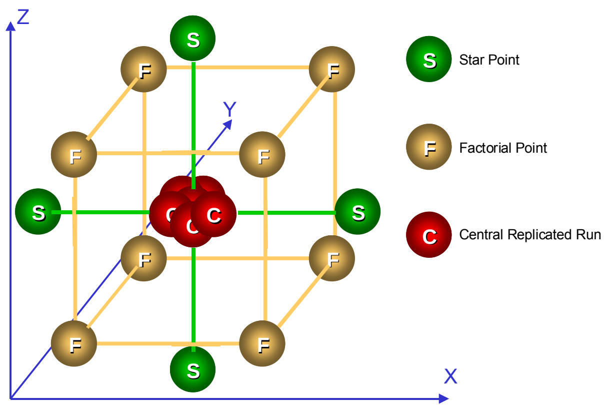

Figure 1: CCD Example for 3 Variable Civil Disorder Metamodelling

A detailed description of the reference input data and experimental Scenario is defined in PIOVRA project as well as all the metrics for measuring the performances and capabilities of agents.

2. CGF FOR URBAN DISORDERS

The present research is related to the necessity to test new intelligent CGF on complex scenarios; these CGF are able to develop autonomously proper reactions and response to the scenario evolution considering their individual perceptions, organizational structures, specific profiles as well as human behavior modifiers dynamically evolving during the simulation based on events and activities.

These CGF represents an important step forward for complex scenario analysis and in particular their major benefits emerge when the unit to model are characterized by complex behavior.

A very good example in this sector is proposed by the urban disorders, where many not military entities are involved; these entities have not clear, predefined, rules and react dynamically to the scenario evolution; for instance demonstration growth and decrease based on all the events and actions reproduced by each single entity: police forces, single agitators, terrorists, political movements, criminal organizations, militia and military forces, etc In this case the CGF was developed by DIPTEM for detailed simulation reproducing from large crowd to small groups and even single individuals; the simulation is characterized by a combined (discrete and continuous combined models) and stochastic modelling; however in a such complex scenario it becomes critical to properly tune the parameters defining behavior of different objects as well as characterizing the scenario; for this reason it was completed a metamodelling devoted to identify the correlation among the scenario independent variables and target functions (i.e. maximum violence level reach during the demonstration).

In this case two different experimental campaign was defined to reproduce two different configuration of the scenario from user point of view:

- Campaign 1: Short Term evolution of the civil disorders; this is devoted to investigate how the crisis evolves, so it is articulated over a timeframe of about 24 hours and cover just civil crisis start up, evolution and its end.
- Campaign 2: Medium Term evolution of the urban disorders; this is devoted to investigate how the after crisis moves to a stabilization of the urban areas and covers between 3-15 days after a big demonstration/riot endings.

For each campaign it was defined a set of variable sot be used example for testing the effectiveness of developing metamodels for this context; at the same example of metamodels are proposed for the specific scenario developed that covers a medium town size (about 300'000 inhabitants) where three different ethnic groups operate; the town police force is divided in two organization (federal and local) with different attitude respect local population and military forces are present to protect strategic infrastructures (i.e. embassies); on the ground two criminal organization are controlling specific areas of the town and also the local health care system is modeled.

The results obtained for this scenario in the two different configuration are specific, but the proposed methodology is pretty general.

3. METAMODELLING

From the computational perspective, the concept of metamodeling is used in mathematics, and is practically applied in computer science and computer engineering/software engineering.

In computer science and related disciplines, metamodeling is the construction of a collection of "concepts" (things, terms, etc.) within a certain domain. A model is an abstraction of phenomena in the real world, and a metamodel is yet another abstraction, highlighting properties of the model itself.

This model is said to conform to its metamodel like a program conforms to the grammar of the programming language in which it is written. In this case we can obtain metamodels by calculating the regression in various points of the domain of the chosen variables.

Response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The method was introduced by G. E. P. Box and K. B. Wilson in 1951. The main idea of RSM is to use a set of designed experiments to obtain an optimal response. Box and Wilson suggest using a first-degree polynomial model to do this. They acknowledge that this model is only an approximation, but use it because such a model is easy to estimate and apply, even when little is known about the process.

An easy way to estimate a first-degree polynomial model is to use a factorial experiment or a fractional factorial designs. This is sufficient to determine which explanatory variables have an impact on the response variable(s) of interest. Once it is suspected that only significant explanatory variables are left, then a more complicated design, such as a central composite design can be implemented to estimate a second-degree polynomial model, which is still only an approximation at best. However, the second-degree model can be used to optimize (maximize, minimize, or attain a specific target for) a response.

Some extensions of response surface methodology deal with the multiple response problem. Multiple response variables create difficulty because what is optimal for one response may not be "very" optimal for other responses. Other extensions are used to reduce variability in a single response while targeting a specific value, or attaining a near maximum or minimum while preventing variability in that response from getting too large.

Significant criticisms of RSM include the fact that the optimization is almost always done with a model for which the coefficients are estimated, not known. That is, an optimum value may only look optimal, but be far from the truth because of variability in the coefficients.

A contour plot is frequently used to find the responses of two variables to find these coefficients by including a large number of trials in each and combinations of them, and using some sort of interpolation to find potentially better intermediate values between them. But since experimental runs often cost a lot of time and money, it can also be difficult to pinpoint the ideal coefficients, as well; there are frequently strategies used to find those values with minimal runs.

4. EXPERIMENTAL DESIGN

In this case the metamodels are obtained by applying regression techniques; in the proposed case the related equations are 2nd order polynomial approximation of the target functions in function of the five variables considered. The experimental campaign has given the elements to identify the metamodels through design of experiments (DOE).

In this case it is applied a design of experiments based on central composite design (CCD) that is combining a factorial design with central replicated runs for variance estimation and star point for metamodel stabilization as proposed in the above figure for a 3 independent variable case; in our example the CCD involves a set of runs composed as following.

To support the analysis the authors developed a simple analysis tool in VBA© in order to process all the data and obtain response surfaces on request by specifying which input and output to consider.

4.1. Direct civil disorder: campaign 1

As anticipated this configuration of the experimental scenario is devoted to reproduce the urban disorders on short term, concentrating on its evolution, related counter actions by police, militia and military forces as well as contingencies and concurrent actions carried out by different actors (i.e. criminal activities taking opportunities of riots).

Coolness parameter represent the profile of the units in term of capability to resist to provocation, while terrorist actions is a discrete variable representing the following alternatives:

- no terrorist activity at all;
- limited terrorist activity to a single action concurrent with the civil disorders;
- multiple terrorist actions coordinated with civil disorders.

The variables of Campaign 1 are:

- X1: N° Demonstrators;
- X2: Coolness Military;
- X3: N° Policemen;
- X4: Coolness Police;
- X5: Terrorist.

Regressions, campaign 1:

- Campaign1, target function 1 – Overall Importance of Demonstrator Goal Achieved

$$Y_{1,1} = 6364.38 - 0.25x_1 - 145.51x_2 - 3.76x_3 - 77.58x_4\, 391.68x_5 + 0.00004x_1^2 + 1.13x_2^2 + 0.01x_3^2 + 1.08x_4^2 + 150.17x_5^2 \quad (1)$$

- Campaign1, target function 2 –Value of Losses on critical entities

$$Y_{1,2} = 732.54 - 0.01x_1 - 13.97x_2 - 0.24x_3 - 8.33x_4 - 17.93x_5 + 0.000002x_1^2 + 0.09x_2^2 + 0.0004x_3^2 + 0.09x_4^2 + 47.05x_5^2 \quad (2)$$

- Campaign1, target function 3 - Maximum Level of violence during the Civil Disorders

$$Y_{1,3} = 3742.38 - 0.18x_1 - 80.20x_2 - 2.49x_3 - 43.03x_4 + 457.22x_5 + 0.00003x_1^2\, 0.60x_2^2 + 0.003x_3^2 + 0.61x_4^2 + 33.88x_5^2 \quad (3)$$

- Campaign1, target function 4 – Average Level of violence during the Civil Disorders

$$Y_{1,4} = 210365.5 - 8.01x_1 - 4877x_2 - 43.94x_3 - 1307.16x_4 + 10173.87x_5 + 0.001x_1^2 + 33.99x_2^2 + 0.07x_3^2 + 15.23x_4^2 + 1918.45x_5^2 \quad (4)$$

- Campaign1, target function 5 - Total Number of Disable People within Military Forces

$$Y_{1,5} = 801.03 - 0.02x_1 - 16.93x_2 - 0.41x_3 - 9.50x_4 + 55.56x_5 + 4.42E-06x_1^2 + 0.126x_2^2 + 0.0005x_3^2 + 0.12x_4^2 + 11.18x_5^2 \quad (5)$$

4.2. Civil disorder stabilization: campaign 2

In this case the experimentation of scenario is focusing on reproduction of medium term evolution, considering the stabilization of the area after significant urban disorders and includes the influence of population, ethnic groups, police and para-militar forces, military units, terrorists, criminal organizations, etc.
The variables of Campaign 2 are:

- X1: N° Military Units;
- X2: Coolness Military;
- X3: N° Police;
- X4: Gang’s Force;
- X5: Terrorist.

Regressions, campaign 2:

- Campaign2, target function 1 - Overall Importance of Demonstrator Goal Achieved

$$Y_{2,1} = -730.088 + 131.773x_1 + 14.241x_2 +$$
$$1.343x_3 - 1.175x_4 - 138.492x_5 - 16.126x_1^2 -$$
$$0.095x_2^2 - 0.002x_3^2 + 0.003x_4^2 + 61.996x_5^2 \quad (6)$$

- Campaign2, target function 2 - Value of Losses on critical entities

$$Y_{2,2} = 0 + 0x_1 + 0x_2 + 0x_3 +$$
$$0x_4 + 0x_5 + 0x_1^2 + 0x_2^2 +$$
$$0x_3^2 + 0x_4^2 + 0x_5^2 \quad (7)$$

- Campaign2, target function 3 - Maximum Level of violence during the Scenario Evolution

$$Y_{2,3} = 3850.72 - 3.58x_1 - 115.61x_2 +$$
$$1.04x_3 - 0.76x_4 + 37.83x_5 + 2.22x_1^2 + 0.85x_2^2 +$$
$$0.001x_3^2 + 0.001x_4^2 + 0.53x_5^2 \quad (8)$$

- Campaign2, target function 4 - Average Level of violence during the Scenario Evolution

$$Y_{2,4} = 329353.3 + 4328.04x_1 - 11109.3x_2 +$$
$$119.24x_3 + 80.38x_4 - 8409.71x_5 - 456.18x_1^2 +$$
$$79.33x_2^2 - 0.11x_3^2 + 0.15x_4^2 + 11420.19x_5^2 \quad (9)$$

- Campaign2, target function 5 - Total Number of Disable People within Military Forces

$$Y_{2,5} = 34.2428 + 19.1784x_1 - 1.2413x_2 + 0.0567x_3 -$$
$$0.1267x_4 - 13.3951x_5 - 2.3918x_1^2 + 0.0093x_2^2 -$$
$$0.0001x_3^2 + 0.0003x_4^2 + 5.9329x_5^2 \quad (10)$$

5. IDENTIFICATION OF METAMODELS

Experimental designs used in RSM must make trade-offs between reducing variability and reducing the negative impact that can be caused by bias. In the case of the proposed civil disorder experimental campaign the authors have selected some of the most interesting response surface, in which some minimum or maximum values are identified by a particular condition of the input variables.

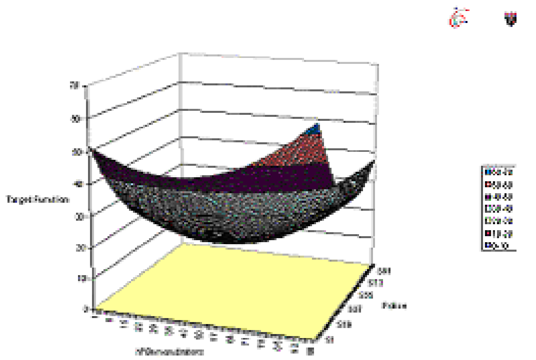

Figure 2: Campaign I - Total number of Disable People within our forces

The present graph propose the estimation of total number of Disable People respect the number of Demonstrators [the axis is from 0 to 99 corresponding to the range of analysis 2500-4500] and the number of policeman [250 to 550 policemen]; the RSM demonstrates that there is an ideal correlation between number of police forces and demonstration size if all the other variables are fixed on reference values; this is a simple 3D projection of the Metamodel that in reality is depending from 5 variables plus all the other boundary conditions (i.e. weather, population attitudes etc.). This is an example of the proposed analysis.

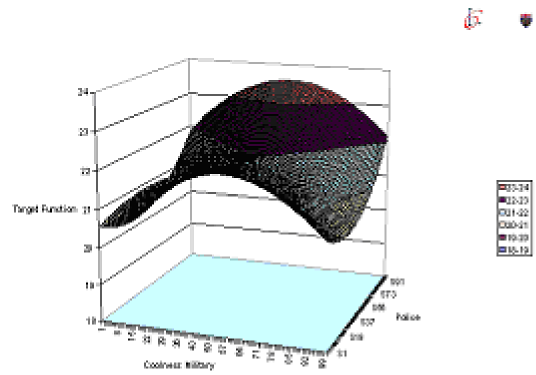

Figure 3: Campaign II - Total number of Disable People within our forces

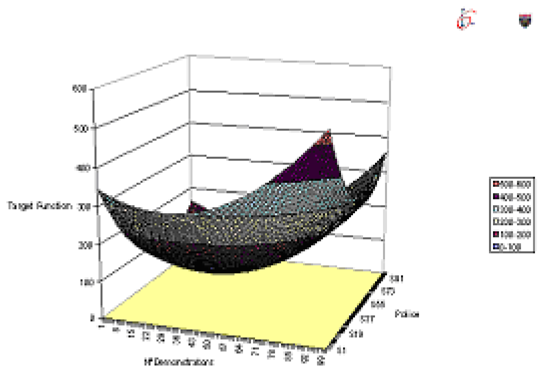

Figure 4: Campaign I - Importance factor for demonstrator goal achieved

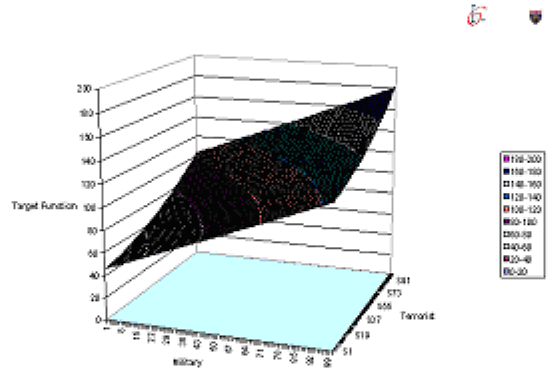

Figure 5: Campaign II - Maximum level of violence

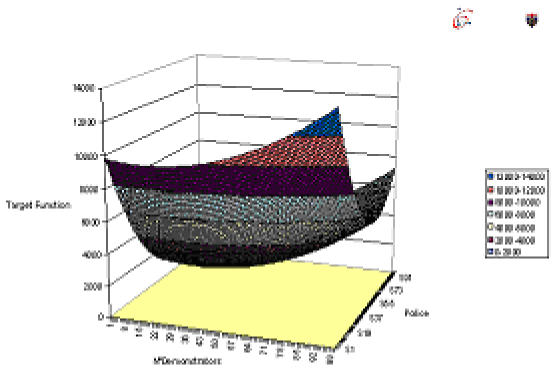

Figure 6: Campaign I - Average level of violence

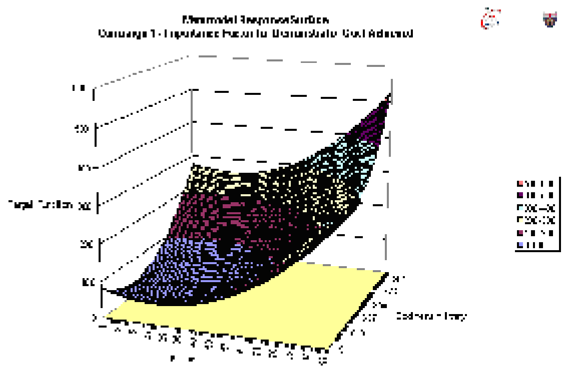

Figure 7: Campaign II - Importance Factor of Goal Achieved

6. CONCLUSIONS

The proposed analysis confirmed the effectiveness of PIOVRA Agents and the possibility to develop innovative Computer Generated Forces to investigate complex scenarios; the experimental analysis performed is an useful guideline for process definition to study the influence of the different factors on the target functions for supporting further application of Scenario analysis and CGF evaluation. The civil disorder experimental analysis allowed to demonstrate the importance of design of experiments and metamodelling in supporting course of action mapping in complex interoperable simulation combining intelligent CGF and different systems.

In addition the authors completed other additional tests on the Interoperability based on PIOVRA Agents with others Simulators has been conducted in HLA; it has been completed the demonstration of integrating in a HLA Federation PIOVRA, JTLS (a constructive simulator by Roland and Associates) and COCODRIS (a Virtual Simulator developed by DIPTEM) The combination of Theater Wargaming, Intelligent CGF and Synthetic Environment in HLA provides additional opportunities for applying experimental analysis methodologies and it confirms the potential to expand the possibilities in term of representation, understanding and control of the battlefield as expected in the present research. Further tests have been conducted with others solutions (i.e. Sheharazade from University of Arizona for Stability and Support Operations).

ACKNOWLEDGMENTS

The authors thanks Italian and French Ministry of Defense (MoD) and EDA (European Defense Agency) for their support; a special thanks to the LSIS Team that was actively involved in the project.

REFERENCES

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

Bruzzone A.G., Massei M., B.M. (2007) “Demonstration for Human Behavior Modeling Within Civil Disorder Scenarios”, *Proceedings of SCSC2007*, San Diego CA, July

Bruzzone A.G., Rocca A. B.M., (2006) "Movements and Attrition within Areas affected by Civil Disorders", *Proceedings of EMSS*, Barcelona, October

Bocca E., Bruzzone A.G., Rocca A. (2006) "Algorithms devoted to Reproduce Human Modifiers in Polyfunctional Agents", *Proceedings of SCSC*, Calgary, August

Bruzzone A.G., Kerckhoffs (1996) "*Simulation in Industry*", Genoa, Italy, October, Vol. I & II, ISBN 1-56555-099-4

Bruzzone A.G., Giribone P. (1998) "Decision-Support Systems and Simulation for Logistics: Moving Forward for a Distributed, Real-Time, Interactive Simulation Environment", *Proc. of the Annual Simulation Symposium IEEE,* Boston

Bruzzone A.G., Petrova P., B.M., B.C. (2004) "*Poly-functional Intelligent Agents for Computer Generated Forces*", Proceedings of Wintersim2004, Washington DC, December

Bruzzone A.G., Williams E.(2005) "*Summer Computer Simulation Conference*", SCS International, San Diego

Fishwick, P. (1995) "*Simulation Model Design and Execution*", Prentice Hall, New Jersey

Hamilton John A. Jr., Nash David A., Pooch Udo W. (1996) "*Distributed Simulation*", CRC Press

Kuhl F., Weatherly R., Dahmann J., Kuhl F., Jones Anita, (1999) "*HLA: Creating Computer*

Simulation Systems", Prentice Hall; ISBN: 0130225118

Rozenblit J., Bruzzone A.G., Momem F., Saetta S. (2007) "A Modelling and Simulation of Coarse of Action (COA) Consequences in Stability and Support Operations", *Proc.of EUROSIW2007*, Santa Margherita, Italy, June

Zeigler B.P., Ball G., Cho H.J., Lee J.S. (1999) "Implementation of the DEVS Formalism over the HLA/RTI: Problems and Solutions", *Proc. Of SIW* Orlando, June