The International

Workshop on Applied Modelling & Simulation

PVA EXPO PRAHA, FFF

Praha, Czech Republic, October 17-19, 2018

Edited by:

Agostino G. Bruzzone

Marina Massei

Jan Mazal

Miquel Angel Piera

www.liophant.org/conferences/2018/wams

ISBN 9788885741225 WAMS 2018 PDF

ISBN 9788885741232 WAMS 2018 Paperback

The International

Workshop on Applied Modelling & Simulation

WAMS 2018

Edited by:

Agostino G. Bruzzone

Marina Massei

Jan Mazal

Miquel Angel Piera

www.liophant.org/conferences/2018/wams

PVA EXPO PRAHA, FFF

Praha, Czech Republic, October 17-19, 2018

Publication of Simulation Team

Printed in Genoa, Italy

ISBN 9788885741225 WAMS 2018 PDF

ISBN 9788885741232 WAMS 2018 Paperback

The International

Workshop on

Applied Modelling & Simulation

www.liophant.org/wams

Praha, Czech Republic, October 17-19, 2018

Hosted at PVA EXPO PRAHA, FFF

Organized by

Simulation Team, Liophant Simulaton, MITIM, DIME Genoa University, MSC-LES

In cooperation with

MESAS and Future Force Forum

With Scientific Patronage of:

Simulation Team, DIME, University of Genoa

International Multidisciplinary Council of Simulation

Liophant Simulation

MSC - LES - University of Calabria

McLeod Institute of Technology and Interoperable M&S, Simulation Team, Genoa Center

Latvian Simulation Center

Spanish Simulation Center - LOGISIM

LSIS, University of Aix-Marseille

Perugia Simulation Center

M&S Net

Latvian Simulation Society

MIK, Riga TU

GRVA LAMCE COPPE UFRJ

Russian Simulation Society

Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario

MIMOS

Central Lab

University of Cagliari

WAMS 2018 ORGANIZATION COMMITTEE

General Co-Chairs: Agostino Bruzzone, Simulation Team Genoa, University of Genoa, Italy
Jan Mazal, Brno University of Defence, Czech University

Program-Chair: Miquel Angel Piera, Spain/Barcelona , Spain

Organization Chairs: Marina Massei, DIME University of Genoa, Italy
Cecilia Zanni-Merk, Icube, INSA Strasbourg, France

WAMS2018 INTERNATIONAL PROGRAM COMMITTEE

- Agostino Bruzzone, MITIM - Genoa Center, University of Genoa, Italy
- Felix Breitenecker, Wien TU, Austria
- Michael Conroy, KSC NASA, USA
- Luciano Di Donato, Inail, Italy
- Gerson Gomes Cunha, COPPE UFRJ, Brazil
- Riccardo Di Matteo, Simulation Team, SIM4Future, Italy
- Paolo Fadda, Central Labs, Italy
- Gianfranco Fancello, University of Cagliari, Italy
- Claudia Frydman, LSIS, France
- Murat Gunal, Turkish Naval Academy, Turkey
- Jan Hodicky, Brno University of Defence, Czech University
- Jen Hsien Hsu, De Montforrt University, Leeds, UK
- Janos Sebestyen Janosy, Centre for Energy Research, Hungarian Academy of Sciences
- Emilio Jiménez, Universidad de La Rioja, Spain
- Ali Riza Kaylan, Bogazici University, Turkey
- Luiz Landau, LAMCE UFRJ, Brazil
- Francesco Longo, UNICAL, Italy
- Marina Massei, Liophant,Italy
- Matteo Agresta, DIME, Italy
- Ian Mazal, Brno University of Defence, Czech University
- Yuri Merkuryev, RIGA TU, Latvia
- Tuncer Oren, Ottawa International, Canada
- Miquel Angel Piera, Spain/Barcelona , Spain
- Vaclav Prenosil, Masarykova Univerzita, Hungary
- Andrea Reverberi, DCCI, Italy
- Stefano Saetta, Perugia, Italy
- Grazia Tucci, DICEA, Florence University, Italy
- Gregory Zacharewicz, IMS University of Bordeaux, France
- Cecilia Zanni-Merk, Icube, INSA Strasbourg, France

WAMS 2018 EDITORS

Agostino G. Bruzzone

Liophant Simulation

Via Molinero 1, 17100 Savona, Italy

www.liophant.org

Marina Massei

DIME University of Genoa

Via Opera Pia 15, 16145 Genova, Italy

www.itim.unige.it

Jan Mazal

University of Defence

Kounicova 65, 602 00 Brno-střed, Czech Republic

www.unob.cz

Miquel Angel Piera

UAB

Campus de la UAB, Plaça Cívica, 08193 Bellaterra, Catalonia, Spain

www.uab.cat

Printed in Genoa, Italy

ISBN 9788885741225 WAMS 2018 PDF

ISBN 9788885741232 WAMS 2018 Paperback

Welcome to WAMS2018

The 11th WAMS concentrates on Applications of Simulation and Computer Technologies and it is organized in synergy with MESAS and FFF in the wonderful framework of Prague, one of most popular destinations in Europe.

Indeed the new 11th edition in 2018 is another great opportunity for the International Simulation Community to meet together in Czech Republic where Simulation has very long tradition and that is currently particularly active in some applications areas on this subjects.

In facts, WAMS, the International Workshop on Applied Modeling and Simulation, is part of major event attracting thousands of experts and scientists from worldwide and attended by major authorities of Czech Republic.

This year WAMS is focusing, as always, on pretty innovative use; specifically WAMS2018 includes papers on Modeling and Simulation including Federation for Space Expeditions, new Materials, Strategic Engineering. We should thanks the authors for their submissions and for integrating comments and suggestions by reviewers. Indeed we thanks the International Program Committee for the support provided to the Workshop.

In facts, WAMS is a workshop very effective in networking and very useful to set up new proposals and projects. Worldwide specialists have the opportunity to participate and to interact within this important International Forum on Applied M&S. The audience includes usually both scientists, users and vendors operating in applying advanced techniques to the main application areas and sectors including Industry, Business, Logistics Environment, Services & Defense.

WAMS started as a series of international workshops organized in Latin America, AMS2004 (Rio de Janeiro) and AMS2006 (Buzios); these events were focusing on Application and Theory of Modeling & Simulation. In the following years, WAMS was organized in both side of Atlantic Ocean (i.e.Rio de Janeiro, Italian Riviera), while in 2011, WAMS was co-located with the International Marine Defense Show in St.Petersburg Russia organized in Joint Cooperation with SPIIRAS Russian Academy of Science. In 2012, WAMS was held in Rome in connections with the NATO CAX Forum.

The WAMS 2013 was back in Latin America and attracted scientists, technicians and experts from world leading Universities, Institutions, Agencies and Companies; indeed WAMS 2013 edition was held in Buenos Aires, Argentina and was attended by all Latin America Countries as well as by scientists from Europe, North America, Asia and Australia.

In 2014, WAMS moved in the wonderful framework of the Bosphorous (Istanbul, Turkey) in co-location with the NATO CAX Forum. Therefore WAMS returned in Italy in 2015 (Bergeggi), 2016 (Cagliari) and 2017 (Florence) back in co-location with a major NATO event. After this three events in Italy we are finally moving to Prague and working to promote M&S in this region

We wish you a very fruitful workshop as well as the opportunity to enjoy the town;

Next year Workshop will be in Singapore (www.liophant.org/wams) and we encourage you to become active member supporting the event by proposing tracks, sessions, reviewing papers and promoting the networking.

Agostino G. Bruzzone

Jan Mazal

Miquel Angel Piera

Marina Massei

WAMS Track Chairs

- **Digital Fruition of Cultural Heritage & Architecture**
  Chairs: Grazia Tucci, Florence University
- **Serious Games**
  Chairs: Michael Conroy, KSC NASA, Riccardo Di Matteo, MAST
- **Simulation Techniques and Methodologies**
  Chairs: Giovanni Luca Maglione, SIM4FUTURE; Simone Youngblood, APL Johns Hopkings University, USA
- **Simulation for Applications**
  Chairs: Matteo Agresta, University of Genoa; Jen Hsien Hsu, De Montforrt University, Leeds, UK
- **Simulation for Emergency & Crisis Management**
  Chairs: Marina Massei, DIME, Italy - Terry Bossomaier, Charles Sturt University, Australia
- **Simulation Tools for Human Reliability Analysis Studies**
  Chair: Antonella Petrillo, University of Napoli, Partenope, Italy
- **Serious Games for Strategy**
  Chairs: Francesco Bellotti, Elios Lab, Italy - Gregory Zacharewicz,University of Bordeaux
- **Strategic Engineering & Simulation**
  Chairs: Agostino Bruzzone, Simulation Team Genoa, University of Genoa, Italy - Ian Mazal, Brno University of Defence, Czech Rep. - Anna Franca Sciomachen, DIEC, Italy
- **CBRN & Crisis Simulation**
  Chairs: Andrea Reverberi, DCCI, Italy
- **Immersive Solution for Product Design**
  Chairs: Letizia Nicoletti, Cal-Tek srl
- **Innovative Solutions supporting Interoperability Standards**
  Chairs: Antonio Padovano, MSC-LES, UNICAL
- **Mixed Reality & Mobile Training enabling new Educational Solution**
  Chairs: Marco Vetrano, Simulation Team

WAMS Session Chairs

- **WAMS I, M&S**
  Riccardo Di Matteo, SIM4Future
- **WAMS II, Strategies & Simulation,**
  Marina Massei, DIME University of Genoa, Italy
- **WAMS III, Advances in Simulation**
  M.J.D.Bonato, FACENS, Sorocaba Engineering College, Brazil
- **WAMS IV, M&S and Serious Games Panel**
  Felix Breitenecker, TU Wien
  Panelists:
  - **Agostino G. Bruzzone – Simulation Team**
  - **Jan Mazal - Unversity of Defence, Czech Rep.**
  - **Anna Sciomachen – DIEC, Italy**
  - **Michal Štepanovský – FIT, Faculty of Technology in Prague, Czech Rep.**
  - **Riccardo Berta - DITEN, Italy**

WAMS2018 Table of Contents

夫未戰而廟算勝者，得算多也；
未戰而廟算不勝者，得算少也；
多算勝，少算不勝，而況於無算乎？
吾以此觀之，勝負見矣。 (1)

Sun Tzu, the Art of War .

(1) "*the general who wins a battle makes many calculations in his temple ere the battle is fought. The general who loses a battle makes, but few calculations beforehand. Thus do many calculations lead to victory, and few calculations to defeat: how much more no calculation at all! It is by attention to this point that I can foresee who is likely to win or lose*"

SIMULATION OF PRE-HUMAN PIONEERING AND RAW MATERIAL FACTORY ON MARS

Bonato M. J. D. [(a)],Carneiro A. B. [(b)], Koga R. Y.[(c)], Leite F. T. [(d)], Rodrigues A. L. B. V. [(e)], Rodrigues D. B. V. [(f)], Teixeira T. M.[(g)], Todesco G. [(h)]

FACENS (Faculdade de Engenharia de Sorocaba) - Sorocaba Engineering College
Rodovia Senador José Ermírio de Moraes, 1425 - Sorocaba - São Paulo – Brazil

mauriciojandir@gmail.com [(a)], andre.carneiro@facens.br[(b)], rafa_yumi99@hotmail.com[(c)], fabricio.torquato1@gmail.com [(d)], andrea.braga@facens.br [(e)], diogo.rodrigues@facens.br [(f)], thamoreira@icloud.com [(g)], glauco.todesco@facens.br [(h)]

ABSTRACT
This paper aims to present the work developed on the NASA (National Aeronautics and Space Administration) SIMULATION EXPLORATION EXPERIENCE (SEE 2018) by FACENS Brazil team. The SEE uses the Distributed Observation Network (DON) and High-Level Architecture (HLA). This year, the FACENS team chose to work on Mars.
In this work, four simulations were developed: two rovers, one excavation mine and one oxygen factory. All simulated systems target human pre-colonization on Mars. For its development, a research of the Martian environment was carried out, from the atmospheric composition, through its acceleration of gravity and composition of the soil. The simulations used Java language for programming and three-dimensional modeling to facilitate the visualization of what is being simulated in real time. Finally the results obtained during the project are presented.

Keywords: simulation, mars, space mission, HLA, DON, SEE, rover, oxygen factory.

1. INTRODUCTION

The SEE is a project created by NASA (National Aeronautics and Space Administration), with the goal of integrating teams from different universities to accomplish some of the proposed missions. Thus, each participating university assembles a team that will be responsible for modeling and simulating a part of the proposed mission.
Since 2015 FACENS team has participated in the SEE. In 2017, FACENS team was responsible for the modeling and simulation of a functional lunar habitat, with all essential subsystems, as well as for creating an astronaut model, which interacted not only with the lunar habitat, but also with the simulations of other Universities. In 2018 part of the mission was the development of a pre-colonization human base on Mars. Therefore, FACENS team chose to develop and simulate this part of the project.
Thereby, models were created, or as they are called in the project, Federates, of a mine for extraction of hydrated salts, more specifically calcium perchlorate, which has the capacity to retain water, a rover aiming at removing this material from the ground and to supply an oxygen factory. The oxygen factory uses water, found in the calcium perchlorate for the production of oxygen. In addition, a rover whose purpose is to find water in the Martian subsoil.

2. SEE MISSION 2018

The 2018 NASA SEE mission was focused on in the first human pre-colonization on Mars. The SEE Mar's team for 2018 should center its activities on issues that would make a pre-colonization possible. Activities like acquiring and processing raw materials necessary for future human survival: water, oxygen, and power and rocket fuel. For enabling these activities, the development and the use of autonomous systems, vehicles and drones, aiming to manage fields and self-operating factories and mapping, locating and excavating the soil.
The SEE teams were able to use the Mars scenario to develop and model its activities, entirely based on the team's imagination and intellect, at all times relying on real information.
The goals were to prepare Mar's scenario for future colonization, exploration of resources and the development of technologies.

3. MARS ENVIRONMENT SIMULATION

Considering the proposals of the SEE 2018 mission, it was necessary to consider in this project the extreme environmental conditions that can be found in Mars; however, it was not considered possible meteorites that could reach the Federates, being added in future research and studies on these subjects.

3.1. Environmental Conditions

3.1.1 Gravity

The Mars gravity on the surface of the Equator is 3.72 m / s². (SOLAR VIEWS, accessed February 27, 2018)

3.1.2 Pressure

The pressure of Mars varies every six months and according to the formation of a snow cover, due to carbon dioxide at the poles, alternately in each one. Therefore, when the South Pole cap is higher, the average pressure observed by the Viking 1 probe was of 6.8 millibars, while in other times the average pressure was 9.0 millibars, the pressures observed by the Viking 2 probe at the same time that the southern cap was higher, were 7.3 and 10.8 millibars. (SOLAR VIEWS, accessed February 27, 2018).

3.1.3 Atmosphere

The atmosphere is composed mostly of carbon dioxide mixed with some gases, such as the most common: oxygen, water, neon, argon and nitrogen. (SOLAR VIEWS, accessed February 27, 2018).

3.1.4 Humidity

Mars humidity depends on the temperature and amount of steam in the atmosphere, during the summer afternoon the humidity is 5% and 100% on the autumn and winter nights. (NASA, 2015).

3.1.5 Temperature

The surface temperature ranges from -140 °C to 20 °C (-220°F to 68°F), with a medium temperature of -63 °C (-81,4°F) in the day and night transition, occurring in 24 hours and 37 minute cycles. (SOLAR VIEWS, accessed February 27, 2018).

3.1.6 Resources

Its composition is somewhat similar to that of the Earth, the crust and the surface have a composition of iron-rich basaltic rock (MARS NASA, accessed March 29, 2018).

3.1.7 Radiation

Mars radiation varies about 210 micrograms per day. This variation is due to the shielding difference that the atmosphere of Mars provides in the period of one day. (ESPINOZA, 2013).

4. GENERAL ARCHITECTURE OF THE SEE 2018 ENVIRONMENT

4.1 Technology and Framework

For a better understanding of how the distributed simulation used in the SEE 2018 project works, it is necessary to understand the underlying technologies.

4.2 HLA – High-Level Architecture

In a distributed simulation, each component integrated into the system produces data and information that will be used by other components.

Where, at the beginning of the simulation, applications and standards are defined that will be responsible for calculations and communications between the components, so that data integrity is achieved.

For example, rovers, which explore the Martian soil, generate information that will be transmitted to the control centers, which in turn has the function of analyzing this data and deciding what next action should be taken by the rovers.

For this reason, it is necessary to use an architecture standard that is capable of managing the communication between the components of the simulation. Therefore, the use of the IEEE 1516 standard called HLA was adopted by the SEE project.

There are several implementations of IEEE 1516, but those commonly found in SEE editions are those developed by Pitch Technologies and VT Mak, from which temporary licenses are made available to the teams participating in the SEE. Both companies have implementations in Java and C ++. Each team has the option to choose which of the two languages it wants to develop the component that will be integrated into the simulation. In order for the simulation to work, it is necessary to configure the Run-Time Infrastructure (RTI), which is a middleware that acts as a means of intercommunication between the components of the simulation. (Möller et al.2012).

During a simulation distributed with the standards of the IEEE 1516 it is used the name of Federate when referring to the components that are integrated in the simulation and thus calling of Federation the simulation. With a Federation configured on the network, it is possible to have Federates instances integrating the simulation using the RTI to intercommunicate. The SEE Federation is defined by the program SpaceMaster and EarthEnvironment developed by the development teams of Pitch Technologies in partnership with NASA.

Facens team chose to use the Java language for implementation and the tools developed by Pitch Technologies. The company provides a number of tools for the IEEE 1516 standard, such as Pitch Visual OMT (Object Model Template) for file 2
editing Federation Object Model (FOM). In addition to tools, the RTI developed by them has a graphical interface and Web resources to visualize information and manage the simulation through the pRTI Pitch.

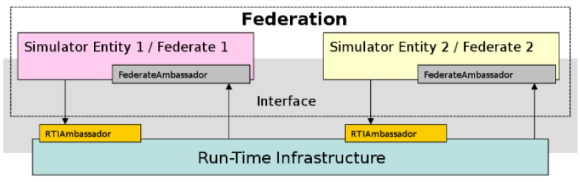

Figure 1: Federation.

4.2.1 Federation Object Model

A FOM allows the interoperability between Federates in a simulation supported by OMT specification. (Dumond and Little 2003). It is based

on object-model representation that can be loaded at runtime.

In a FOM file, it is encountered mainly a definition of objects, datatypes and interactions. Usually it can be called as “the language of federation” (Möller et al.2014) because it contains the definition of data exchanges between the Federates.

4.3 SEE HLA Starter Kit

To improve the performance of SEE teams, members of the SMASH Lab of Calabria University have developed a Starter Kit Framework (SKF) that provides a kit containing all preconfigured information regarding RTI and the Federation used in the simulation, the "HLA Starter Kit". The project has been evolving over the years with improvements and updates based on the Environment developed by NASA. The code and versions of the project are available in GitHub. The project implements annotations that facilitate the mapping of objects with the data defined in the FOMs. In addition to implementing easy Federate configuration, Federation integration, lifecycle, and default objects for all Federates (Garro and Falcone 2017). One of the main functionalities of the project is the facilitation of the implementation of classes that operate like capture of Federates properties like position and rotation, information that will be used in the 3D simulation application (DON – Distributed Observation Network).

4.4 3D Models

Since it is a software-level simulation, a visual facilitator is needed to better understand the progress of the simulation, so each team needs to build a 3D virtual model that represents each of its Federates. These templates can be built into software like 3ds Max or AutoCAD, in extension ".obj" format that will be loaded into the DON application. Our team used 3ds Max which is a three-dimensional modeling program developed by Autodesk to create the 4 Federates (Excavation Mine (MINE), Mars Miner (MAMI), Oxygen Factory (O2FAC) and Water Finder (WAFI) based on the structural requirements of the SEE.

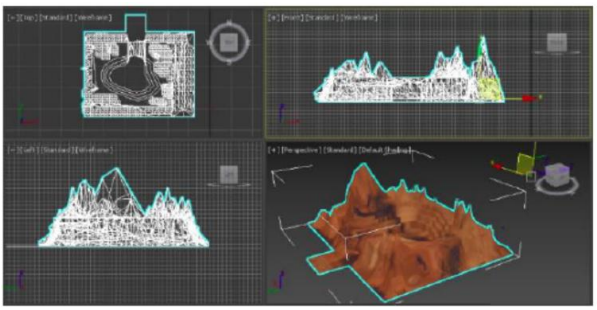

Figure 2. 3D Models

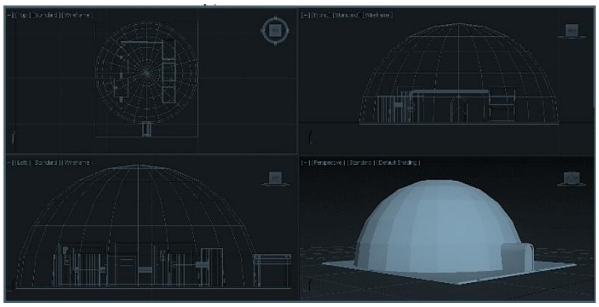

Figure 3. 3D Models

5. RAW MATERIAL FACTORY

In the SEE 2018 project, FACENS team developed a group composed of 4 (four) Federates, all located on the Martian surface. In order to better understand the Federate group, it was called FACENS Raw Material Factory Federate, where its functionality is to be responsible for searching and managing materials like Oxygen and Water.

Among the Federates developed by FACENS team, there is the Excavation Mine (MINE), which is a representation of a place full of hydrated salts. In this exploration environment, there are two types of autonomous exploration vehicles, the Mars Miner (MAMI), an excavation vehicle, which will collect calcium perchlorate and transfer it to the Oxygen Factory (O2FAC); an automated factory specialized in the production and storage of the oxygen, where the calcium perchlorate will serve as raw material.

Lastly, completing the 4 (four) Federates, it was developed the Water Finder (WAFI), a vehicle that searches and collects water in the Martian subsoil. This vehicle searches in territories of the Jezero crater, in which the mobility paths of the vehicles are sent via a Federate controller that was developed by the University of Central Florida (UCF) called Mars Grid, whose function is to map and manage all Federates located on the Martian surface.

5.1 Excavation Mine – MINE

For the development of the raw material factory, we have as main Federate the MINE, whose main functions are to provide data regarding the Martian soil to be used as extraction information for the rovers.

MINE was developed to simulate a proper site for excavation in Martian soil where it has a large amount of valuable resources for the production of water in Mars (hydrated ores - hygroscopes), such materials will be excavated by Mars Miner.

At the boundary of the mine, Mars Miner moves freely exploring, digging with its drill, clawing with its mechanical claw, and looking for hydrated minerals such as calcium perchlorate for the use of water absorbed in ores for the production of oxygen and the possible use of it in the production of fuel.

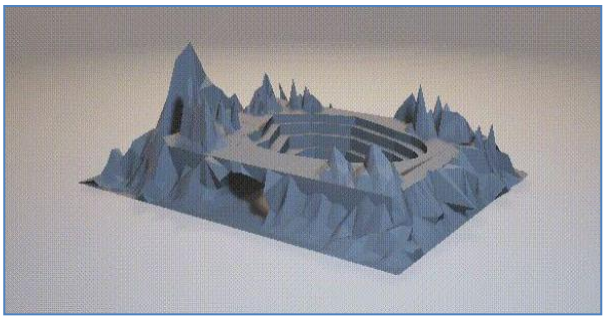

Figure 4: Excavation Mine.

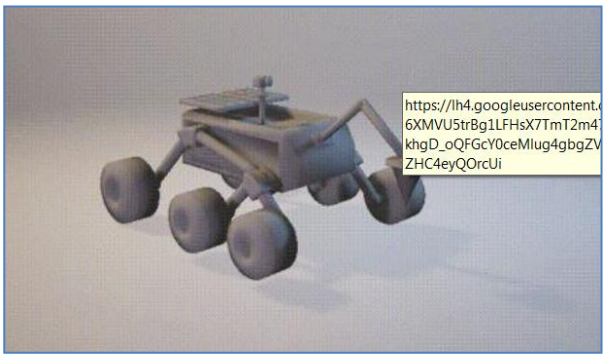

Figure 5: Mars Miner – MAMI.

5.2 Mars Miner – MAMI

The raw material factory is a Federate group that has the characteristic of searching for resources on Martian soil, in a PRE-HUMAN PIONEERING period. The Mars miner comes with the idea of being one of the first rovers that will have the role of finding, mapping their discovery site for future missions and collecting the material. The MAMI is a medium-sized vehicle that has 6 wheels. It also has a drill, for digging rocks, and a mechanical claw, with the goal of picking ores and placing them in a container, attached to the back of the vehicle.

5.3 Oxygen Factory

The Oxygen Factory will be used for two functions, the first being the control center of the rovers in which it is responsible for the decision of the actions taken by the rovers, and the second being responsible for the production of oxygen in an automated way.
The O2FAC is powered by solar energy, and it has all of its communication panels in a remotely and automated way. Where it uses water extracted from the hygroscopic mineral called calcium perchlorate or frozen water for the production of oxygen.

5.4 Water Finder – WAFI

In order to search for water points in Martian soil, a specialized rover with a Ground Penetration Radar (GPR) is used to map the subsoil of Mars to locate water and ice, a Long Range Drill (LRD) to excavate the soil and obtain a sample of the water or ice found. A battery with solar panels will power the vehicle and the collected samples will be stored in the Sample Tube Storage (STS), which has capacity for 30-tubes.

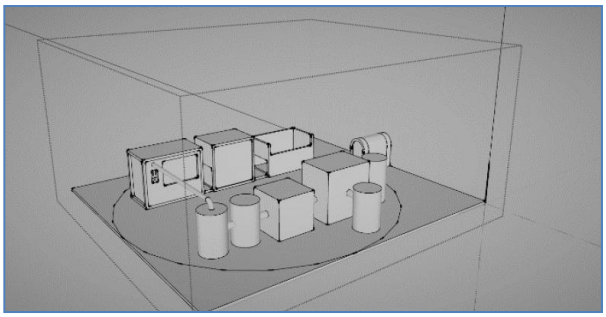

Figure 6: Oxygen Factory.

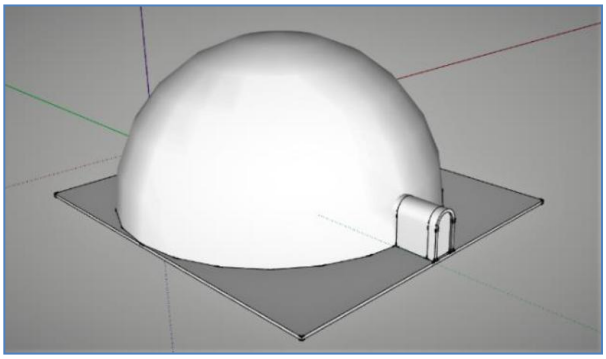

Figure 7: Oxygen Factory.

The GPR will analyze the ground as the rover moves. If the data show signs of ice or water on the spot, the rover stops and picks up a sample, using the LRD, and stores it in the STS.

Figure 8: Water Finder – WAFI.

6. RESULTS AND VALIDATIONS

After the development of all Federates conceived by FACENS team, and the definition of the boundaries in the FOM, it was possible to integrate the codes in the DON and to test the interactions between all Federates developed by Facens team (Water Finder, Mars Miner, Excavation Mine and Oxygen Factory). The interaction between the Federates worked as expected, the rovers were moving from the excavation mine to the oxygen factory, and from the factory to the mine.
During the project, several meetings were held with the other teams in order to check the progress of each one. Through these meetings, it was possible to establish partnerships, in addition to the exchange of knowledge.

This year FACENS team established a partnership with the University of Central Florida (UCF) team. The university provided the locomotion path for the Water Finder to search for water on Martian soil through the Federate developed by them, the Mars Grid.
The Federates were tested in the simulation software several times in order to correct texture related errors. In order to improve the interaction between the Federates, a refactoring of the codes took place. With this, the Federates were ready to be presented at the event held in Sofia, Bulgaria, on May 10, 2018, closing the SEE 2018 project.

7 CONCLUSIONS

Along with the development of the SEE2018 project, it was possible to create a simulation of a pre-colonization on Mars. Aiming at the pre-colonization, FACENS team focused on the search and extraction of raw material and resources in order to obtaining oxygen, with the aim of storing it for future manned missions. Through researches, the team discovered that the soil of Mars is rich in perchlorates, among them, the Calcium Perchlorate, a hygroscopic ore, that has the characteristic of absorbing moisture; the moisture absorbed by the ore could be converted into liquid water to obtain oxygen. On the other hand, the research also showed the possible existence of water in its frozen form in the subsoil of Mars, making it another option for obtaining oxygen.
The NASA Modeling and Simulation project in partnership with FACENS was a great opportunity for team members to interact with other teams, exchange ideas, make partnerships, and besides develop skills and experience.
The partnership established this year by FACENS team was with Central Florida University (UCF), which through its Federate (Mars Grid) provided the way for the Water Finder rover to search for water.
In addition to the partnership, FACENS team assisted other teams in building their Federates, such as Bulgaria with its aircraft carrier and Germany with its space station.
To conclude, the project was a great opportunity for FACENS team to interact with other teams and exchange ideas, knowledge and experiences.

REFERENCES

Espinoza L., 2013. Radiation measurements on Mars. Available from: https://www.nasa.gov/jpl/msl/mars-rover-curiosity-pia17600.html#.WsosZi7wbIU [Accessed 29 March 2018]

Greicius T., 2015. Nasa Mars rover´s weather data bolsters case for brine. Available from: https://www.nasa.gov/jpl/msl/nasa-mars-rovers-weather-data-bolster-case-for-brine [Accessed 29 March 2018]

Mars Nasa, 2018. Mars Facts. Composition. Available from: https://mars.nasa.gov/allaboutmars/facts/#?c=theplanet&s=composition [Accessed 29 March 2018]

Hamilton C.J., 2018. Mars Introduction. Views of the solar system. Available from: http://solarviews.com/eng/mars.htm [Accessed 27 February 2018]

HLA tutorial. http://www.pitchtechnologies.com/wp-content/uploads/2014/04/TheHLAtutorial.pdf. Accessed 15 May 2016.

Falcone, A., Garro, A., Longo, F., & Spadafora, F. (2014). Simulation exploration experience: A communication system and a 3D real time visualization for a moon base simulated scenario. In 2014 IEEE/ACM 18th International Symposium on Distributed Simulation and Real Time Applications (DS-RT) (pp. 113–120).Google Scholar

AGI STK components. http://www.agi.com/products/stk/modules/default.aspx/id/stk-components. Accessed 15 May 2016.

Walker, J. G. (1984). Satellite constellations. Journal of the British Interplanetary Society, 37, 559–572.Google Scholar

Bulgatz, D., Heater, D., O'Neil, D. A., Norris,B., Schricker, B. C., & Petty, M. D. Design and implementation of lunar communications satellite and server federates for the 2012 SISO Smackdown Federation. In Proceedings of the Fall 2012 Simulation Interoperability Workshop(pp. 10–14).Google Scholar

FINITE ELEMENT SIMULATION OF DYNEEMA® UD

M. Hazzard[(a)], U. Heisserer[(b)], H. van der Werff[(c)], S.R. Hallett[(d)]

[(a)] DSM Materials Science Center, Urmonderbaan 22, 6167 RD Geleen, The Netherlands
[(b)] DSM Materials Science Center, Urmonderbaan 22, 6167 RD Geleen, The Netherlands
[(c)] DSM Dyneema, Urmonderbaan 22, 6167 RD Geleen, The Netherlands
[(d)] Advanced Composites Centre for Innovation and Science, University of Bristol, Bristol, BS8 1TR, UK

[(a)] Mark.Hazzard@dsm.com
[(b)] Ulrich.Heisserer@dsm.com
[(c)] Harm.Werff-van-der@dsm.com
[(d)] Stephen.Hallett@bristol.ac.uk

ABSTRACT

This contribution shows a finite element methodology to capture the behavior of Dyneema® UD composites under high velocity ballistic impact. A homogenized sub-laminate approach separated by a cohesive tied interface using fracture mechanics was employed to capture the behavior of panels made with Dyneema® HB26. The modelling approach uses readily available material models within LS-DYNA, a commercial finite element code specializing in transient non-linear dynamics. Ballistic impact models utilizing rate effects and damage showed similar modes of deformation and failure to that observed in literature, and provide a good approximation for ballistic limit and back face deformation under 600 m/s impact speed. The mechanisms of failure in the model were also investigated, which highlight the transition zone between progressive failure on the strike face to bulge formation at the rear. Finally the importance of fiber tensile strength is discussed, highlighting the benefits of Dyneema® Force Multiplier Technology.

Keywords: Dyneema®, Ballistic Impact, Finite Element Analysis.

1. INTRODUCTION

Composites from Ultra-high molecular weight polyethylene (UHMWPE) Dyneema® are increasingly being used in impact scenarios due to their extremely high specific tensile strength and stiffness (Cunniff, 1999; van der Werff and Heisserer, 2016). DSM is the inventor and manufacturer of Dyneema®, DSM's premium brand for UHMWPE fibers and Dyneema® UD. Capturing the material behaviour through numerical modelling techniques over a range of loading conditions provides the prospect of being able to predict current performance for use as a design tool, and also provide insight into the complex deformation and failure mechanisms observed during highspeed impact (Lässig *et al.*, 2015; Nguyen *et al.*, 2016) which can be difficult to fully capture analytically (Phoenix and Porwal, 2003). The difficulty in numerical modelling lies in translating the composite architecture, which involves several hierarchies at different length scales, to a computationally efficient model. This difficulty is compounded with Dyneema® armour grade composites, compared with composites such as carbon fiber epoxy, as load transfer within the composite is limited due to the relatively low matrix properties and high fiber volume fractions. When using a continuum approach, which is often the case to reduce computational expense, lack of load transfer over a single element can be difficult to capture. This makes capturing the failure event locally as well as the global deformation problematic.

Cross-ply impacts with homogenised solid elements using a custom continuum unit cell response based on micro-scale modelling of a single [0°/90°] yarn cross over were previously modelled (Grujicic *et al.*, 2009). The difficulty in capturing delamination and back face deformation (BFD) following impact was observed. In a detailed study with extensive material characterisation, a non-linear orthotropic hydrocode model using a solid element continuum model for impacts on Dyneema® HB26 in ANSYS Autodyn was outlined (Lässig *et al.*, 2015). Whilst results were in good agreement for ballistic limit, BFD was unable to be captured due to the difficulty in capturing imperfect out-of-plane load transfer. When unable to capture BFD to a reasonable degree of accuracy, the deceleration on the projectile differs to experimental results, and therefore the contact force between the projectile on the laminate also differs, with potential to lead to invalid failure criterion. This model was recently advanced to better capture the ballistic limit and BFD by using a sub-laminate approach, with sub-laminates separated by tied interfaces in order to represent delamination (Nguyen *et al.*, 2016). A similar sub-laminate approach has been used here, also in conjunction with an adjoining fracture mechanics based interface to represent inter-laminar matrix adhesion in LS-DYNA. The aim of this modelling approach is to provide a readily available validated material model that is computationally efficient for use in LS-DYNA for ballistic impact. This can then be used for initial design

purposes and highlight the mechanisms of deformation and failure within the composite.

2. METHODOLOGY

All finite element analysis was performed in LS-DYNA explicit, with the material model based on Dyneema® HB26. HB26 is produced as a cross-ply [0°/90°/0°/90°] layup containing SK76 fiber and a polyurethane based matrix. Following stacking to a nominal thickness and hot compression, the hard-ballistic panel has a high fiber volume fraction, typically above 80%. Due to the low density of HB26, thicker panels also drive the requirement for computationally efficient modelling techniques. Cross-plies have been homogenized to represent the composite layup as a sub-laminate, and these sub-laminates are then stacked and separated by a cohesive tied interface (Figure 1). Single element sub-laminates have been shown to be a reasonable approximation due to the low bending stiffness of HB26 composite (Hazzard *et al.*, 2018), allowing for kink band formation that typically results at the fiber and inter-laminar level (Liu and Thouless, 2014). This is recommended when unable to use different tension and compressive properties in the sub-laminate, as representing beam stiffness with 3-5 elements per sub-laminate increases bending stress and bending rigidity.

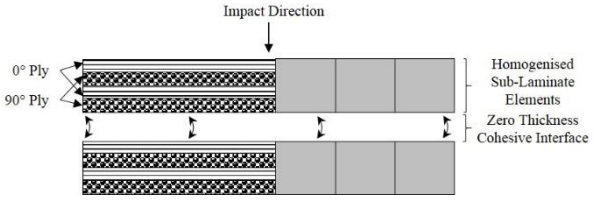

Figure 1: Schematic representation of sub-laminate homogenisation connected via a zero-thickness cohesive interface.

The material model used for the sub-laminate is M162, a commercially available material model for LS-DYNA where 6 stress components contribute to damage which is followed by strain softening through damage parameters. Rate effects are also included, which provide the capability to reasonably capture deformation at relatively low rates of loading as well as ballistics (Gama and Gillespie, 2011; Hazzard *et al.*, 2016, 2018). The sub-laminate material card for M162 is given in Table 2 within the appendix; for a full description please refer to (Hazzard et al., 2018). Between the sub-laminates is the cohesive tied interface which is a segment to segment based contact. This uses the Dycoss mixed mode model, with input given in Table 3 in the appendix. An additional automatic surface to surface contact is also applied between each sub-laminate and the laminate part set to prevent inter-part penetration between sub-laminate parts following erosion. Finally, an eroding contact is used between the projectile and the laminate part set. The projectile used here for validation is a 20 mm diameter FSP, impacting plates of 300×300 mm of varying target thickness and has been validated against ballistic tests performed by Nguyen *et al* (Nguyen, Ryan and Cimpoeru, 2015). The projectile model uses a simplified Johnson Cook model (M98) (Nguyen *et al.*, 2016). Boundary conditions were not modelled as this has previously been shown to be negligible with this particular impact scenario (Nguyen *et al.*, 2016). All ballistic limits (V_{BL} = V_{50}) were estimated using a Lambert-Jonas approximation (Lambert and Jonas, 1976).

3. RESULTS AND DISCUSSION

3.1. Ballistic Model Validation

Ballistic limit was investigated over a range of target thicknesses from 5 mm to 50 mm. Ballistic limit fits, based on V_I and V_R (initial and residual velocity respectively) are given in Figure 2 with a minimum of 3 penetrations. The V_{50} is then compared against non-dimensional areal density, a parameter that considers the projectile mass and projected frontal area allowing comparison of differing ballistic tests (Heisserer and Werff, 2012). It was observed that the model provides relatively good predictions for ballistic limit and projectile deformation up to 600 m/s, however at greater velocities it under predicts performance. It is believed that at higher velocities, an equation of state becomes increasingly important to capture shock mechanics and energy dissipation, something which has not been implemented within this model. Lässig *et al* (Lässig *et al.*, 2015) also observed the increasing importance of an equation of state at greater impact velocities within a fully homogenised model.

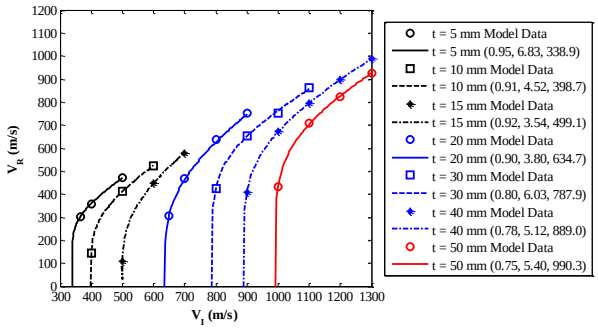

Figure 2. Lambert-Jonas ballistic approximation from model impacts with varying thickness t, with curve fit parameters given in the legend (a, p, V_{BL}).

BFD and shear hinge progression was compared with experimental results from Nguyen *et al* (Nguyen *et al.*, 2016), showing good correlation to experimental results for a 10 mm target thickness for both BFD and shear hinge expansion (Figure 4). However, at target thicknesses greater than 20 mm larger BFD is observed than experimental observations. This is thought to be due to over perforation of the laminate. Thicker laminates again require greater impact velocities in an impact regime where an equation of state is required. A third result at 36 mm target thickness and 888 m/s impact velocity showed complete perforation within the model,

whilst experimental results showed an unperforated response, further supporting the lower than expected energy absorbance in the initial local failure zone. When unperforated, hinge progression was still reasonably accurate suggesting shear hinge wave speed is less dependent on the remaining thickness of the laminate compared with BFD.

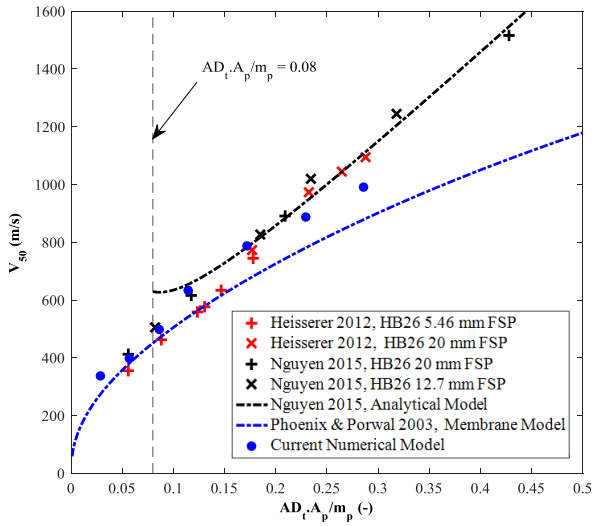

Figure 3. Experimental, analytical, and current finite element predictions for V_{50} for UHMWPE laminates compared with non-dimensional areal density.

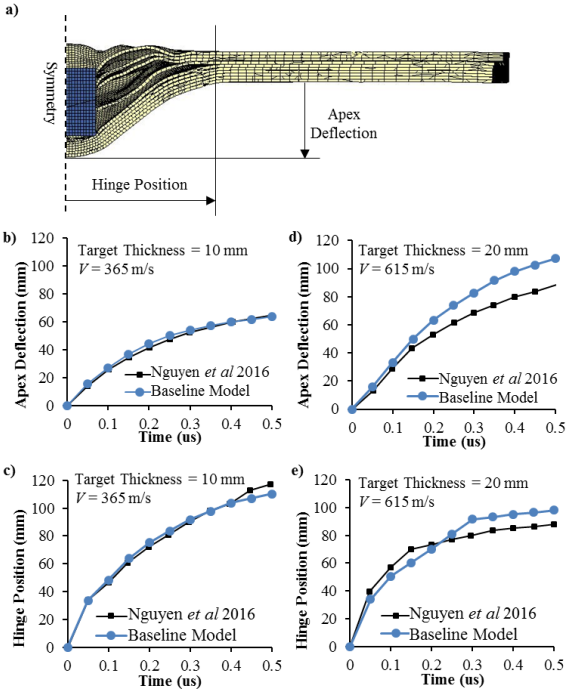

Figure 4. a) Schematic of apex deflection and hinge position progression with time for b-c) 10 mm target at 365 m/s impact velocity and d-e) 20 mm target at 615 m/s impact velocity.

3.2. Mechanisms of Ballistic Deformation

The mechanisms of deformation appear accurately captured when observing the impact event, as can be seen in Figure 5a. For thin targets or at the rear of thicker targets, large shear pull-in can be observed surrounding primary fibers that were in direct contact with the projectile. In this case, minimal projectile deformation was also observed and the projectile was stopped and finally tumbled off its vertical axis. For thicker laminates two zones of failure are observed, with an initial local failure around the projectile, followed by several delaminations and then membrane action. There does appear to be some over-delamination of the laminate compared with what is observed typically in an experiment; this is thought to be due to the resolution of cohesive interfaces, however a trade-off between number of interfaces, element size, and computational cost is required. Where the laminate fails locally, no shear-pull in was observed. Shear pull-in started to occur following initial delamination's, whilst projectile deformation was higher at the higher impact velocity (Figure 5b). Also, noticeable in all impact cases was the excess wrinkling of the shear hinge when the target is catching the projectile in a mode similar to membrane action. This was thought to be caused through simplification of the in-plane shear response (effectively bi-linear), combined with over-delamination of the target. It is thought that the wrinkles effectively increase shear stiffness locally, providing reasonable approximations for BFD (Hazzard *et al.*, 2018).

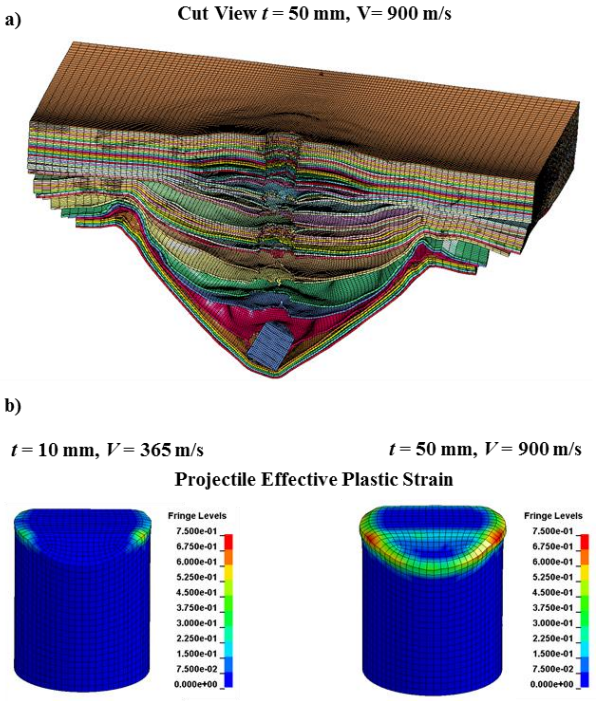

Figure 5. a) a cut view of 50 mm target thickness with 900 m/s FSP impact, with different colours highlighting each sub-laminate. b) Differing projectile deformation at low and high impact velocities.

It has previously been proposed that the determining factor for the mode switch from progressive failure to back face bulging is triggered by a reflective relief wave from the rear surface (Nguyen, Ryan and Orifici, 2016), or a critical thickness of penetration is reached, causing minimal bending resistance, initiating bulging (Karthikeyan and Russell, 2014). Both suggest that when a critical pressure between the projectile and the target laminate is reached, the laminate can now act in a mode similar membrane deformation. Following investigation of the model with a 20 mm FSP impact at 900 m/s on a 50 mm thick laminate, the reflective tensile relief wave was observed to reach the oncoming projectile in under 40 µs, substantially reducing contact force on the projectile from the laminate (Figure 6). However, the projectile continues to fail plies in a progressive manner, indicating that the tensile relief wave is only one factor in controlling the transition from progressive local failure to bulging deformation. In the current 50 mm target model, the projectile force at which the mode switch was observed was approximately 90-100 kN, (≈ 286 MPa pressure assuming the FSP projected circumferential area). This seems low compared with theories of indirect tension, which assume compressive strength equal to that of tensile strength, and lower than the compressive strength input, which suggests that locally higher stresses around sharp projectile geometry plays a role. Some sub-laminates ahead of the one in direct contact with the projectile were also observed to be damaged by the high-pressure front, prior to relief wave interaction.

3.3. Numerical Study

A brief numerical study was also performed to investigate the driving mechanisms of energy absorption within the model. Laminate tensile strength was assumed from testing that provided the highest tensile strength from cross-ply tests on a single ply, 1250 MPa (Heisserer and van der Werff, 2016), however the effects of the low matrix shear strength causing unequal loading of fibers in a multi-ply configuration has been shown to reduce load bearing capability compared with what is expected from volume fraction and single fiber tests (Russell *et al.*, 2013). In this parametric study tensile strength was therefore varied from 1050 to 1494 MPa, the latter is that expected based on a volume fraction calculation using a measured SK76 fiber tensile strength of 3.6 GPa (negligible matrix properties) (Russell *et al.*, 2013). The parameters that were modified with the effects on a 10 mm thick target impact given in Table 1. The benefits of increasing tensile strength are clearly observable, supporting the experimentally observed improved performance of HB grades with the newer, higher tenacity Dyneema® SK99 fiber compared with SK76. SK99 now reaches up to 4.1 GPa tensile strength providing exceptional ballistic resistance. This supports more simplified analytical observations such as the Cunniff velocity, which identifies the fiber modulus and fiber tensile strength as the driving parameters for ballistic performance (Cunniff, 1999). Figure 7 highlights the Cunniff velocity for varying fibers and the capability of Dyneema® Force Multiplier Technology family. When considering the experimentally obtained maximum tensile strength, the Dyneema® fiber can achieve the lowest weight currently of the described fiber systems (Van der Werff *et al.*, 2017).

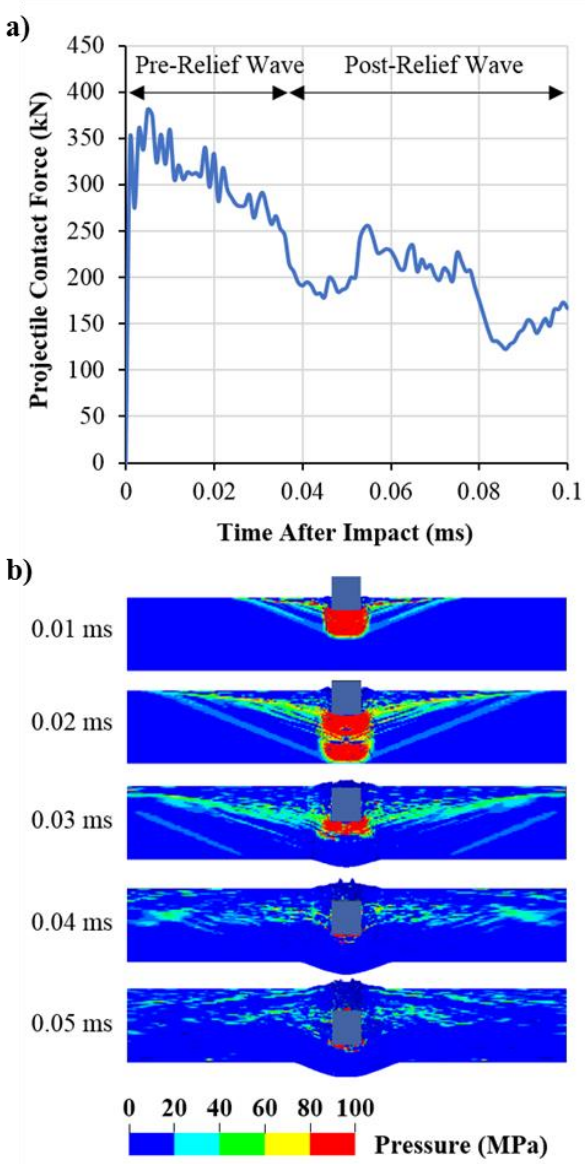

Figure 6. a) Projectile contact force against a 50 mm target laminate at 900 m/s impact speed with time, b) visual contour plot highlighting the arrival time of the reflected pressure relief wave.

Table 1. Tensile strength parametric study of 10 mm target thickness.

Tensile Strength *SaT* & *SbT*(MPa)	**V_{50} (m/s) Lambert-Jonas Fit**	**V_{50} Δ%**	**BFD (mm) V_I = 365 m/s, time = 0.5 ms**	**BFD Δ%**
1050 (-16%)	357	-10.5	Perforated	
1150 (-8%)	375	-6.0	69.8	+9.7
1250 (-)	399	-	63.6	-
1350 (+8%)	435	9.0	60.6	-4.7
1494 (+19.5%)	461	15.5	61.3	-3.6

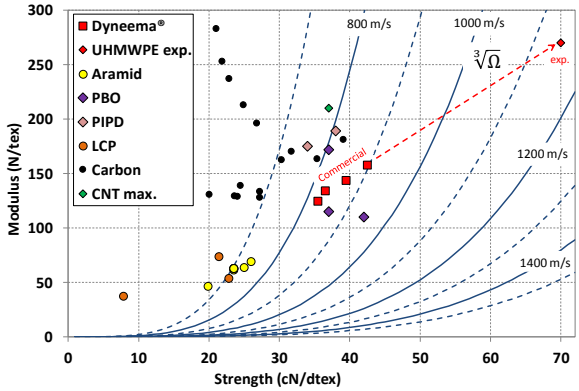

Figure 7. Typical Cunniff velocity plot showing the capability of Dyneema® and expected future prospects (Van der Werff *et al.*, 2017).

4. CONCLUSION

A finite element numerical model that provides reasonable predictions of ballistic limit and BFD up to 600 m/s has been presented. Mechanisms of deformation are representative of what is typically observed experimentally, with initial local progressive failure followed by delaminations leading to global scale bulge deformation. The simplified in-plane shear model captures drawing in during bulge deformation, however wrinkles are observed which are not so prominent during experimental observations. The contact force on the projectile shows the effect of relief wave interaction, causing a clear reduction on contact force. However, on thicker laminates at higher speeds, this was only one factor as contact force remained high enough to initiate failure following interaction. A brief parametric study highlighted the importance of fiber tensile strength, supporting experimental results for improved ballistic performance of newer hard ballistic Dyneema® grades made with SK99 fibers as part of the Force Multiplier Technology family. In the future, updates relating to newer grades of Dyneema® will be investigated as well as the influence of projectile type.

ACKNOWLEDGMENTS

The authors acknowledge the support of the EPSRC through the ACCIS Centre for Doctoral Training grant, EP/G036772/1, and the financial contribution of the Defence Science and Technology Laboratory (dstl) for funding this research. We would also like to thank Professor Lorenzo Iannucci for helpful background discussions, Assistant Professor Bazle Gama for discussions surrounding MAT162 and Dr Galal Mohamed for general advice on numerical modelling in LS-DYNA.

APPENDIX

Table 2. M162 material card for HB26 sub-laminates.

Property	Symbol	Value	Units	Ref.
Density	ρ	0.00097	g/mm^3	-
Young's Modulus aa	E_{aa}	34257	MPa	(Russell *et al.*, 2013)
Young's Modulus bb	E_{bb}	34257	MPa	(Russell *et al.*, 2013)
Young's Modulus cc	E_{cc}	3260	MPa	(Lässig *et al.*, 2015)
Poisson's Ratio ba	v_{ba}	0	-	-
Poisson's Ratio ca	v_{ca}	0.013	-	(Lässig *et al.*, 2015)
Poisson's Ratio cb	v_{cb}	0.013	-	(Lässig *et al.*, 2015)
Shear Modulus ab	G_{ab}	173.8	MPa	(Hazzard *et al.*, 2015)
Shear Modulus ca	G_{ca}	547.8	MPa	(Chocron *et al.*, 2014)
Shear modulus cb	G_{cb}	547.8	MPa	(Chocron *et al.*, 2014)
Longitudinal Tensile Strength a	S_{aT}	1250	MPa	(Heisserer and van der Werff, 2016)
Longitudinal Compressive Strength a	S_{aC}	1250	MPa	-
Transverse Tensile Strength b	S_{bT}	1250	MPa	(Heisserer and van der Werff, 2016)
Transverse Compressive Strength b	S_{bC}	1250	MPa	-
Through Thickness Tensile Strength c	S_{cT}	1E20	MPa	-
Crush Strength c	S_{FC}	1250	MPa	(Attwood *et al.*, 2014)
Fiber Mode Shear Strength	S_{FS}	625	MPa	-
Matrix Mode Shear Strength ab	S_{ab}	1.8	MPa	(Hazzard *et al.*, 2015)
Matrix Mode Shear Strength bc	S_{bc}	1.8	MPa	(Hazzard *et al.*, 2015)
Matrix Mode Shear Strength ca	S_{ca}	1.8	MPa	(Hazzard *et al.*, 2015)
Residual Compressive Strength Factor	S_{FFC}	0.1	-	-
Failure Model (2 = fabric cross-ply)	A_{MODEL}	2	-	-
Coulomb Friction Angle	Phi_C	0	degrees	-
Delamination Scale Factor	S_{DELM}	1	-	-
Limiting Damage Factor	OMG_{MX}	0.999	-	-
Eroding Axial Strain	E_LIMT	0.06	-	-
Eroding Compressive Volume Strain	ECRSH	0.05	-	-
Eroding Volumetric Strain	EEXPN	4	-	(Gama and Gillespie, 2008)
Coefficient of Strain Rate Fiber Strength Properties	C_{rate1}	0.0287	-	(Russell *et al.*, 2013)
Coefficient of Strain Rate for Axial Moduli	C_{rate2}	0.1163	-	(Russell *et al.*, 2013)
Coefficient of Strain Rate for Shear Moduli	C_{rate3}	0.225	-	(Russell *et al.*, 2013)
Coefficient of Strain Rate for Transverse Moduli	C_{rate4}	0.1163	-	(Russell *et al.*, 2013)
Coefficient of Softening for Axial Fiber Damage	*am1*	20	-	-
Coefficient of Softening for Transverse Fiber Damage	*am2*	20	-	-
Coefficient of Softening for Crush Damage	*am3*	20	-	-
Coefficient of Softening for Matrix Failure	*am4*	-0.8	-	(Nguyen *et al.*, 2016)

Table 3. Mixed mode cohesive interface model.

Property	Symbol	Value	Ref.
Mode I Tensile Strength (MPa)	T	1.6	(Lässig *et al.*, 2015)
Mode I Initial Stiffness (N/mm^3)	K_I	60	-
Mode I Fracture Energy (N/mm)	G_{Ic}	0.544	(Grujicic, Arakere and He, 2009)
Mode I Traction Max' Displacement (mm)	D_{IF}	0.908	-
Initial Stiffness Ratio (-)	K_{II}/K_I	0.6	-
Mode II Shear Strength (MPa)	S	2.6	(Karthikeyan *et al.*, 2013; Hazzard *et al.*, 2015)
Mode II Fracture Energy (N/mm)	G_{IIc}	1.088	
Mode II Traction Max' Displacement (mm)	D_{IIF}	1.21	-
Exponent of Powerlaw (-)	PARAM	1	-

REFERENCES

Attwood, J. P. *et al.* (2014) 'The out-of-plane compressive response of Dyneema ® composites', *Journal of the Mechanics and Physics of Solids*, 70, pp. 200–226. doi: 10.1016/j.jmps.2014.05.017.

Chocron, S. *et al.* (2014) 'Modeling unidirectional composites by bundling fibers into strips with experimental determination of shear and compression properties at high pressures', *Composites Science and Technology*, 101, pp. 32–40. doi: 10.1016/j.compscitech.2014.06.016.

Cunniff, P. M. (1999) 'Dimensionless parameters for optimization of textile-based body armor systems', in *Proceedings of the 18th International Symposium on Ballistics*. San Antonio: TX, Technomic Publishing Company, Inc, pp. 1303–10.

Gama, B. and Gillespie, J. W. (2008) 'Punch shear based penetration model of ballistic impact of thick-section composites', *Composite Structures*. Available at: http://www.sciencedirect.com/science/article/pii/S0263822307002681 (Accessed: 24 October 2016).

Gama, B. and Gillespie, J. W. (2011) 'Finite element modeling of impact, damage evolution and penetration of thick-section composites', *International Journal of Impact Engineering*, 38.4, pp. 181–197. Available at: http://www.sciencedirect.com/science/article/pii/S0734743X1000196X.

Grujicic, M. *et al.* (2009) 'Material modeling and ballistic-resistance analysis of armor-grade composites reinforced with high-performance fibers', *Journal of Materials Engineering and Performance*, 18(9), pp. 1169–1182.

Grujicic, M., Arakere, G. and He, T. (2009) 'Multi-scale ballistic material modeling of cross-plied compliant composites', *Composites Part B: Engineering*, 40(6), pp. 468–482. Available at: http://www.sciencedirect.com/science/article/pii/S1359836809001012 (Accessed: 9 April 2014).

Hazzard, M. K. *et al.* (2015) 'An Investigation of the in-plane performance of ultra-high molecular weight polyethylene fibre composites', in *International Conference of Composite Materials*. Copenhagen, pp. 19–24.

Hazzard, M. K. *et al.* (2016) 'Effect of Fibre Orientation on the Low Velocity Impact Response of Thin Dyneema® Composite Laminates', *International Journal of Impact Engineering*, 100, pp. 35–45. doi: 10.1016/j.ijimpeng.2016.10.007.

Hazzard, M. K. *et al.* (2018) 'Finite Element Modelling of Dyneema ® Composites : From Quasi- Static Rates to Ballistic Impact', *Under Review*, pp. 1–37.

Heisserer, U. and Werff, H. van der (2012) 'The relation between Dyneema® fiber properties and ballistic protection performance of its fiber composites', in *15th International Conference on Deformation, Yield and Fracture of Polymers*, pp. 242–246. Available at: http://www.academia.edu/download/42729048/The_relation_between_Dyneema_fiber_prope20160216-1134-tzjo7m.pdf (Accessed: 30 August 2016).

Heisserer, U. and van der Werff, H. (2016) 'Strength Matters: Which Strength of Dyneema Fiber Composites to Use in Hydrocode Models? A Discussion.', in *Internation Ballistics Symposium*. Edinburgh, pp. 1–5.

Karthikeyan, K. *et al.* (2013) 'The effect of shear strength on the ballistic response of laminated composite plates', *European Journal of Mechanics - A/Solids*, 42, pp. 35–53. doi: 10.1016/j.euromechsol.2013.04.002.

Karthikeyan, K. and Russell, B. (2014) 'Polyethylene ballistic laminates: Failure mechanics and interface effect', *Materials & Design*, (63), pp. 115–125. Available at: http://www.sciencedirect.com/science/article/pii/S0261306914004464 (Accessed: 25 February 2015).

Lambert, J. and Jonas, G. (1976) 'Towards standardization in terminal ballistics testing: velocity representation.' MD: Ballistic Research Laboratories Aberdeen Proving Ground. Available at: http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA021389 (Accessed: 6 December 2016).

Lässig, T. *et al.* (2015) 'A non-linear orthotropic hydrocode model for ultra-high molecular weight polyethylene in impact simulations', *International Journal of Impact Engineering*, 75, pp. 110–122. Available at: http://www.sciencedirect.com/science/article/pii/S0734743X1400150X (Accessed: 25 August 2014).

Liu, G. and Thouless, M. (2014) 'Collapse of a composite beam made from ultra high molecular-weight polyethylene fibres', *Journal of the Mechanics and Physics of Solids*, 63, pp. 320–335. Available at: http://www.sciencedirect.com/science/article/pii/S0022509613001749 (Accessed: 27 August 2015).

Nguyen, L. *et al.* (2016) 'A methodology for hydrocode analysis of ultra-high molecular weight polyethylene composite under ballistic impact', *Composites Part A: Applied Science and Manufacturing*, 84, pp. 224–235. Available at: http://www.sciencedirect.com/science/article/pii/S1359835X16000294 (Accessed: 10 August 2016).

Nguyen, L., Ryan, S. and Cimpoeru, S. (2015) 'The effect of target thickness on the ballistic performance of ultra high molecular weight polyethylene composite', *International Journal of Impact Engineering*, 75, pp. 174–183. Available at: http://www.sciencedirect.com/science/article/pii/S0734743X14001547 (Accessed: 22 October 2014).

Nguyen, L., Ryan, S. and Orifici, A. C. (2016) 'A numerical investigation on the response of thick ultra-high molecular weight polyethylene composite to ballistic impact', *Proceedings - 29th International Symposium on Ballistics, BALLISTICS 2016*, 2.

Phoenix, S. L. and Porwal, P. (2003) ‘A new membrane model for the ballistic impact response and V50 performance of multi-ply fibrous systems’, *International Journal of Solids and Structures*, (40 (24)), pp. 6723–6765. Available at: http://www.sciencedirect.com/science/article/pii/S0020768303003299 (Accessed: 19 August 2014).

Russell, B. P. *et al.* (2013) ‘The high strain rate response of Ultra High Molecular-weight Polyethylene: From fibre to laminate’, *International Journal of Impact Engineering*, 60, pp. 1–9. doi: 10.1016/j.ijimpeng.2013.03.010.

Van der Werff, H. *et al.* (2017) ‘On the Ultimate Potential of High Strength Polymeric Fibers To Reduce Armor Weight’, in *International Ballistics Symposium*.

Van der Werff, H. and Heisserer, U. (2016) ‘High-performance ballistic fibers: ultra-high molecular weight polyethylene (UHMWPE)’, in *Advanced Fibrous Composite Materials for Ballistic Protection*. Woodhead Publishing, pp. 71–107. doi: 10.1016/j.aquatox.2013.11.019.

AUTHORS BIOGRAPHY

Mark graduated with a PhD in composite materials from the University of Bristol in 2017, with focus on the impact performance of ultra-high molecular weight polyethylene fiber composites. This involved mechanical materials characterization as well as finite element modelling of high speed impact and was supported by dstl. This work has continued in conjunction with the University at DSM Dyneema with Dr Ulrich Heisserer and Dr Harm van der Werff, using models to help support end users and provide a material card that can be utilized in design. Prior to this Mark completed a master’s degree in aerospace engineering in 2011, also at the University of Bristol gaining broad knowledge relating to aviation and aircraft. Mark is now continuing materials research within the DSM Materials Science Center on several projects relating to mechanical properties.

STRATEGIC ENGINEERING AND INNOVATIVE MODELING PARADIGMS

Agostino G. Bruzzone
DIME, University of Genoa
agostino@itim.unige.it
www.itim.unige.it

Riccardo Di Matteo
SIM4Future
riccardo.dimatteo@sim4future.com
www.sim4future.com

Kirill Sinelshchikov
Simulation Team
kirill@simulationteam.com
www.simulationteam.com

ABSTRACT
Modeling and Simulation (M&S) is an important approach which could be used to find possible solutions of many actual problems in various fields, starting from training of personnel and up to strategic planning of company development. In this paper, it is presented an analysis of typical constraints and limitations imposed by both M&S developers and final users as well as proposed solutions of these issues, such as utilization of MS2G (Modeling, interoperable Simulation and Serious Games) paradigm during development. Furthermore, it is proposed a multidisciplinary training course in Strategic Engineering aimed to create a new generation of M&S developers and users, capable to utilize new approaches of problem solving and strategic planning.

Keywords: *Modelling & Simulation, Interoperability, Decision Support, Strategic Engineering, Serious Games*

1 INTRODUCTION

Nowadays, the world faces numerous problems caused by Geo-political situations and fast evolution of society, which affect humanity in different ways (Bruzzone 2018). For instance, changing the economic and political situation is otherwise causing alternation of approaches to public safety and security. Many of these changes are caused by recent technological advances, which could be observed in virtually all fields, starting from communication and interconnectivity and up to IoT (Internet of Things), Big Data and AI (Artificial Intelligence). Obviously, new technologies and approaches create new challenges, however, in case of proper understanding of their potential they could be seen also as opportunities, which would allow analyzing, foreseeing and solving critical strategic issues of the modern world. Strategy is an ancient term which comes from Greek and means army leading (*stratos* and *agein*). In fact, the necessity of proper military Strategy in order to succeed was known from millennia, however, the understanding of its indispensability in management and control in other fields was realized much later. For instance, according to Jomini, "Strategy is the art of good direction" ("La Stratégie est l'art de bien diriger", Jomini, Prècis de l'Art de la Guerre, 1838). At the same time, Von Clausewitz stated: “we need a philosophy of strategy that contains the seeds of its constant rejuvenation, a way to chart strategy in an unstable environment” (Vom Kriege, 1832). For these reasons, in order to succeed today, it is critically important to rely on strategic planning, which in its turn requires new simulators and models capable to deal with the current level of complexity of the world. Obviously, in order to create and utilize properly such technologies it is necessary to apply proper approaches and engineering methodologies. In this context, it is important to highlight a MS2G paradigm, which allows to partially solve the mentioned issues by improving interactivity of simulation and involving more regular users. In fact, this paper proposes an overview of how to create and use new simulation models, highlighting importance of preparation of personnel responsible for strategic decision making.

2 CHALLENGES

As mentioned, new technologies coupled with smart algorithms are able to provide and elaborate big amounts of data, to predict sophisticated behavior of complex systems by analyzing numerous alternatives, as well as to be easily adapted to utilize new information, tasks and boundary conditions (Bruzzone 2018). Considering this, it is easy to imagine the impact of these technologies that could have on the field of decision making at different levels, from small company management to a country budgeting. The first researches, aimed to utilize simulation as decision support tool, were performed in the 60’s, however, in that period, they were quite rare and available mostly for big governmental and industrial entities (Longo 2011), due to technological and methodological limitations of such solutions. Despite such limitations, the necessity of M&S solutions were clear, in fact, some of early works, such as Mission Earth initiative and GENI (Global Energy Network Institute) global

simulation, were inspired by Club of Rome, established in 1968 at Accademia dei Lincei in Italy (Meadows et al., 1972). John McLeod, founder of Society for Computer Simulation International (McLeod 1968, 1986; McLeod John & Suzette, 1974; Clymer 1969, 1980, 1994; House & McLeod 1977), established another important example of such initiatives, named "Mission Earth". The initiative was focused on development of new simulators capable to address in the innovative way concepts used in World Simulation Game and support development of new strategies (Fuller 1969). As mentioned, notable example of a project development in this framework is GENI, which was related to solve the problem of power distribution in a global scale in order to support world development (McLeod 1999; Clymer A. 1993; Clymer M. & Mechoso 1997). Hence, it is clear that understanding of M&S as well as some of supporting technologies were known for many years, however, for many reasons, from limited understanding and up to difficulty in data acquisition, their development and utilization was mostly performed by volunteers with scientific background. In contrary, nowadays, big amount of available data, possibility of cooperation between scientists and interoperability of various models allowed to develop new generation of solutions as well as to distribute them between many users, providing "Service to the Society" by means of M&S.

These considerations open a new question: "so why we don't do all this marvelous use of simulation if it is possible?". To understand this issue it is important to consider mentioned characteristics of technological enablers, for instance, the technical possibility to combine different models is indispensable in context of complex strategic problems (Bruzzone et al. 2014). In fact, if we analyze the mentioned case of worldwide power distribution, it is clear the necessity to combine models, which address different aspects of civilization and society, from quality of life and up to politics.

One of open technological issues is related to the fact that even in case of utilization of consolidated, since many years, interoperable simulation standards, such as HLA (High Level Architecture), it is still difficult to integrate simulators (Kuhl et al.2000; Bruzzone & Massei 2017). Indeed, the standards are mostly related to the technological aspects of interoperability while missing the conceptual ones (Bruzzone et al. 2017a), at the same time, some programming aspects, especially the ones which affecting reliability, need to be improved (Bruzzone 2017). Another important aspect is related to the human factor, which is quite difficult to model considering its stochastic nature (Bruzzone et al. 2015). As mentioned, another major issue is quantity and quality of available information: while in the past it was difficult to obtain it due to limited data sources, now it possible to collect and transmit it in quasi-real time. Hence, it is possible to elaborate, check, validate and filter as well as to extrapolate information, which in practice, was not possible in the past (McAfee et al., 2012, Sanchez, 2014).

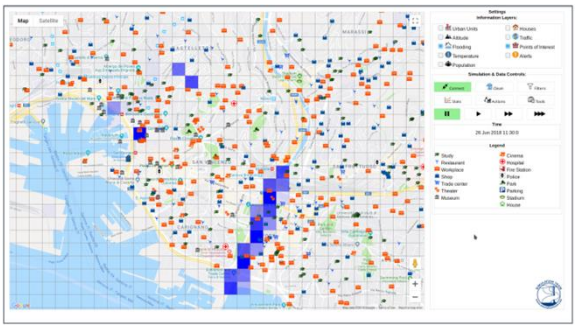

Figure 1. Decision Theater GUI

Considering all mentioned factors, it is important not to underestimate recent advances in AI (Artificial Intelligence) based algorithms, which significantly changed approach to data elaboration (Wu et al., 2014; Najafabadi et al., 2015). Furthermore, it is important to take into account new ways to utilize technologies as well as their perceptions by new generation of users. In fact, new mobile solutions are widely operated by people without specific preparation or knowledge, hence, in order to benefit from such equipment and provide MSaaS (Modeling and Simulation as a Service) or cloud services (Li et al.,2010; Cayirci 2013) it is necessary to improve their reliability, immersive capability and interactivity.

Considering the analyzed issues it is clear that despite huge capabilities of simulation, the community as well as scientists and developers have to work hard in order to make M&S more usable and reliable. In the last years to address such issue, it was proposed an MS2G paradigm, which highlights necessity of immersive solutions rather than technically perfect representation of the reality, allowing to regular users to understand and utilize M&S solutions. At the same time, it is fundamental to consider the importance of preparation of final users and creation of multidisciplinary teams (Elfrey 2006; Bruzzone et al.2014b, 2017b). For instance, such goal could be achieved by introduction of new educational programs to support evolution of potential users. While considering actual opportunities it is important to forecast future challenges. In fact, complex scenarios created by MS2G combined with modern technologies (e.g. Data Science, AI & Machine Learning, Internet of Everything) allow to create an innovative context, creating in the same time new challenges. In fact, technological evolution must never be underestimated. For example, some technologies, such as GPS and autonomous driving systems were operational since 90's, however, available data was very limited and algorithms much simpler, allowing to vehicles only to plan routes without considering many important aspects such as traffic (Varaiya 1993; Bart et al. 1996). In contrary, nowadays it is common to see compact and light smartphones capable to identify with high precision optimal path, providing in the same time tips to the user, for instance, information about points of interest (Kim 2017; Wan et al., 2016).

For example, nowadays it is expected from the simulation not only to analyze several important world-

level scenarios, but also to support decision makers at all levels, optimizing costs and improving efficiency. At the same time, application of MS2G paradigm could improve trustiness between institutions and population by providing easy to understand and utilize models while proposing various solutions of everyday problems (Bruzzone et al.2014b). For instance, it could be possible to utilize M&S to compare, check and validate solutions proposed by different leaders, allowing to citizens to make their own proposals and improving reactions of decision makers at changing conditions and situations. In order to provide an example of this kind of M&S solution it is possible to mention an ongoing project the authors are working on, which is related to crisis management support and currently utilized by different authorities involved in traffic management in Genoa after the collapse of "Morandi Bridge" (Harding 2018). In this case, the initial model, which was developed as part of Decision Theater project with the aim to support strategic urban planning and to address typical for Genoa issues related to flooding, was adopted to extend its capability to simulate road traffic (Bruzzone et al.2017b). The project was finalized in the end of 2017, which means that at the day of the tragedy the public administration had already available model of the city (fig. 1). At the same time, it is necessary to understand possible consequences of improper use of simulation, making it necessary to address not only technical but also ethical issues (Oren et al., 2002; Balci, 1997). In fact, not validated or deliberately corrupted models could lead to wrong decisions. Furthermore, in case if the end user does not have understanding of subject, the misused simulation could provide invalid results. For instance, in case of garbage collection optimization without considering necessities of the population, it could cause even reducing of efficiency. This because the solution should be related not only to optimization of garbage truck route, but to more sensitive factors; for instance in some countries it is common to pay back for empty bottles (Huang et al., 2005; Duma & Nemeslaki 2013).

3 SOLUTIONS

As mentioned, one of new enabling concepts in M&S is MS2G, which allows to develop new solutions capable to benefit from synergy of these methodologies, namely interoperable simulation and immersive capabilities, typical for serious games. Furthermore, MS2G allows the users to become decision makers with corresponding time and resource constraints (Bruzzone 2018). In this case, it could be useful to provide interoperability between different models, at the same time, maintaining controls on fidelity of single components. To address issues related to improper use of the simulation, it is necessary to train and educate people in strategic view. Obviously, a special strategic 'forma mentis' and properly balanced multidisciplinary preparation are required to fully take advantages provided by modeling and simulation.

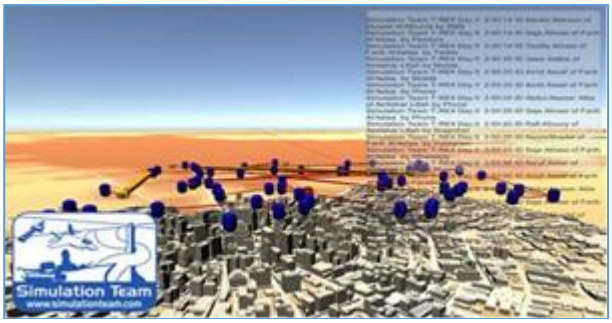

Figure 2. Hybrid Warfare Simulation for Strategies

Furthermore, it is clear that one of the key issues in this case is related to availability of personnel with required skills and experience. For this reason, new initiatives such as STRATEGOS, master program in strategic engineering recently activated at the Genoa University (www.itim.unige.it/strategos), are aimed to address such issue. Indeed, STRATEGOS is devoted to prepare a new generation of engineers capable to support decision makers. One of important problems of the M&S, which to be addressed, is related to mentioned ethics of the simulation. For example, new solutions are capable to predict behavior, analyze communications and biodata. However, as said Mahatma Gandhi, "freedom is not worth having if it does not include the freedom to make mistakes"; obviously, improper utilization of such technologies could give possibility to control single individuals or groups, cause mass computational intelligence, otherwise to predict and influence evolution of entire society as it happen with psychohistory (Asimov 1951); it is clear that such scenarios are not so good for the humanity. These issues are already analyzed in scientific literature, highlighting the importance of proper utilization of technologies maintaining in the same time pragmatic approach (Duderstadt 2005; Blackmore 2006, Barrat 2013).
It is difficult to find the final solution, however, it is clear importance of identification of such problems as early as possible. In fact, human being is able to be responsible and to act ethically, to lead for equality and freedom and to make right decisions despite consequences.

4 STRATEGIC ENGINEERING

As analyzed, strategic engineering could be one of many potential solutions of actual and expected problems in the field of Decision Support. In fact, the main goal of the course is to create multidisciplinary framework with strong scientific foundations, that could allow to prepare experts and create new interoperable and interconnected models, hence, it is evident the necessity of synergy with such paradigms as MS2G (Bruzzone 2018). In fact, such engineering approaches allow to develop strategies in various fields, such as Industry, Business, National and International Activities, Defense and Homeland Security.

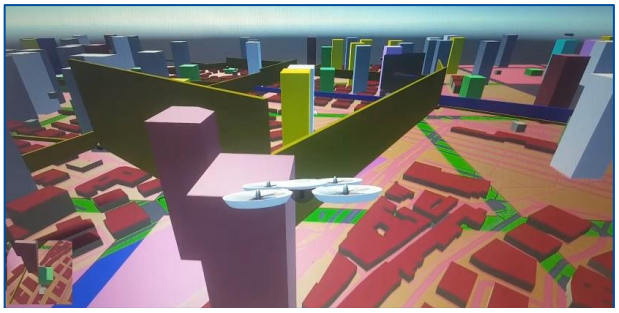

Figure 3. ARPIA

Obviously, if used by a strategic engineer, such technologies as M&S, Data Analytics, AI, IoT and cloud based solutions allow to solve numerous complex problems in these fields. For these reasons, in order to improve efficiency of problem solving, it is necessary to consider not a single technologies and concepts, but their effective synergy, such as the one which could be achieved between MS2G and Strategic Engineering, reaching another level of decision making and complex problem solving. In fact, well prepared personnel with best available tools is capable to develop new strategies in numerous sectors, especially if multidisciplinary elements are indispensable to succeed (Elfrey 2006). Hence, it is necessary to define and develop capabilities and skills required for strategic engineering, create educational programs which would benefit from collaboration between scientific institutions, industry and public administration in order to train new specialists to develop and utilize new methodologies and instruments (Bruzzone 2018). In order to provide examples of solutions, which benefit from synergy of MS2G concepts and multidisciplinary approach, it is possible to consider following applications:

ARPIA: MS2G in Urban Strategic Planning

ARPIA (Augmented & virtual Reality for Population modeling based on Intelligent Agents) is an interoperable Simulation Environment which utilizes different Simulation Models and IA-CGF to reproduce City Dynamic Evolution as well as People Consensus and Population Behaviors in different boundary conditions, for instance, during normal everyday life otherwise in case of crisis, figure 3. (www.itim.unige.it/projects/arpias.html).

T-REX: MS2G in Homeland Security

T-REX (Threat network simulation for REactive eXperience) is an example of MS2G dedicated to analyze different types of mission environments, such as Homeland Security and Hybrid Warfare; indeed, T-REX supports HLA interoperability standard and capable to be federated with other elements to evaluate different aspects and their interactions (e.g. economics, finance, politics) even through interoperability among models, figure 2 (www.liophant.org/projects/t-rex.html).

SO2UCI: MS2G for Defense & Cyber Warfare

SO2UCI (Simulation for Off-Shore, On-Shore & Underwater Critical Infrastructure) is a Simulation for Vulnerability Reduction in Critical Infrastructures considering direct/indirect impacts & multiple domains (www.itim.unige.it/projects/so2uci.html)

These examples highlight advantages of combining multidisciplinary approach and MS2G paradigm; a possible way to achieve it could be by means STRATEGOS educational programs. In fact, considering complexity of the world, today strategic thinking and strategy development are key competitive factors. In this context, strategy means ability to handle numerous variable factors, take into account their uncertain nature, consider scalability, extensibility and dependability. Good statement which confirms these considerations was done by Ma Yun (also known as Jack Ma) co-founder and executive chairman of Alibaba: "If you want to grow, find a good opportunity. Today, if you want to be a great company, think about what Social Problem you could solve". In fact, following of these strategies allowed Alibaba to grow in net revenues in one month by 56%, achieving 23.8 GUSD revenues and 6.2 GUSD profits. Hence, it is clear impact of proper strategy and quantitative analysis of various data in the field of complex systems.

Despite these considerations, nowadays there are only several Master Programs in the world, dedicated to strategy development, multidisciplinary preparation and utilization of M&S and innovative enabling technologies. Indeed, in the world of today, engineering is more than designing of new systems, technologies and products, now it requires to identify and develop new strategies, processes, solutions and organizations. These considerations are especially important considering that due to quite long life cycle of innovative systems, to forecast their behavior it is necessary to consider many variables, different scenarios and uncertainties. At the same time, proper M&S approach and quantitative analysis are fundamental for the final success. However, nowadays these strategic aspects are addressed by traditional approaches, performing qualitative static analysis of the problem, omitting opportunities provided by modern M&S, AI and data acquisition solutions, capable to address same problems in more effective dynamic way.

Indeed, the aim of this initiative is to setup an innovative international engineering master program, which would benefit from synergy of mentioned technologies and approaches, address in the new way decision support. These results could be achieved by strategic engineering, with deep scientific knowledge and technical skills, capable to develop, tailor, assess and utilize innovative strategic methodologies.

The outcome profile of this master is expected to operate in various domains, from manufacturing and engineering and up to military sector and society development, being capable to design new methodologies, apply strategies and utilize appropriate models (Bruzzone 2018).

CONCLUSIONS

In this paper it is presented an innovative approach to combine new simulation paradigms such as MS2G with the Strategic Engineering, a new discipline arising from the necessity to combine enabling technologies in decision support; it is evident that this potential could allow to prepare a new generation of engineers to address the future challenges by using simulation as strategic science to model and investigate complex systems. In addition, it is also outlined the opportunity for Government, Institutions and Companies to enroll these new engineers into their staffs and also to support the development of new educational initiatives in this sense. Indeed, it is proposed a new master program, which would benefit from this approach and will use simulation as main support tool to sustain education in this field. Furthermore, critical issues, opportunities and requirements relate to this combination are proposed in relation to real case studies, where the approach was successfully applied in a wide spectrum of sectors from defense to homeland security and industry.

REFERENCES

Asimov (1951) “Foundation”, Gnome Press, NYC

Blackmore, S. (2006). Conversations on consciousness. Oxford University Press, UK

Balci, O. (1997, December). Verification validation and accreditation of simulation models. In Proceedings of the 29th conference on Winter simulation (pp. 135-141). IEEE Computer Society.

Barrat, J. (2013). Our final invention: Artificial intelligence and the end of the human era. Thomas Dunne Book, Macmillam, NYC

Bruzzone A.G. (2018) “MS2G as Pillar for Developing Strategic Engineering as a New Discipline for Complex Problem Solving”, Keynote Speech at I3M, Budapest, September

Bruzzone A.G., Massei M., Longo F., Maglione G.L., Di Matteo R., Di Bella P., Milano V. (2017) "Verification and Validation Applied To an Interoperable Simulation for Strategic Decision Making Involving Human Factors", Proc.of WAMS, Florence, September

Bruzzone A.G., (2017) "Smart Simulation: Intelligent Agents, Simulation and Serious Games as enablers for Creating New Solutions in Engineering, Industry and Service of the Society. Keynote Speech at International Top-level Forum on Engineering Science and Technology Development Strategy- Artificial intelligence and simulation, Hangzhou, China

Bruzzone A.G., Agresta M., Sinelshchikov K. (2017a) “Simulation as Decision Support System for Disaster Prevention”, Proc. of SESDE, Barcelona

Bruzzone A.G., Massei, M. (2017b) “Simulation-Based Military Training”, in Guide to Simulation-Based Disciplines, Springer, pp. 315-361

Bruzzone A.G., M. Massei, F. Longo, L, Nicoletti, R. Di Matteo, G.L.Maglione, M. Agresta (2015) "Intelligent Agents & Interoperable Simulation for Strategic Decision Making On Multicoalition Joint Operations". Proc. of DHSS, Bergeggi, Italy

Bruzzone A.G., Massei M., Agresta M., Poggi S., Camponeschi F. & M. (2014) "Addressing strategic challenges on mega cities through MS2G", Proc. of MAS2014, Bordeaux, September

Bruzzone A.G., Massei, M., Tremori, A., Poggi, S., Nicoletti, L., & Baisini, C. (2014a) “Simulation as enabling technologies for agile thinking: training and education aids for decision makers” International Journal of Simulation and Process Modelling 9, 9(1-2), 113-127

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", Proc. of WAMS, Istanbul, September

Cayirci, E. (2013, December). Modeling and simulation as a cloud service: a survey. In Proceedings of the 2013 Winter Simulation Conference: Simulation: Making Decisions in a Complex World, IEEE

Barth, M., Johnston, E., & Tadi, R. (1996). Using GPS technology to relate macroscopic and microscopic traffic parameters. Transportation Research Record: Journal of the Transportation Research Board, 1520, 89-96.

Duderstadt, J.J. (2005). A roadmap to Michigan's future: Meeting the challenge of a global knowledge-driven economy, National Academy Press, Washington, D.C.

Clymer, A.B. (1993, December). Applications of discrete and combined modeling to global simulation. In Proceedings of the 25th conference on Winter simulation (pp. 1135-1137). ACM.

Clymer, A.B. & Mcleod, J. (1993) “Mission Earth Symposium”, Summer Computer-Simulation Conference, San Diego, July 18-20

Clymer, A.B. (1994). " Mission Earth Symposium: World Simulation for Education”, Proc. of the National Educational Computing Conference, Boston, June 13-15

Clymer A.B. (1980). Simulation for training and decision-making in large-scale control systems: Part 1: Types of training simulators. Simulation, 35(2), 39-41.

Clymer, A. Ben (1969, April). The Modeling and Simulation of Big Systems. In Proceedings of the Pittsburgh Simulation and Modeling Conference.

Clymer, M.G., & Mechoso, C. R. (1997) “Mission Earth: Modeling and Simulation for a Sustainable Global System”, Proc. of the Western Simulation Multi Conference, SCS, Phoenix, January 12-15

Duma L., Nemeslaki A. (2013) “Of Aluminium, Recycling and the Homeless: A case study of technology driven social inclusion”, Proc. of EGPA Annual Conference, Edinburgh, September

Elfrey P. (2006) “Moving out the Planet”, Invited Speech at Summer Sim, Calgary, Canada, July

Fuller, R. B. (1969). The World Game. Ekistics, 286-292

Harding J. (2018)“CCTV shows Genoa bridge collapse”, BBC News, August 21

House, P. W., McLeod, J (1977). Large-scale models for policy evaluation. John Wiley & Sons, NYC

Huang, G. H., Linton, J. D., Yeomans, J. S., & Yoogalingam, R. (2005). Policy planning under uncertainty: efficient starting populations for simulation-optimization methods applied to municipal solid waste management. Journal of Environmental Management, 77(1), 22-34.

Kim, J. H. (2013) “Universal GPS traffic monitoring system”, U.S. Patent No. 8,386,157, U.S. Patent and Trademark Office, Washington, DC:

Kuhl, F., Dahmann, J., & Weatherly, R. (2000). Creating computer simulation systems: an introduction to the high level architecture. Upper Saddle River: Prentice Hall PTR

Li, B. H., Zhang, L., Wang, S. L., Tao, F., Cao, J. W., Jiang, X. D., ... & Chai, X. D. (2010). Cloud manufacturing: a new service-oriented networked manufacturing model. Computer integrated manufacturing systems, 16(1), 1-7

Longo, F. (2011). Advances of modeling and simulation in supply chain and industry, Simulation, August 26

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D. J., & Barton, D. (2012). Big data: the management revolution. Harvard business review, 90(10), 60-68.

McLeod, J. (1999). Simulation as a Possible Tool for Peace. Simulation, 72(5), 348-352.

McLeod, J., & McLeod, S. (1995) “Mission Earth And The Big Bird From The Ashes”, Simulation, SCS, vol.64, n.1, June 1

McLeod, J. (1986). Computer modeling and simulation: The changing challenge. Simulation, 46(3), 114-118.

McLeod, J. (1968). Simulation: the dynamic modeling of ideas and systems with computers. McGraw-Hill.

McLeod, John & McLeod Suzette (1974) “Simulation in The Service of Society: World Simulation Organization”, Simulation, SCS/SAGE, April 1st, doi.org/10.1177/003754977402200412

Meadows, D. H., Meadows, D. H., Randers, J., & Behrens III, W. W. (1972). The limits to growth: a report to the club of Rome (1972). Google Scholar

Najafabadi, M. M., Villanustre, F., Khoshgoftaar, T. M., Seliya, N., Wald, R., & Muharemagic, E. (2015). Deep learning applications and challenges in big data analytics. Journal of Big Data, 2(1), 1.

Oren, T. I., Elzas, M. S., Smit, I., & Birta, L. G. (2002, July). Code of professional ethics for simulationists. In Summer Computer Simulation Conference (pp. 434-435). Society for Computer Simulation International; 1998.

Sanchez, S. M. (2014, December). Simulation experiments: better data, not just big data. In Proceedings of the 2014 Winter Simulation Conference (pp. 805-816). IEEE Press.

Varaiya, P. (1993). Smart cars on smart roads: problems of control. IEEE Transactions on automatic control, 38(2), 195-207

Wan, J., Liu, J., Shao, Z., Vasilakos, A. V., Imran, M., & Zhou, K. (2016). Mobile crowd sensing for traffic prediction in internet of vehicles. Sensors, 16(1), 88

Wu, X., Zhu, X., Wu, G. Q., & Ding, W. (2014). Data mining with big data. IEEE transactions on knowledge and data engineering, 26(1), 97-107

TEMPUS FUGIT: TIME AS THE MAIN PARAMETER FOR THE STRATEGIC ENGINEERING OF MOOTW

***Agostino Bruzzone*[(a)]*, Paolo Di Bella*[(b)]**

[(a)] DIME, Genoa of Genoa

[(b)] DIMS, PhD Program of Genoa University

[(a)] *agostino@itim.unige.it*

[(a)] *paolo.dibella@liophant.org*

[(a)] *www.itim.unige.it/strategos*

[(a)] *www.liophant.org/projects*

ABSTRACT

This paper reviews, based on current operations, some of the critical issues to be addressed in order to develop a strategic capability based on innovative technologies. Indeed the aspect of time and timing is outlined as one of the main factors that lead to success as it is well known not only in military operations, but even in common life.

It is evident that the approach proposed based on introducing science and models into this context emerges as one of the crucial elements to succeed, as well as the necessity to let decision makers and experts to interact within common immersive and intuitive interactive simulation frameworks. These considerations suggest the need to develop strategic engineering as a new discipline addressing these issues and preparing new generations of decision makers and scientists**.**

INTRODUCTION

Observing the world and history is a great teacher and could help into identify gaps and opportunities; indeed today technologies sound as great enablers, however it is very important to decide how to use and to shape new solutions. From this point of view this paper goes into evaluating up-to-date situations as well as consolidated knowledge to identify a need for developing new capabilities based quantitative approaches. One of most popular books on strategy, dating back to 500 BC, states:

夫未戰而廟算勝者，得算多也；
未戰而廟算不勝者，得算少也；
多算勝，少算不勝，而況於無算乎？
吾以此觀之， 勝負見矣。

Figure 1 – T-REX as support for Hybrid Warfare

Indeed Sun Tzu define the importance of completing proper quantitative analysis by saying that "*the general who wins a battle makes many calculations in his temple ere the battle is fought.*

The general who loses a battle makes, but few calculations beforehand. Thus do many calculations lead to victory, and few calculations to defeat: how much more no calculation at all! It is by attention to this point that I can foresee who is likely to win or lose".

It is evident that today, the calculation capability mentioned by Sun Tzu relies on advanced modelling and simulation used to support decisions as well as on data science and smart techniques to support decisions. These aspects are obviously fundamental in war, but even in other mission environments as well as in industrial business and it is fundamental to guarantee access to this capability by preparing the "calculation" systems, the people that have to operate and feed them as well as the decision makers that should be able to get benefits from their usage.

Indeed this paper presents the related considerations and propose an approach to develop new capabilities in strategic management in operations other than war.

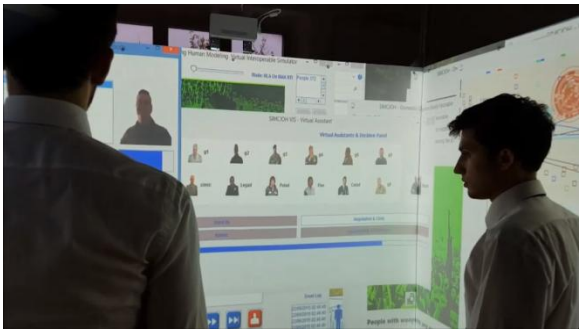

Figure 2–Cooperative Decision Making in SIMCJOH

In facts one of the most scares resource in developing strategies is often the Time and this paper consider it in its wide definition including physical and human phenomena that affect execution of plants; it is evident that Time could often make difference between success and failure respect strategy development.

MODELS FOR SUPPORTING STRATEGIES

In facts the main goal of this paper is to consider the issues related to Time within different kinds of operations with special attention to Military Operations Other Than War (MOOTW) and to consider it respect other Measures of Merits (MoM). From this point of view, it is interesting to consider the potential of a new emerging discipline such as Strategic Engineering in supporting achievements of strategic goals respect existing risks and stochastic factors, especially into unusual mission environments such international mission, asymmetric or hybrid warfare. It is important to outline that these context have been already investigate by the authors in terms of creating simulation solutions able to support analysis as well as new doctrine development respect complex mission environments (Bruzzone et al.2016); these results have been presented both to Nations and NATO and resulted a successful example of models that could be effectively used for creating a Strategic Engineering Capability; in figure 1 is proposed the T-REX Simulator operating from a an immersive interactive interoperable solution developed by Simulation Team is proposed to allow analyst to investigate a complex scenario involving threat networks population behavior, cyber warfare, critical infrastructures (i.e. power grid, oil resources, water resources), autonomous systems on both side.

In this sense the authors participated in experimentation of innovative solutions based on new paradigm MS2G (Modeling, interoperable Simulation and Serious Games) devoted to support Commander and his staff in Strategic Decision Making respect SIMCJOH Project (Di Bella 2015). Figure 2 propose the example on how cooperative decision making is carried out immersed in the Time of Scenario Dynamics by interacting with the simulator and population behavior as well as with the virtual humans representing Commander's staff (Bruzzone et al. 2015)

COMMON SENSE, QUOTES & PROVERBS FROM THE PAST

In many cases, people think that *common sense* can solve most of the problems; in facts this assumption could be true in several contexts, but we have to consider that *common sense* is a very rare gift and that, usually, we should rely on techniques and methodologies to find solutions considering most people don't have a speak of *common sense*.

As starting point it could be interesting to remind the definition of *Strategy*; the word derives etymologically from Greek and results from combining στρατός (army) and ἄγω (leading); indeed based on classic definitions the *Strategy* relies on capability to develop effective plans able to achieve success in challenging situations such as business, politics, war, etc. Looking back to quotes from the past a very good definition is provided by General Jomini in his "Prècis de l'Art de la Guerre" (1838AD): ""La Stratégie est l'art de bien diriger" (Strategy is the art of well leading"). Therefore modern experts of strategy since over two centuries point out very actual problems in this context; indeed it is really shocking to read the following statement by Carl Von Clausewitz, as written in the book edited by his wife Marie (1832AD): "*We need a philosophy of Strategy that contains the seeds of its constant rejuvenation, a way to chart strategy in an unstable environment*".

Now the necessity to develop a conceptual approach and methodologies to continuously control strategy evolution respect a very dynamic and unstable environment, makes it evident the actuality of this consideration.

If we look to the words of one of the major text in strategic planning, Militarische Werke (Von Moltke, 1871) it is clearly outlined the challenge to keep plan up dated respect evolving situation and the need to proper develop this capability:

"*Strategy is a system of expedients*"

"*No plan of operations extends with any certainty beyond the first contact with the main hostile force*"

In addition to hostile force dynamics, it should be even consider the difference on mission environments requiring specific approaches and avoiding possibility generalize single case.

Indeed, in 1926, the Russian Commander and Professor, Aleksandr Svechin, wrote in his book on Strategy that "*it is extraordinarily hard to predict the conditions of war. For each war it is necessary to work out a particular line for its strategic conduct. Each war is a unique case, demanding the establishment of a particular logic and not the application of some template*". So the knowledge of these aspects was known since millennia and the theory was formalized centuries ago; however it seems even today we have problems in real operations; for instance many modern results into a mess based on external view, such happen in the past in Korea, Vietnam, Gulf Wars (Betts 1978, Mueller & Mueller 1993; Summers 2009; Pauly 2017). From this point of view even humanitarian operations and large plan often fail in many contexts even related to small regions when resource applied appear to be huge (Muchemi 2017; Bruzzone et al., 2017); sometime it seems we are very focused on short terms objectives or detailed aspects missing the real strategic perspective, or vice versa, we look to satisfy so many inter-related factors generating not satisfactory results. From this point of view it is interesting to remind a very well know proverb "*cannot see the forest for the tree*"; indeed this sentence evolved from an old statement "*I see, ye can not see the wood for tree*", dating back almost 5 centuries as reported by John Heywood. Indeed if we look at recent operations based on very sophisticated equipment and infrastructures and well trained resources we are usually so focused on detailed planning that we miss the whole picture and the limited success achieved. From an opposite point of view, a common objection to people stating that the apparent failures and difficulties into achieving strategic goals is related to the real complexity of the problems. This topic is even more popular nowadays, in a period where political and cultural movements, currently defined as "populist", apply severe simplifications often without strong foundations, in some way emotionally reacting to partial/total failure of strategic management carried out over years by Institutions and qualified Experts. Currently as reaction against this attitude, it is becoming very popular among experts the sentence "*complex problems have simple, easy to understand wrong answers*"; this is usually known as Grossman's Law and results from *misquoting* Mencken's phrase "*for every complex problem, there is a solution that is simple, neat, and wrong*". Now, this absolutist statements are currently promoted by opponents of *populism* reacting exactly on the same mood, in facts such assumption sounds questionable as "*involution*" of a much more acceptable sentence "*we should be careful about simple solutions to complex problems*" (Statell 2014). Despite author's personal point of view and the evidence that we need good capabilities and skills to solve problems, it is important to consider that thinking back to history we can find many cases where simple solutions solved pretty complex problems; the most well know case, still mentioned today as example, date back to the Gordian Node, a problem pretty complex solved by Alexander with a single slash of his sword as reported by Arrian of Nicomeda, 2'300 years ago.

This considerations is willing to allow readers to reject all polarized approaches such as Black/White, or Simple/Compex, but to apply lateral thinking realizing that things need to be analyzed considering their specifc nature and characteristics; from this point of view the example of Alexander the Great, not just Gordian node, but his whole life, propose us a man born into a court where assassinations and intrigues were so common and complex that the capabilities required to survive were gigantic; so despite the simplification of Alexander as a "great general" and "gifted horseman warrior" it is an evident simplification, considering that his capabilities were much more articulated just to allow him to survive in early years; without to mention that when he obtained the power on his kingdom he resulted capable of transforming "phalanxes" into an army able to travel the world and conquer gigantic empires, usually located at a distance that today could require over 2 months by forced march on roads that at his time don't even exist. This consideration leads to point out that the complexity on past time was not at all so little respect our modern world, so we should not complain on this argument as an excuse for failing in strategic plans nowadays. Another aspect to be mentioned is the problem in taking decisions due to the necessity to satisfy a too wide community of heterogeneous stakeholders;, even in this case another contestable sentence is that we have "*too much democracy*" and that dictatorship systems are more efficient; indeed the importance to have a common plan and single mind in charge is well know, anectodes about Sun Tsu role assignment by Emperor Ho-Lv of Wu or even more the Dictator role that Roman Republic was assigning pro tempore at a very high qualified person to serve as magistrate entrusted with the full authority of the Republic and to face a military emergency or a crisis (Livy 2012, Jones 2015). Therefore the success of strategies does not rely on just dictatorship approach and there are many historical cases that confirm this aspect. The current main problem related common decision making is related to the short terms goals versus long terms achievement and the necessity to satisfy a too wide audience of supporters without capability to lead them.

Figure 3 – CIMIC PSYOPS Interoperable Simulation

Indeed this is exactly a lack of leadership and strategy that, as we said before, lays on leading capability. In facts the western organizations that evolved along the last two centuries have been based on democratic principles obtain great strategic success in many applications; along the years their public opinion as well as general feeling reinforced the concept of fairness, however recently for many reasons, including media manipulation and social network capabilities, we observed a polarization of public opinion on few superficial positions.
This obviously was caused also due to the restriction of "*ideals*" that currently it is strongly concentrated just on individual success and profit with quick and dirt approach based on short time and superficial view missing most of traditional ethical considerations; indeed this attitude is pretty common in declining societies where there is not need to be active and to fight for resources (Gibbon 2017; Gordon 2017). These boundary conditions lead to create a framework where people don't have too much interest in common enterprises, education and training, so they focus on their specific activities loosing trustiness in Institutions and result even more easy than in the past to be manipulated and divided. From some point of view we capsized the original meaning of the Latin sentence "divide et impera" into a new one "divide et from a way to create fractions in opponents to a way to block any decision "divide et cunctare"; this means that we shifted from creating division in opponents to rule over them to a reality where we subdivide in multiple petulant group that just hesitate to finalize any decision.

STRATEGIC ENGINEERING & STRATEGIES

Currently is emerging a new discipline defined as Strategic Engineering that represent comprehensive approach to design, develop and use new solutions in order to achieve strategic results against risks, uncertainty, competitors, threats and within critical environments (Bruzzone 2018). Indeed Strategic Engineering is based on the integrated use of innovative technologies such as M&S (Modeling and Simulation), AI & IA (Artificial Intelligence and Intelligent Agents) and Machine Learning as well as Data Science to face Challenges & Uncertainty in Complex Systems and have a wide spectrum of application fields from Defense to Homeland Security, from Government to Industrial Applications; obviously these capabilities are based on enabling technologies and advances that make possible to collect, analyse and process data in models as it was impossible in past years. Therefore strategic engineering addresses also the crucial issue to create transdisciplinary teams where scientists and decision makers could work together, so it requires an evolution on the skill and methods in use within these categories (Elfrey 2006;). Obviously new Education and Training (E&T) programs in this area will be necessary to prepare new generations to get benefit of this integrated approach.

TIME AS CRUCIAL ELEMENT IN STRATEGIES

Among all challenges in Strategy Development, it is evident that one of most crucial element is represented by Time as well as in the capability achieving specific results quickly and in correspondence to the planning; these elements represent probably one of most crucial element for the final success. Indeed, despite the impossibility to generalize cases, already mentioned, it is evident that examples are very useful to improve general understanding if the above mentioned considerations are kept in mind; so in the following some of these considerations are proposed. Today, a disgruntled Public Opinion in the Western Countries is witnessing the 17th year of the US and NATO intervention in Afghanistan. In such contest, Time, considered both in its physical and human perception dimensions, looks like a neglected factor in the political and military analysis in the Western Countries. This is witnessed by the current statements of US and NATO officials, which are putting the emphasis on "conditions based" end of both Resolute Support (NATO) and Enduring Sentinel (US) operations in Afghanistan rather than time lapse. Sometime it could seems necessary to adopt this approach for the achievement of the missions objectives, therefore it is evident that it could potentially introduce big risk of wasting a scarce resource in conflicts such as Time, marking a turn down in its comprehension and management.
However Time, intended as physical and human phenomena, it is ineludible and its eventual mismanagement poses serious hindrances in strategy development.

As anticipated, the purpose of this paper is to propose a time management in military operations vs other measurable indexes of effectiveness, by the contribution of the surging discipline of Strategic Engineering, which has the potential to achieve strategic results against risks, uncertainty in the management of Military Operations Other Than War (MOOTW) and other types of Asymmetric confrontation.

CHALLENGING SCENARIOS EXIST

There are examples of regions, along centuries, that resulted in very challenging scenarios for military operations. Classical cases could be found from Russia (e.g. Russian Campaigns from Napoleon to World War II) to Vietnam (e.g. Vietnam War, Sino-Vietnamese War) and it is quite possible to observe that the geographical region in terms of terrain and population spirit result to have a fundamental role against opponents even when they belong to a major well trained force (James & Davies 2018, Fuller 2018; Goscha 2017; Sardesai 2018).

Afghanistan is another good example of a region able to provide many troubles to several strong players such as British Empire, Soviet Union and even NATO; this was going along many different conflicts in different times, such as Anglo Afghan War, Afghan Civil Wars, War in Afghanistan (Jalali 2017), Therefore it is interesting to note that in previous centuries, when satellite and drones were not even a dream, Alexander the Great, Genghis Khan and Timur achieved success in the same region by applying each one quite different approaches; as anticipate we don't want to over simplify, but it is evident that strategy could be successfully applied even in challenging scenarios.

A MODERN EXAMPLE: AFGHANISTAN

Let consider a brief exposition of the current situation in Afghanistan in these day (from Press and OSINT).

Nowadays, US Government feels indeed the necessity to bring to a close a 17-year-old war, even though its efforts seems to be jeopardized by the political upheaval in Kabul and the stalemate in the confrontation between Insurgents (Taliban, ISIS K etc.) and the International Community - backed Government of the Islamic Republic of Afghanistan (GIROA). "*Throughout the ups and downs of this conflict, it's become evident that the United States is not going to defeat the Taliban insurgency, even though it can prevent a Taliban victory*" (The Washington Post, 1st September 2018).

The use of local forces to fight the opponent reducing friction for NATO force is effective from some point of view, but strongly affect capabilities on the terrain and affect the trustiness of the different players in a way that could lead to future crisis.

From another perspective, the purely *Train, Assist and Advice* mission carried out by NATO in favor of Afghan Security Forces, named "*Resolute Support*", it is showing instead signals of stability for what concern the presence of NATO troops, even though such cannot be reasonably assessed as timeless.

This case so it is a good example of how quantitative analysis based on reliable models should be applied to consider human factors and timing in strategy development. Indeed the authors were involved, respectively as Project Leader and Military Expert, in the development of innovative M&S solutions applied to Kapisa region in Afghanistan to support operational planning for CIMIC and PSYOPS in strong connection with the general plan. The simulator CAPRICORN was a stochastic simulator, federated with other HLA models and able to reproduce CIMIC and PSYOPS operations as well as their interactions with the human factors of the whole population in the region as well as military units, paramilitary entities and insurgents as proposed in figure 3 (Bruzzone 2013).

TIME MANAGEMENT IN MOOTW

It was already clearly stated that Time is the major aspect in strategy development; now we have to consider the specific concepts of Time Management in War (Warfare) and MOOTW.

In the Modern era, Napoleon should be credited as the first modern Strategist that derived from the management of the forces on the battlefield an insight about "….the vital significance of time and its accurate calculation in relation to space. The loss of time in war is irreparable, in war; Space you can recover…time never, he once asserted" (Chandler 1966). In the contemporary age, the credit to have re-introduced meaningful considerations about time and its impact in the military operations have to be given to Robert R. Leonhard, which elaborated the concepts in his opera "Fighting by minutes: Time and the Art of War", (Leonhard, 1994)

Indeed based on this considerations, Time could be considered as the leading factor in the Strategic Engineering analysis of MOOTW, with a clear distinction between time required vs time available. This is especially true in conditions where the asymmetric threats could obtain support from local population and get reinforced while regular forces are worn down; obviously this situation could be capsized by getting support of the population, condition that is hard to achieve in case of time delay

in operations and long term warfare as happen in other scenarios (Galula 2002, 2006).

As such condition happen, as in the case of Afghanistan, the Time turns to be a decreasing resource for the Western Powers (WP), which are affected by internal public opinion, current alliances framework and neighboring country attitude, and last but not least, economic sustainability.

The consideration about Time drives the desired END State. For instance while to Short Time correspond the military classic confrontation-symmetric warfare; on Long time the Nation evolve into a MOOTW or Civil Wars frame. Both of them as a certain point could potentially crash against the available Time resource. Obviously this resource is not known in advance, and it is continuously decreasing. Indeed currently the authors are considering to develop a model that hazards a correlation among the time necessary to reach the END STATE and the most critical parameters; among these it is considered for sure the human development index of the Country to be stabilized, the GDP of the intervening country, the intervention limit threshold, identified in terms of power (e.g. task force, battlegroup, etc.) beyond which the level of commitment of the intervening nation is subject to the scrutiny of public opinion. All these elements are strong affecting the time scale and to delay specific achievements could result in losing support of public opinion, decision makers or even of your own troops.

In any case, usually the weakest among the competitors try to get more time, in order to overcome the disparity, especially if he could count on some external support (e.g. environmental conditions, local population, domestic public opinion of the opponent, financial sustainability, etc.).

In the proposed asymmetric confrontation ongoing in Asia, the time works against the Western Forces (WF), while it is almost a bottomless resource for the Insurgents. From the other hand, Time in Symmetric Confrontations among Global Military Powers (US, Cina, Russia, etc.) it is non-influent variable, since the power unleashed from the arsenals (in their conventional, nuclear and cyber dimension), could rapidly determine the war exhaustion of one or both sides.

STRATEGIC ENGINEERING & MOOTW

As anticipated, the Strategic Engineering is the process of using engineering approaches and technologies in the designing and analyzing new solutions in order to achieve Strategic Results against time constraints, risks, uncertainty, and multi faced threats in critical environments. Obviously MOOTW/Country Reconstruction Operations are very good examples of this complex scenarios and it is necessary to develop Strategic Engineering in order to guarantee its capability to offers an effective body of knowledge (Discipline) for this purpose. Indeed Strategic Engineering should be structured in order to able to be effective into planning, execution, evaluation, assessment and drive of MOOTW and Country Building Operations at Political and Military Strategic levels. In a future it could be expected to have Strategic Engineering as a resources for MOOTW, in this hypothetical future (for now) the Strategic Engineering Cell could be located inside a Provisional or Transitional Civil-Military Authority with the mission to build and address the civilian parameters for the Stabilization Requirements, which in turns affects the Security and Military Parameters. So, the optic of a Country Stabilization in the contest of a MOOTW driven by Strategic Engineering, it is about economy and infrastructure development at the same pace of security, with an eye to the hourglass. As example, in the stabilization of Afghanistan, the Western Powers have so far followed the traditional approach, which is the one adopted at the end of WWIIs: win militarily, then initiate the dissemination of western style democracy together with an aided economic development. This was indeed right for a symmetric confrontation, where the challenge it was winning the military confrontation in its geometric domain, but has proven so far unsuccessfully in asymmetric conflicts, where instead the time, in its physical and human dimension, it is the dictating size. So far then, the security has been the primary concern to address before all the others, with a constant difficulty by the military establishment to comprehend that even overwhelming victories of the WP are turned into political gains for the Insurgents, because of the media. In any case, the paradigm of any military operation has always been the defeat of the opposing forces. This prove to be the truth in many conflicts, however it is just to mention the case of the French occupation of Spain (1808-1814), where a conventional military force perfected trained to fight against a similar force failed to control the internal insurgence. The focus it has always been the defeat of the military component of the enemy, with little or to late efforts to cope with the country and the time constraints

CONCLUSIONS AND WAY AHEAD

Nowadays, as the long and costly US and NATO commitment to Afghanistan drags itself on rather than with a clear ending, but as condition based, spanning over a temporal dimension which encompass a generation, this brings further evidence that pretending to extinguish a complex conflict

which it is a jigsaw of ethnic and tribal rivalry, civil war, criminal panels, country/institution building framed by (relatively) unfriendly powerful neighbors, just with a strong accent on the military means, it is has been proven not successful. Strategic Engineering in such contests has the potential to introduce a new dimension in the military operations, by integrating in the conflict management the capacities deriving from Quantitative Modeling for to Decision Making Support, paired with Strategic Thinking and Scenario Analysis competencies. Indeed it makes sense to think back to Sun Tzu quote "*....the general who wins a battle makes many calculations..... the general who loses a battle makes few calculations*"; so what we need now is a modern calculator, people able to feed and use it, as well people able to adopt the output of the calculator to define and develop their strategies. By the way the authors are further developing these concepts by working on new MS2G solutions combining their different skills & backgrounds. Indeed one of the authors is a scientist that investigated over several years the Afghan Scenario related to NATO Intervention to apply M&S in different cases and that also served as Project Leader for some years in NATO; while the other author is an Officer with operational experience in several oversee scenarios, including service in Afghanistan right now and in NATO M&S Center of Excellence, currently he is finalizing his PhD defense on use of M&S in this kinds of applications.

REFERENCES

Betts, R. K. (1978). Analysis, war, and decision: Why intelligence failures are inevitable. World Politics, 31(1), 61-89

Bruzzone A.G. (2018) "MS2G as Pillar for Developing Strategic Engineering as a New Discipline for Complex Problem Solving", Keynote Speech at I3M, Budapest, September

Bruzzone, A. G., Massei, M., Bella, P. D., Giorgi, M., & Cardelli, M. (2017). Modeling within a synthetic environment the complex reality of mass migration. In Proceedings of the Agent-Directed Simulation Symposium, SCS, , April

Bruzzone A.G., Massei M., Longo F., Cayirci E., di Bella P., Maglione G.L., Di Matteo R. (2016) "Simulation Models for Hybrid Warfare and Population Simulation", Proc. of NATO Symposium on Ready for the Predictable, Prepared for the Unexpected, M&S for Collective Defence in Hybrid Environments and Hybrid Conflicts, Bucharest, October 17-21

Bruzzone A.G., M. Massei, F. Longo, L, Nicoletti, R. Di Matteo, G.L.Maglione, M. Agresta (2015) "Intelligent Agents & Interoperable Simulation for Strategic Decision Making On Multicoalition Joint Operations". In Proc. of the 5th International Defense and Homeland Security Simulation Workshop, Bergeggi, Italy

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

Chandler (1966) "The Campaign of Napoleon", Vol. 1, p.149

Elfrey P. (2006) "Moving out the Planet", Invited Speech at Summer Sim, Calgary, Canada, July

Fuller, M. G. J. (2018). The Second World War, 1939-45: a strategical and tactical history. Pickle Partners Publishing.

Galula, D. (2002). Pacification in Algeria, 1956-1958 (Vol. 478). Rand Corporation.

Galula, D. (2006). Counterinsurgency warfare: theory and practice. Greenwood Publishing Group.

Gibbon, E. (2017). The History of the Decline and Fall of the Roman Empire. Musaicum Books.

Gordon, R. J. (2017). The rise and fall of American growth: The US standard of living since the civil war (Vol. 70). Princeton University Press

Goscha, C. (2017). Asia. Deng Xiaoping's long war: The military conflict between China and Vietnam, 1979–1991 By Xiaoming Zhang Chapel Hill: University of North Carolina Press, 2015. Pp. 278. Maps, Photos, Index. Journal of Southeast Asian Studies, 48(1), 143-144.

Jalali, A. A. (2017). A Military History of Afghanistan: From the Great Game to the Global War on Terror. University Press of Kansas.

James, L. S., & Davies, S. (2018). Constructing a Literary Memory of the 1812 Russian Campaign in German Central Europe in the Long Nineteenth Century. In Militarized Cultural Encounters in the Long Nineteenth Century (pp. 273-296). Palgrave Macmillan, Cham.

Jones D.G.(2015) "Sun Tzu: Training the Imperial Concubines", Shibumi Management Canada, Nov 16

Kirchick J., (2017) "The British election is a reminder of the perils of too much democracy", Los Angeles Time, June

Leonhard Robert R. (1994) "Fighting by minutes: Time and the Art of War", Leonhard, Praeger

Livy, T. (2012) "The Complete Livy: The History of Rome, Ab Urbe Condita",www.bibliotech.org, reprinting original text published in 14 DC

MacArthur, J. R. (2004). Second front: Censorship and propaganda in the 1991 Gulf War. Univ of California Press.

Muchemi, J. K. (2017), "A Critical Analysis of the Successes, Failures and Challenges of Humanitarian Intervention as a Conflict Management Tool", European Journal of Social Sciences Studies, Vol.2, n.8

Mueller J.E. & Mueller J. (1994) “Policy and opinion in the Gulf War. Univ. of Chicago Press.

Pauly, R. J. (2017). Strategic Preemption: US Foreign Policy and the Second Iraq War. Routledge.

Ryan Missy, Lamothe Dan and Sonne Paul (2018). “New general takes over in Afghanistan amid questions about the U.S. military's future there”, The Washington Post, 1 September

Sar Desai, D. R. (2018). Vietnam: Past and present. Routledge.

Statell, G. (2014) “We Should Be Careful About Simple Solutions To Complex Problems”, Forbes, July 11

Summers, H. G. (2009). On strategy: A critical analysis of the Vietnam War. Presidio Press

ABOUT A CLASS OF MULTICRITERIA MICROARRAY GAMES AND APPLICATIONS TO MEDICAL PROBLEMS

Vito Fragnelli[(a)], **Lucia Pusillo**[(b)]

[(a)]University of Eastern Piedmont, Department of Sciences and Technological Innovation,
Viale T.Michel 11, 15121 Alessandria, Italy
[(b)]University of Genova, DIMA - Department of Mathematics,
Via Dodecaneso 35, 16146 Genova, Italy (corresponding author)

[(a)]vito.fragnelli@uniupo.it, [(b)]lucia.pusillo@unige.it

Abstract. *In this paper, a class of multiobjective games with applications to a medicine setting is studied. We provide the notions of Shapley value and Banzhaf value for a multicriteria game and we apply them to a microarray game (introduced in Moretti et al. TOP, 2007; 15, 256-280). We give an axiomatic characterization too.*

Key words: multiobjective games; Pareto equilibria; microarray games.

1 Introduction

In this paper a class of multiobjective games with applications to a medicine setting is studied. We consider, via mathematical game theory, the genic expression to understand serious diseases as cancer and our goal is to propose a selection method to tumor diagnosis, about the problem see The common application in Medicine is "to teach" to a classificator to distinguish between healthy and sick subjects on the basis of samples given by doctors. A method to make a feature selection is to use Cooperative Game Theory with transferable utility (TU games in literature). Intuitively each gene is considered in a coalition of genes and to each coalition is assigned a value which is showing how much these genes expressions suggest us to distinguish between healthy and sick subjects. Some research results (Albino et al. 2008, Lucchetti et al. 2010,Fragnelli et al. 2008) applied Mathematical Game Theory to analyze the results obtained with microarray techniques which permit to make a photo to thousand of genes expressions in a unique cell through a unique experiment. The starting point is studying the genic expression photos in a cell champion and verifying some particular biological conditions (for example the cells of a subject affected by a tumoral disease).
Mathematical Game Theory has a fundamental role to define the "microarray games" and to evaluate the relevance of genes to regulate or to provoke the onset of a patology taking into account the interactions with other genes. It is well known that many diseases have a genetic origin. In the mathematical literature we find the study of some power indices (Shapley value, Banzhaf value etc. see Gonzalez Diaz et al. 2010) to evaluate the relevance of genes. In this context the Shapley value is studied as a measure about the "importance" of a gene ("relevance index") in the diagnosis. We study the Shapley value for microarray multiobjective games basing our study on the idea of "partnership of genes" (introduced in Moretti et al. 2007). Intuitively this is a gene group with correlated characterizations and which are very important to develop the disease.
The experimental results have shown that the Shapley value is a valid tool to study the expressions of genes and to predict a tumor disease.
The advantage of considering a coalitional game is the possibility to compute a numerical index, the so called *relevance index* which intuitively represents the relevance of each gene taking into account the relevance of the others when, for example, a tumor disease is developping. We study the microarray games introduced in Moretti et al, 2007 and we generalize this problem to a vector one. We consider multicriteria or multiobjectives games because we think that if there are more objectives to take into consideration the solution is more precise and allows to better understand the dangerousness of a disease.
About multiobjective games and their solutions see: Levaggi et al. 2017,Patrone et al. 2007, Pusillo et al. 2012, Voorneveld 1999, Pieri et al. 2010, Pieri et al. 2015, Pusillo 2017 and Sawaragi 1985. In this paper we consider the vector Shapley value and Banzhaf one as expression indices but a research is work in progress about other solutions and a comparison among the results. We give an axiomatic

approach to the vector solution and we prove that there is a unique solution (the Shapley value and the) which satisfies the desirable axioms.
This method can be applied to neurological disease and allergies too.
Another interesting application could be to use this strategic method to evaluate the dangerous behaviours in a town or in a military zone and in this way to give an unusual support to the strategic engineering. Instead of studying the tumoral cells via the expression analysis we can study other strategic or decisional contexts. For example to explore the disposal of military forces, to study the geopolitical scenario or the population trend. Referring to an actual problem: some people says that with immigration the crimes are increasing, is it? We can make a map about the intensity of immigration zones. The method to make this map could be inspired by the method of relevance index in the microarray games.
The paper is organized as follows: in Section 2 there are some results of background, in Section 3 the multicriteria microarray games are considered. In Section 4 we study an axiomatic approach to the Shapley value and in Section 5 an axiomatic approach to the Banzhaf value. Finally Section 6 contens conclusions and open problems.

2 Background

Given a vector $x = (x_1, ..., x_n) \in \prod_{i=1}^n X_i$, we write $X_{-i} = \prod_{j \neq i} X_j$, $x_{-i} = (x_1, ..., x_{i-1}, x_{i+1}, ..., x_n) \in X_{-i}$ and
for all $y_i \in X_i$ and $x_{-i} \in X_{-i}$ $(y_i, x_{-i}) = (x_1, ..., x_{i-1}, y_i, x_{i+1}, ..., x_n)$, $(x_i, x_{-i}) = x = (x_1, ..., x_n)$.
Given $x, y \in \mathbb{R}^n$ we consider the following inequalities on $\mathbb{R}^n$:

$x \geqq y \Leftrightarrow x_i \geq y_i \quad \forall i = 1, ..., n;$

$x \geq y \Leftrightarrow x \geqq y$ and $x \neq y;$

$x > y \Leftrightarrow x_i > y_i \quad \forall i = 1, ..., n.$

Analogously we define $\leqq$, $\leq$, $<$.

We write $\mathbb{R}^m_{++} = \{x \in \mathbb{R}^m : x_i > 0 \ \forall i = 1, ..., m\}$ and $\mathbb{R}^m_{+} = \{x \in \mathbb{R}^m : \ x_i \geq 0 \ \forall i = 1, ..., m\}$

Let us consider a multiobjective (or multicriteria) TU- game $\langle N, v \rangle$ where N is the set of n players and $v : 2^N \to \mathbb{R}^m$ is the characteristic function of the game, with $v(\emptyset) = 0$. It assigns to each coalition $S \in 2^N$ a m-vector, being m the number of objectives, equal for each player:

$$v(S) = \begin{pmatrix} v_1(S) \\ v_2(S) \\ \cdots\cdots \\ v_m(S) \end{pmatrix}.$$

If all players cooperate, the grand coalition forms.
Let us write

$$\alpha_i(v, S) = \begin{cases} v(S \cup \{i\}) - v(S), & \text{if } \ i \notin S \\ v(S) - v(S \setminus \{i\}), & \text{if } \ i \in S. \end{cases}$$

Definition 2.1 *A multicriteria game $\langle N, v \rangle$ is convex if it is valid*

$$\alpha_i(v, S) \leqq \alpha_i(v, T),$$

$\forall S \subset T$ and $\forall i \in N$.

Definition 2.2 *$< N, v >$ is a monotonic game if $\forall S \subset T \subset N$ it turns out $v(T) \geqq v(S)$*

Definition 2.3 *We call i a dummy player if $v(S \cup \{i\}) = v(S) + v(\{i\})$ $\forall S \subset N$.*
We call i a null player if $v(S \cup \{i\}) = v(S)$ $\forall S \subset N$.

We say that the game $< N, v >$ has the *monotonic property* if:
given $T, S \in 2^N \setminus \{\emptyset\}, T \subset S$ then $v(S) \geqq v(T)$

We say that a cooperative game has the property of
weak-superadditivity if

there is no $S \in 2^N \setminus \{\emptyset\}$ s.t. $v(S) < \sum_{i \in S} v(i)$.

Let us define the imputation set for a multicriteria game

Definition 2.4 *A pre-imputation of the game is a matrix $X = (x^i_j) \in \mathbb{R}^{m \times n}$ such that $\sum_{i=1}^n (x^i_j) = v_j(N)$ for each $j = 1, 2, ..., m$*

$$X = \begin{pmatrix} x^1_1 & x^2_1 & \cdots & x^n_1 \\ x^1_2 & x^2_2 & \cdots & x^n_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ x^1_m & x^2_m & \cdots & x^n_m \end{pmatrix}$$

We write $X^S = \sum_{i \in S} X^i$, $X^N = v(N)$.
We will call the set of pre-imputation of the game $I^*(N, v)$
The pre-imputation $X \in I^*(N, v)$ is an imputation if $X^i \geqq v(i)$ $\forall i \in N$. The set of all imputations is called $I(N, v)$.

Definition 2.5 *Let us define two cores for the game* $< N, v >$*:*

$C(N, v, \geqq) = \{X \in I^*(N, v) |\ X^S \geqq v(S), \forall S \in 2^N \setminus \{\emptyset\}\}$.

and $C(N, v, \geq) = \{X \in I^*(N, v) |\ X^S \geq v(S), \forall S \in 2^N \setminus \{\emptyset\}\}$.

Theorem 2.1 *If a multicriteria cooperative game is convex then the core* $C(N, v, \geqq) \neq \emptyset$.
Proof: see Fernandez Garcia et al. 2006.

We remind that $i = 1, ...n$ *are the players and* $j = 1, ..., m$ *are the objectives,* $v(S) = (v_1(S), v_2(S), ..., v_m(S))^T$.

Let G^k be the space of the multicriteria games with k objectives (and the same number of players), it is a vectorial space with dimension $(2^n - 1) \times k$ which can be defined by the unanimity games and by the identity games:

Definition 2.6

$$u_S^l(T) = \begin{cases} (0, ..., 1^{(l)}, ...0) & \text{if } S \subset T \\ (0, ..., 0, ...0) & \text{if } S \not\subset T. \end{cases}$$

$$i_S^l(T) = \begin{cases} (0, ..., 1^{(l)}, ...0) & \text{if } S = T \\ (0, ..., 0, ...0) & \text{if } S \neq T. \end{cases}$$

Each game can be written as a linear combination of some of these games which define the basis.
Especially by using the identity games:

$$v = \sum_{l \in K} \sum_{S} v_l(S) i_S^l$$

$K = 1, 2, ..., k$. Analogously if we consider a unanimity game as a linear combination of identity games, it turns out:

$$u_S^l = \sum_{T, S \subset T} i_T^l$$

3 Multicriteria microarray games

Remind some definitions about the microarray games with m objectives and N the player-genes set.
Let us consider an $n \times m$ matrix $M = (m_{ij})$ such that m_{ij} has value 0 or 1 and $\forall j = 1, ..., m$ let us define its support: $sptm_{.j} = \{i,\ s.t.\ m_{ij} = 1\}$ and defining the unanimity game in the following way:

$$u_S^l(T) \begin{cases} (0, ..., 1^{(l)}, ...0) & \text{if } sptm_{.j} \subset T \\ (0, ..., 0, ...0) & otherwise. \end{cases}$$

Then the microarray game associated to $M^l = (m_{ij})^l$ is defined as

$v^l = \frac{1}{m} \sum_{j=1,...,m} u_j^l$ where $l = 1, ...k$ are the objectives.

Let us consider the following example where we consider a Microarray Experimental Situation (MES for short) with the tuple
$E = \langle N, S_R, S_D, A^{S_R}, A^{S_D} \rangle$ where A^{S_R}, A^{S_D} are the two real valued expression matrices with genes in samples normally and abnormally expressed respectively.

Example 3.1 A^{S_R}

	Sample 1	Sample 2	Sample 3	Sample 4
Gene 1	$\binom{7.77}{0.5}$	$\binom{8.95}{0.2}$	$\binom{6.48}{0.3}$	$\binom{1.94}{0.6}$
Gene 2	$\binom{20.40}{12}$	$\binom{14.75}{10}$	$\binom{34.88}{4}$	$\binom{20.35}{5}$
Gene 3	$\binom{0.49}{8}$	$\binom{5.79}{13}$	$\binom{1.00}{20}$	$\binom{16.47}{9}$

A^{S_D}

	Sample 1	Sample 2	Sample 3
Gene 1	$\binom{3.26}{0.9}$	$\binom{-1.63}{0.4}$	$\binom{1.58}{0.7}$
Gene 2	$\binom{89.52}{4.6}$	$\binom{17.35}{11}$	$\binom{15.76}{18}$
Gene 3	$\binom{4.66}{11}$	$\binom{-3.80}{21}$	$\binom{19.44}{12}$

The discriminant method is the same for the two objectives.
$\hat{m}(A^{S_D}, A^{S_R})_{ij} = \begin{pmatrix} a \\ b \end{pmatrix}$ where $a, b \in 0, 1$, the value 0 means that the gene is normally expressed (intuitively it is not dangerous for the desease), the value 1 means that the gene is abnormally expressed, so it is dangerous. The values $\begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ mean an high degree of dangerousness, $\begin{pmatrix} 0 \\ 0 \end{pmatrix}$ mean no degree of dangerousness, instead

$\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ or $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ keep attention because: this is a warning situation and it can become dangerous.
The value 1 is so determined:
If $A_l^{S_{D_{ij}}} \geq max_{h \in S_R}(A^{S_{R_{ih}}})$ or $A_l^{S_{D_{ij}}} \leq min_{h \in S_R}(A^{S_{R_{ih}}})$
and the value is 0 in any other case.
The matrix M will be:

$$\begin{pmatrix} \binom{0}{1} & \binom{1}{0} & \binom{1}{1} \\ \binom{1}{0} & \binom{0}{0} & \binom{0}{1} \\ \binom{0}{0} & \binom{1}{1} & \binom{1}{0} \end{pmatrix}$$

where

$$\text{supp}m_{\cdot 1}=\{1,2\},$$

$$\text{supp}m_{\cdot 2}=\{1,3\},$$

$$\text{supp}m_{\cdot 3}=\{1,2,3\}.$$

So the microarray game will be:

S	$\emptyset$	$\{1\}$	$\{2\}$	$\{3\}$	$\{1,2\}$	$\{1,3\}$	$\{2,3\}$	$\{1,2,3\}$
$v(S)$	0	0	0	0	$\frac{1}{3}$	$\frac{1}{3}$	0	1
	0	0	0	0	$\frac{1}{3}$	$\frac{1}{3}$	0	1

Definition 3.1 *Let $v \in M_m^N$ (that is a vector microarray game). A coalition $S \in 2^N$, $S \neq \emptyset$ is called a partnership of genes in the game v if $\forall T \subset S$ $S \neq T$, and $\forall R \subset N \backslash S$ it turns out $v(R \cup T) = v(R)$*

intuitively in a partnership the subsets of genes of S are not important (for the disease) or they are important as much as the elements out of S We can write each game v via the unanimity game u_S:
$v = \sum_{S \subset N, S \neq \emptyset} \lambda_S u_S$. Now let us define a solution for a cooperative game: the Shapley value. In the scalar case, it was introduced by Shapley in fifties. A generalization to a multicriteria setting was given by [FP]. It is one of the most interesting solution concept in cooperative game theory. Intuitively it has a link with the average of the marginal contributions of each player entering (see [Pe] and [FP] for more details).

Definition 3.2 *The Shapley value of $\langle N, v \rangle$ denoted by $\phi(v)$, is defined, for each player $i \in S$:*

$$\phi_i(v) = \sum_{S \subset N; S \ni i} \frac{(s-1)!(n-s)!}{n!}[v(S) - v(S \backslash \{i\})] =$$

$$= \sum_{S \subset N; S \ni i} \frac{(s-1)!(n-s)!}{n!} \begin{pmatrix} v^1(S) - v^1(S \setminus \{i\}) \\ v^2(S) - v^2(S \setminus \{i\}) \\ \dots\dots\dots\dots\dots \\ v^m(S) - v^m(S \setminus \{i\}) \end{pmatrix}.$$

Where s and n denote the cardinality of the coalitions S and N respectively.
We remind that an *allocation rule* ψ is a map which assigns to each $\langle N, v \rangle$ an element of $\mathbb{R}^{n \times m}$.
A "good" allocation rule verifies the following axioms:
1) Efficiency property (EFF for short): $\sum_{i \in N} \psi_i(v) = v(N)$

2) Weak Monotonicity property (WMON for short): given two games $\langle N, v \rangle$, $\langle N, w \rangle$ such that: $\alpha_i(v, S) \geqq \alpha_i(w, S)$, $\forall S \subset N$ and $\forall i \in N$
then $\psi(v) \geqq \psi(w)$.

3) Dummy Out property (DUMOUT for short): for all $\langle N, v \rangle$ and all set of dummies $D \subset N$, it turns out $\psi_i(v) = \psi_i(v_{N \backslash D})$ for all $i \in N \setminus D$ where $v_{N \backslash D}$ is the restriction of the characteristic function v to the set $N \setminus D$ of players. Intuitively if the dummies of a game abandon it, the others do not dislike and the allocation does not change.

The Shapley value verifies the three axioms written. To explain better the notations let us consider the following example discussed in [PP15]:

Example 3.2 Let $\langle N, v \rangle$ be a cooperative game with two criteria:

S	$\{1\}$	$\{2\}$	$\{3\}$	$\{1,2\}$	$\{1,3\}$	$\{2,3\}$	$\{1,2,3\}$
$v(S)$	10	20	30	40	40	60	90
	15	25	10	50	30	50	80

where we mean $v(\{1\}) = \begin{pmatrix} 10 \\ 15 \end{pmatrix}$, $v(\{2\}) = \begin{pmatrix} 20 \\ 25 \end{pmatrix}$, ...

$v(\{1,3\}) = \begin{pmatrix} 40 \\ 30 \end{pmatrix}$, ... and so on.

The Shapley value for the bi-criteria game is:

$$\phi(v) = \begin{pmatrix} 18,3 & 33,3 & 38,3 \\ 22,5 & 37,5 & 20 \end{pmatrix}.$$

Let us introduce the vector Banzhaf value which is another punctual solution for cooperative games, it was introduced to measure the power of the members in a voters coalition.

Definition 3.3 *Given $v \in G^k$, the Banzhaf value is the function*

$$\beta : G^k \to \mathbb{R}^{k\times n}$$

which associates to v $k \times n$ matrix

$$\beta(v) = \begin{pmatrix} & \\ \beta_1(v), ..., \beta_n(v) & \\ & \end{pmatrix}.$$

Thew columns $\beta_i(v)$, for $i = 1, ..., n$, are the vectors

$$\beta_i(v) = \begin{pmatrix} \beta_i^1(v) \\ \vdots \\ \beta_i^k(v) \end{pmatrix}$$

where $v = (v^1, ..., v^k)$,

$$\beta_i^l(v) = \sum_{S\subseteq N: i\in S} \frac{1}{2^{n-1}} m_i(v^l, S).$$

For the game in the example 3.1 the Shapley and the Banzhaf value are so defined:

$$\beta(v) = \frac{1}{4}\begin{pmatrix} 14 & 18 & 22 \\ 130 & 190 & 50 \end{pmatrix}.$$

and

$$\Phi(v) = \frac{1}{6}\begin{pmatrix} 18 & 26 & 30 \\ 210 & 220 & 90 \end{pmatrix}$$

The two indexes show us that gene 1 captures more attention about the desease.
In a real application we have to consider a lot number of genes so a software as MATLAB or R can help us.

4 An axiomatic approach for the Shapley value

We consider a cooperative game with n players and 2 objectives to simplify the notations but each property can be studied for m objectives.
Let $v \in M_m^N$, the set of microarray games with N players and $m = 2$ objectives,

a coalition $S \subset 2^N \setminus \emptyset$ is called a genes partnership for the game v if $\forall T \subset S, T \neq S$ and $\forall R \subseteq N \setminus S$ it is valid $v(R \cup T) = v(R)$ (componentwise).
Axiom 1.
Let v be a game with two criteria and $N = 1, ..., n$ players, $v = \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$,
Let be the solution $F = \begin{pmatrix} H \\ G \end{pmatrix}$, then it has the PARTNERSHIP RATIONALITY (PR for short) if

there is no $S \subset 2^N \setminus \emptyset$, S partnership of genes in the game v. s.t.

$$\sum_{i\in S} H_i(v) < w_1(S)$$

$$\sum_{i\in S} G_i(v) < w_2(S)$$

Axiom 2.
Let $v \in M_m^N$, $m = 2$, the solution F (a matrix $m\times 2$) has the PARTNERSHIP FEASIBILITY (PF for short) if there is no $S \subset 2^N \setminus \emptyset$ and partnership of genes for the game v such that

$$\sum_{i\in S} H_i(v) > w_1(N)$$

$$\sum_{i\in S} G_i(v) > w_2(N)$$

Axiom 3.
Let $v \in M_m^N$, $m = 2$, the solution F has the PARTNERSHIP MONOTONICITY (PM for short) if

$$F_i(v) \geqq F_j(v)$$

$\forall i \in S, \forall j \in T$, $S, T \subset 2^N \setminus \{\emptyset\}$ where S, T are partnership of genes in v such that $S \bigcap T = \emptyset$, $v(S) = v(T)$, $v(S \bigcup T) = v(N)$ and $|S| \leq |T|$.

In other words, given

$F_i = \begin{pmatrix} H_i \\ G_i \end{pmatrix}$ it verifies $H_i(v) \geq H_j(v)$ and $G_i(v) \geq G_j(v)$ (the partnership monotonicity is valid componentwise). Intuitively, considering two different and disjoint partnerships of genes generating the same number of tumors in a sample and if the set of genes outside the union of those partnerships is irrelevant for the illness, then the players-genes in the smaller partnership are more relevant that those in the bigger one.
Axiom 4.
Let $v \in M_m^N$, $m = 2$, the solution F has the EQUAL

SPLITTING PROPERTY (ES for short) if

$$F(\frac{\sum_{i=1}^{k} v_i}{k}) = \frac{\sum_{i=1}^{k} F(v_i)}{k}$$

intuitively, each sample must have the same degree of reliability, for example the power of a gene on two samples must be equal to the sum of the powers on each sample.

Axiom 5.
Let N be a finite set of players-genes, and let $v \in M_m^N$, the solution F has the NULL GENE PROPERTY (NG) if for all null gene $i \in N$ it turns out $F_i(v) = 0$.
Intuitively: if a player-gene contributes nothing to each coalition then the solution gives to it a null relevance.

Axiom 6.
Let N be a finite set of players-genes, and let $v \in M_m^N$, the solution F has the EQUAL TREATMENT PROPERTY (ETP) if for each game $v \in M_m^n$ and for all partnership of genes S and for each $i, k \in S$ it turns out $F_i(v) = F_j(v)$.
Intuitively: the allocation rule gives the same relevance to each element in the same partnership.

Lemma 4.1 *If S is a partnership the Shapley value of the game gives the same relevance index to each element in S.*

Proof the proof follows because the vector Shapley value verifies Axiom 6 componentwise. □

Proposition 4.1 *The Shapley value verifies*
a) the partnership monotonicity (PM)
b) the partnership rationality (PR)
c) the partnership feasibility (PF).

Proof a) Sh(v) verifica la PM
b) Sh(V) verifies (PR)
The microarray game is monotonic and convex as linear combination of unanimity games (which are monotonic and convex). so the (PR) property follows from the coalitional property of the Core $C_{\geqq}(v)$

c) by the fact that the $Sh(v) \in C(v)$ it turns out $\sum_{i \in N \setminus S} \phi_i(v^1) \geq v^1(N \setminus S)$ and $\sum_{i \in N \setminus S} \phi_i(v^2) \geq v^2(N \setminus S)$ but for the efficiency property of Shapley value $\sum_{i \in N} \phi_i(v) = v(N)$, so $\sum_{i \in S} \phi_i(v^1) \leq v^1(S)$ and $\sum_{i \in S} \phi_i(v^2) \leq v^2(S)$ and this is the (PF) property.

Theorem 4.1 *There is one and only one solution for the microarray multicriteria game verifying the properties EFF, AN and ADD for the partnership. It is the Shapley value.*

Proof The proof is similar to the scalar case.

5 An axiomatic approach for the Banzhaf value

Axiom 7.
The solution F has the property of individual consistency (IC for short) su MM^N, if

$$F_i(u_{\{i\}}) = 1$$

for all $i \in N$.

Axiom 8.
The solution F has the property of average loss (AL for short) on MM^N, if $\forall v, v_{Sl} \in MM^N$ it turns out

$$\frac{1}{s} \sum_{i \in S} [F_i(v) - F_i(v_{Sl})] = F_l(v_{Sl}) - F_l(v)$$

Axiom 9.
Let N a finite set of genes, the solution F has the property of total loss (TL for short) on MM^N, if $\forall v, v_{Sl} \in \mathcal{M}^N$, it turns out
$\sum_{i \in S} [F_i(v) - F_i(v_{Sl})] = F_l(v_{Sl}) - F_l(v)$

Let $v \in MM^N$ and let M the matrix which generates it. Let l a null gene for the game v and $k \neq l$ another gene. let us consider a new matrix M^{lk} with rows so defined:
if $i \neq l$ $m_{i.}^{lk} = m_{i.}$, and $m_{l.}^{lk} = m_{k.}$.
we will call v_{lk} the new game associated to the matrix M^{lk}.

Axiom 10.
The solution F has the property of pairwise consistency (PC for short) on MM^N, if $v, v_{lk} \in MM^N$ then

$$F_k(v) = F_l(v_{lk}) + F_k(v_{lk}).$$

Theorem 5.1 *There is one and only one solution for the microarray multicriteria game verifying the properties NG, S, ES, IC, PC. It is the Banzhaf value.*

Proof The proof is similar to the scalar case (see Lucchetti et al. 2010).

6 Conclusion and open problems

In the present paper we have considered an approach to multiobjective microarray games. The idea of many objectives comes from considering that if we have many parameters to study then the expression analysis is more precise.
We have investigated the results via two solutions of the cooperative games: the Shapley value and the Banzhaf one. They have been considered as relevance indices for genes and many experiments in mathematical literature prove that they are a good choice (see Moretti et al. 2007). There are a lot of problems to investigate, some are written hereafter:
1) consider other solutions (as tau-value, nucleolus, Alexia value, E-equilibrium (Gonzales Diaz et al. 2010, Patrone et al. 2007, Pusillo et al.2012) and compare the obtained results,
2) consider the problem via networks games,
3) study the problem via machine learning,
4) another interesting application could be to use this strategic method to evaluate the dangerous behaviors in a town or in a military zone and in this way to give an unusual support to the strategic engineering.

Some of these issues are work in progress.

References

[1] Albino D., Scaruffi P., Moretti S., Coco S., Di Cristofano C., Cavazzana A. et al. *Identification of low intratumoral gene expression heterogeneity in neuroblastic tumors by wide genome expression analysis and game theory.* Cancer 113, 6, 1412-1422, (2008).

[2] F.R.Fernandez Garcia and J.Puerto Albandoz "Teoria de Juegos Multiobjetivo", Universidad de Sevilla, (2006).

[3] Fragnelli V., Moretti S.,*A game theoretical approach to the classification problem in gene expression data analysis*, Computers and Mathematics with Applications, 55, 5, 950-959, (2008).

[4] Gonzalez Diaz J., Garcia Jurado I., Fiestras Janeiro M.G. "An Introductory course on Mathematical Game Theory" American Mathematical Society- Real Sociedad Matematica Espanola, (2010)

[5] Levaggi L., Pusillo L., *Classes of multiobjective games possessing Pareto equilibria*, Operation Research Perspectives, 4, 142–148 (2017).

[6] Lucchetti R., Moretti S., Patrone F., Radrizzani P. *The Shapley and Banzhaf value in microarray games* Computers and Operations Research, 37, 1406–1412, (2010).

[7] Moretti S., Patrone F., Bonassi S. *The class of microarray games and the relevance index*, TOP, 15, 256-280, (2007)

[8] Patrone F., Pusillo L., Tijs S. *Multicriteria games and Potentials* TOP, 15, 138-145, (2007).

[9] Peters H., "Game Theory- A Multileveled Approach". Springer (2008).

[10] Pieri G., Pusillo L. *Interval Values for Multicriteria Cooperative Games*, AUCO Czech Economic Review 4, 144-155, (2010).

[11] Pieri G., Pusillo L., *Multicriteria partial cooperative games*, Applied Mathematics, special issue on Game Theory, 6,12 , 2125-2131, (2015)

[12] Pusillo L. *Vector Games with potential functions* Games , 8, 1–11 (2017).

[13] Pusillo L., Tijs S. *E-equilibria for multicriteria games*, Annals of the International Society of Dynamic Games, by Pierre Cardialaguet and Ross Cressman, Springer ed., 12, 217-228, (2012).

[14] Sawaragi, Y., Nakayama, H., and Tanino, T., "Theory of Multiobjective Optimization". Academic Press, Orlando, FL, (1985).

[15] Voorneveld M. *Potential Games and Interactive Decisions with Multiple Criteria*, Dissertation series n.61, CentER of Economic Research- Tilburg University, The Netherlands, (1999).

NATO NEEDS FUTURE STRATEGIC ENGINEERS

Jan Mazal
Faculty of Military Technology, University of Defence in Brno, Czech Republic
Email: jan.mazal@unob.cz
URL: www.unob.cz

Agostino Bruzzone
DIME, University of Genoa, Italy
Email: agostino@itim.unige.it
URL: www.itim.unige.it

ABSTRACT
Contemporary dynamic world and security environments bring many changes and new challenges which were not significant or apparently visible before. One of the today's world significant trend, amplified by continuous pursue for the effectiveness improvement and lack of qualified personnel, is much wider penetration of advanced methods and technology (M&S, AI and so) into a "Strategic" decision making field, particularly in various non-technological areas.
This trend leads to a need for additional research in management areas, revitalization of operational research principles implemented in "social-everyday" practice, integration of IoT (internet of things) and thus BigData and DataFarming concepts in decision support infrastructure, and mainly appropriate personnel development (education and training).
Mentioned gap or needs, as it was indicated yet, is also apparent in the highly conservative resorts like defence, were the potential synergy in E&T with civilian education is highly possible and some serious research activities were already started within NATO (for instance STO/MSG-152 - NATO Modelling and Simulation Professional Corps Development).
The article deals with the analyses of contemporary trends and future needs in various areas (including defence and security sector), and it evaluates the potential perspectives, solutions, architectures, providing a proposal for a convenient study programme and its design and implementation.

Key Words: *Education & Training, Strategies, Strategic Engineering, Decision Support, Simulation*

INTRODUCTION

Based on a long term experience, only the rational approaches in decision making give us the best chances to succeed in contemporary complex environment and, as a prove, we could consider the leading position we achieve thanks to the science and technology development.

Philosophically, if we think, as a human being, about our role in the universe, from where are we coming and where are we going, we do not know the truth yet, but it seems that we are "genetically programmed" to search the answers and we do not know how much time we have for our "answer search" mission. So one rational outcome of this challenge is the decision to put our research and development effort to the limit, to do the maximum possible. As it was said, human beings are genetically programmed to search for right solutions in a smart way, what actually enabled us to survive and evolve on the earth, therefore this approach, step by step, is affected and modified by the routine life and/or many other constrains/boundary conditions.

MODERN CONTINGENCIES ON STRATEGIES

In general the boundary conditions force the people to develop more and more sophisticated solutions as much as the environment turn to be complex, for instance by introducing large and strong interconnected social structures (Powerll 1992).
In facts, along many areas we face the situation, that *strategic* government/management positions are "occupied" by "political" instead of "expert" personnel, searching usually the "*comfortable*", instead of "*rational*" solution. In particular in recent time the search for extreme short terms "*consensus*" as happen in Stock Exchange looking to next quarter or the political world focusing on continuous polls are very good example were the "strategy" is dictated by very short horizon and contingent elements; even international organizations are affected by this approach and if we step back and look to the effective progresses in humanitarian or military initiatives by major organizations, we could easily realize discontinuities in terms of objects, actions as well as lack of decision capability (Mintzberg 1994); these factors provide an high probability of failure in finalizing any strategic plan. Sometime we could accept the limited results achieved, justifying the results by the complexity of the problems, the

different specific interests of the participants and by articulated constraints; however this is just a simplified view, considering that major problems with very articulated networks of participants and harsh limitation were solve in the past centuries (Macchiavelli 2009; Luttwak 2016; Dawson 2018)

These aspects were always present along the ages, therefore today this situation is overstressed by the fact that the complexity of the problem we have to face is very high and often involve consideration on long terms (e.g. climate change, R&D investments, demographics) while our goals are very short terms (e.g. next quarter profits, next vote in Board of Director or local/national/federation elections).

It could be possible to attribute these problems to lack of decision capability, divergent interests, search for consensus; indeed in case of accepting this theory, one solution could be found in the "single strongman command in charge" or in "dictatorial structures", but this is not the only way and not necessary the best one as history demonstrated many times. Vice versa sometimes it is necessary to get to the origins (rationalism) to succeed and this fact is surely more than only important, but probably decisive for the 21 century in almost any domains. Indeed this corresponds to outline that education and training using new technologies to finalize rational decisions even in complex systems could be the way to create a common and effective capacity to face with strategies nowadays. Indeed, contemporary dynamic world and security environment brings many changes and new challenges which were not significant or visible before; in other cases in the past there were no appropriate methods and technologies available to deal with such problems considered "unsolvable".

One of the today's world significant trend, coming from the time of economic crises and amplified by increasing automation and *robotization* is continuous pursue for the effectiveness in manufacturing or other areas, with reliance on lack of qualified personnel. This fact lead to a much wider penetration of advanced methods and technology (M&S, AI and so) not only in tactical areas and weapon arsenal, but also into a "*strategic*" decision making field (particularly in various non-technological areas), were you have very tiny space for a mistake (strategic mistakes usually lead to a complete failure of a system of a defeat).

CURRENT GLOBAL SITUATION AND NEEDS IN MILITARY

Current situation and complexity of interconnected operations domains (land, air, sea, space, cyber) in context of the world security environment and it's continuous deterioration trend lead us to the early threat identification and to the search for the possible solutions in advance. Based on the mentioned complexity and many "hybrid factors", changing the contemporary warfare into a tremendously complicated field, it results that an effective management of this issue could be hard to be effectively resolved relaying just on intuition and experience. This is especially true because, even very good experience of decision makers sometime arised in very different mission environments and could be hard to be applied successfully otherwise without properly understand the context and develop specific experiences (e.g. virtual experience, immersive environments) by using innovative technologies to quickly enhance the capabilities of a command; this concept was demonstrated by SIMCJOH as proposed in figure 1 (Di Bella 2015). In addition to the above mentioned consideration we have to be aware, that our potential opponents have similar access to the advanced military technology, like we have, they are thinking in a same way like we do and they will not give us a favor to behave like we wish to. From this point of view it is interesting to consider the modern concept of Hybrid Warfare, as evolution of previous not linear approach to war supported by new technologies (Bruzzone et al.2016); this concept is often attributed to Gen. Gerasimov, however if we read even just the title, and even better the whole article, we could easily realize the dimension of his view talking about the "*value of Science in the foresight*" (Gerasimov 2013). Even thought that armies are very conservative systems, there exist many attempts to change the routine or usual way of thinking in a decision making domain and this could represent an opportunity for major advances.

One of the well documented attept from 2008 is the DARPA's project – DEEP GEEN, which was focused on the Command and Control enhancement, especially MDMP (Military Decision Making Process) computer support and routine tasks automation. Contemporary, same as the past MDMP is usually executed in the way driven by the intuition and experience of individuals, thus this approach was significant breakthrough in C2 philosophy built on human intuitive judgment. The outcomes of the project did not significantly change the situation in the NATO C2 yet, but apparent improvement seems to be "shining on a horizon".

Another interesting example, from this point of view, is proposed by SIMJOCH initiative devoted to immerse commanders in new mission environments combining different technologies such as MS2G (Modeling, interoperable Simulation and Serious Games), VR (Virtual Reality), IA (Intelligent Agents), HBM (Human Behavior Models) & Virtual Humans (Bruzzone et al.2015)

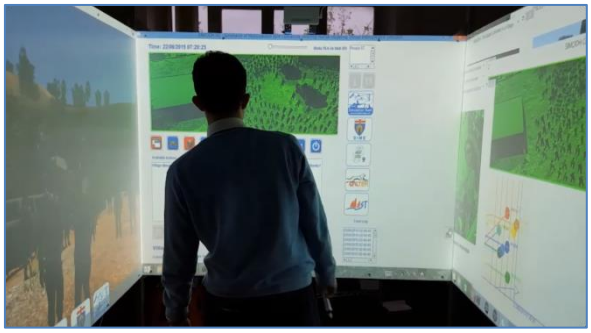

Figure 1 –Commander evaluate COAs in SIMCJOH

THE MILITARY DECISION MAKING PROCESS

When we look at the MDMP (Military Decision-Making Process) and its steps, which are usually similar in all NATO armies, even some details could vary, we could see a logical and highly "burocratically structured" process, fully employing a tens of individuals from the battalion (or higher echelon) staff. Contemporary structure of MDMP is visualized on following figure 2, proposed by Battle Command Mission Program. One of the fundamental problem of contemporary MDMP is IPB (Intelligence Preparation of the Battlefield) an Operational Planning phase linked to a COA's(Course of Actions) Development (having a roots of its philosophical concepts in the Second World War), which is, due to the human personnel reliance only, limited to the counts of possible enemy and friendly COA's. Also the planning phase of friendly COA's goes to the depth, rather convenient for static, low dynamic or predictable conflicts.

RESEARCHES AND INVESTIGATIONS

Nevertheless this concept for todays and future warfare seems to be obsolete and still, there is the continuous search for innovation on that field (Massei et al. 2014). In the following a couple of examples are proposed in terms of this new approach.

Deep Green

As anticipated one of the significant attempt on this way, was the US ARMY project DEEP GREEN (as mentioned before), solved by DARPA in 2008.

Deep Green concept was inspired by a Deep Blue supercomputer (1997) and is focused on development of a decision-making support system for US Army commanders.

Figure 2 - Military Decision Making Process

The core of the system was based on the feature of advanced predictive capabilities to enable computers to efficiently and accurately predict possible future scenarios, based on an analysis of the current situation. Obviously a very critical aspect is related to the ability to create a reliable COP (Common Operational Picture), in order to give army commanders a better view of possible outcomes for their decisions.

Deep Green concept is based on four major components, it's architectural and componentry scheme is proposed in the figure 3 inspired by DARPA research summarized in its technical report. Obviously the idea relies on the capability to develop new High Tech Models and Decision Support Systems (DSS) to be developed based on enabling technologies: In the case of Deep Green the main innovative components were:

Blitzkrieg –analyse current situation and determines possible future outcomes for use in planning. When a plan is presented, Blitzkrieg analyse the plan to point out possible results of that course of action to the commander. Blitzkrieg itself does not plane the action/operation, it merely determines the likely results of a plan formulated by a human commander.

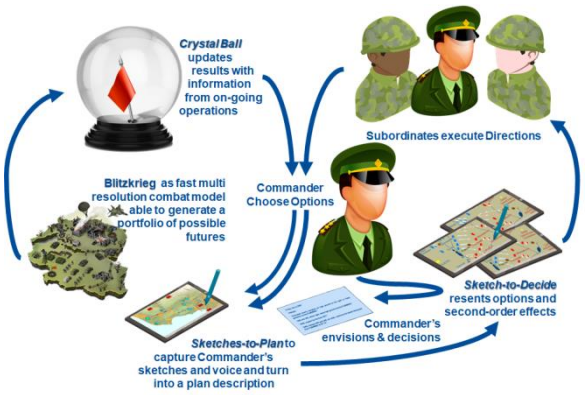

Figure 3 –Hi-Tech based Decision Process Scheme

Crystal Ball – Performs analysis of possible futures generated from the blitzkrieg, and determines the "best" choices by measuring flexibility, usefulness, and likelihood of each. It picks the best of these choices and presents them to the commander. Also updates model of battlefield situation with information pulled from the field. This might include reports from soldiers, through a program similar to the Communicator program that was developed under the Information Awareness Office or through automated RSTA systems such as HART.

Commander's Associate – this is the user interface and visualization component. It consists of "Sketch-to-decide" which presents the commander with a list of options, and "Sketch-to-plan" which is a screen on which the commander can draw up a plan, which Deep Green will interpret and put into action.

Indeed, this approach defines the philosophical fundaments of the new perception of the military management process architecture and redesign a traditional OODA (Observe-Orient- Decide-Act) Paradigm into parallel threads, which should be executed simultaneously. This approach could be more convenient for today's highly dynamic operations and more effective in the computing and analyses effort distribution on the primary aspects of the possible near future (avoids planning to the depth, because long term prediction/estimation is usually useless on dynamic battlefield).Fundamental shift away from the traditional OODA Paradigm is summarized in the figure.

SIMCJOH

The SIMCJOH (Simulation of Multi Coalition Joint Operations Involving Human Modeling) was activated as a major Military Project by Italian MoD in 2012 under leadership of Simulation Team Genoa University (Bruzzone et al.2015). The project was conducted in synergy with Military Organizations (e.g. NATO M&S Center of Excellence COE, CESIVA Italian Simulation and Validation Center, COI Joint Operational Command), Institutions (DIME University of Genoa, MSC-LES) and companies (i.e. CAE Gmbh, Leonardo spa, Mast srl, Cal-Tek). In facts the idea was to provide to Commanders a new generation solution adopting the new MS2G (Modeling & Interoperable Simulation and Serious Game) paradigm able to act as E&T (Education and Training) environment for Strategic Decision Making (Bruzzone 2018a). The concept was further developed in joint cooperation among Simulation Team Genoa University, VMASC Old Dominion University and Commanders with operational experience in different scenarios to identify the needs and opportunities to create such solution (Bruzzone et al. 2013). In facts SIMCJOH project allowed to create and demonstrate a new HLA interoperable immersive framework for the Commander and his staff within strategic decision making over a critical Joint MultiCoalitions scenario; the case study developed dedicated special attention to human factors and the Simulation Team Models on Population and Human Behavior Modeling represent in fact the core element of SIMCJOH Project (Bruzzone et al.2014, 2015). The experimentation faces issues related to strategic decision making over complex scenarios. It is evident that in the case of strategic decision there are many parameters and the human factors usually play a decisive role in the final success, so the use of innovative M&S (Modelling and Simulation) combined with AI (Artificial Techniques) is probably the most promising approach as demonstrated in this Project based on Simulation Team advances (Bruzzone 2013; Bruzzone et al.2011). In facts the combined use of SIMCJOH VIS & VIC, the virtual and constructive components of SIMCJOH project developed by Simulation Team allowed to reproduce by IA-CGF (Intelligent Agent Computer Generated Forces) the situation evolution and test multiple COAs over a complex scenario in an intuitive, immersive, interactive way as proposed in figure 1 (Bruzzone et al.2015). The SIMCJOH VIS & VIC have been created by Simulation Team (DIME, MSC-LES, Cal-Tek and MAST) and successfully tested and integrated in SIMCJOH Federation using Simulation Team IA-CGF. The SIMCJOH Federation includes different simulators such as Simulation Team VIS & VIC, Selex ES & SGA, CAE GESI. The interactive presentation and demonstration of SIMCJOH to Military Community was completed successfully in Rome since January 28, 2016 and replicated, with specific different focuses, several time in different Organizations and Nations (Di Bella 2015).

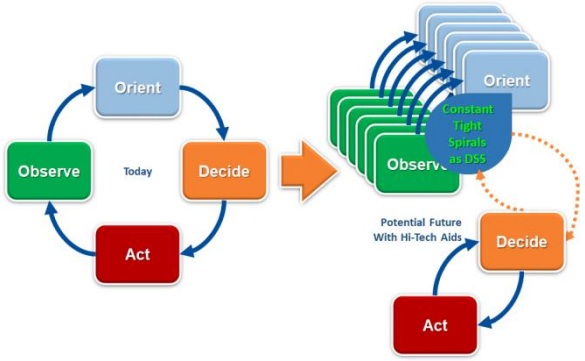

Figure3 - OODA Loop possible evolution

MODELLING AND SIMULATION IN STRATEGIC DECISION SUPPORT DOMAIN

Computer decision support in Strategic domain is one of the biggest challenge for Modelling and Simulation domain, because social-economic system on strategic level are characteristic by a high degree of stochasticity, so realistic outputs from the one simulation could be hardly achieved. The above mentioned cases represent a confirmation of the great potential of this approach, therefore a crucial key is the correct approach and level of understanding of the simulation results. From the logical and philosophical point of view, there is no theoretical boundary limiting a M&S implementation in strategic domains, only the human stereotypes and technology readiness (computationally intensive) could prevent that applications. From the technological point of view situation changed dramatically within a last decade, but human approaches and trust into the possible solutions do not.

Therefore, from a mathematical point of view, the military strategy can be viewed as a selected sequence of the data configurations defined on the set of all possible variations of the system state. Depending on a level of approximation and detail level of the space model, there exist approaches how to implement promising solutions even in strategic domain if it is properly defined the influence of stochastic factors and the performance criteria. Generally, a strategy can be defined as a sequence of transformation vectors driving the transition of the System from state n to n + 1 within a multidimensional space.

Following lines describing a procedural approach to the Strategic Defence Capability Development, what is very common problem for the defence strategists. The aim of the optimal strategy search in the Defence Capability Development problem we could describe as an ideal defence budget distribution to the army specializations in context of readiness for future threat confrontation. The detailed description of the problem solution would exceed the scope of that article, but in generic steps, we could delineate following possible approach:

- Construction of the data model of capabilities (capability model) – aggregating the statuses of quantified coefficients of individual capabilities (vary from the Nations) within a operational spectra. Definition of statistical factors, stochastic variables and fidelity levels. This could be represented as mathematical vector with indexes representing each capability, quantification of each capability should be derived from the current status of organization structures, equipment and armament. Usually calculated from the ratio of current status divided by some “ideal” model of a corresponding basic tactical unit (platoon, company, battalion…)
- Construction of the status graph of the possible configuration of the capability model
  It is the set of possible capability configurations in time to be viewed from the mathematical point of view as the math graph (having a shape of traditional oriented tree) of possible combinations of the data models of the defense capabilities. Usually there are different discrete and limited improvements or degradation of capabilities (e.g. hardly achievable improvements of the capability from 0 to 10 within a one year); this actually drives and reduces the speed of tree expansion in time.
- Evaluation of overall cost and risks of transition between individual configurations of the status graph - Transitions between time steps and potential capability levels should be valued by the financial cost of a given capability improvement, stagnation or deterioration. Usually for simplifications only positive numbers - we do not expect any financial profit from the defence (for instance selling some asset).
- Evaluate operational level of efficiency/readiness for a given status of capability to face the future threats - Evaluate operational efficiency of the capability configuration (model) is one of the key parameters in the capability graph, with several methods being available for the calculation process. Since the one possible option copying an intuitive approach and logic can be characterized by the following steps:
  1. Transformation capabilities into the model organizational structures
  2. Create organization structures of the supposed opponent
  3. Create/define scenarios
  4. Place scenarios into expected/probable areas of the future operational deployment
  5. Execute statistically representative counts of constructive war gaming within each scenario

6. Statistical evaluation of success ratio of given capability configuration and setting this value into the capability graph

- Calculate a possible solution - Calculation of a possible solution could be conducted in two phases, the first is to apply the Foyd-Warshall algorithm or its equivalent to the graph of financial part of capability development expenses, after that, it is necessary to apply a expected budgeting filter on each node in the graph within a time step/year and exclude all "over budget" nodes with its connections from the graph. Second step is the search for the optimal solution or a set of optimal solutions for the development of individual military capabilities in time (e.g. years) so that the total sum of the operational efficiencies of the individual capabilities configurations will be maximal or moves within a certain (max close) interval. This problem could be solved by the original or modified CPM method. In the case of situation where a defined budget capacity for the capability development prevent the effective capability status achievement, addressing forecasted threats and risks, so the military budget for capability development need to be reconsidered (increased).

Mentioned examples indicates, that this trend leads to a need for additional research in management areas, revitalization of operational research principles implemented in "*social-everyday*" practice, there is the time for a BigData and DataFarming concepts in decision support infrastructure, and mainly appropriate personnel development throughout proper education and training.

EDUCATION AND TRAINING PORTFOLIO FOR STRATEGIC PERSONNEL

Mentioned gaps and/or needs, as it was indicated yet, is apparent in many resorts, not only in defence. We could hardly imagine the reliance only on a "single resort courses and training" and close synergy in E&T with civilian education is not only inevitable, but useful to improve final capabilities. In general this aspects are an open issue in many different sectors and require to be addressed effectively (Bruzzone et al.2009; Howell et al. 2003). Some serious research activities were already started within NATO (for instance STO/MSG-152 - NATO Modelling and Simulation Professional Corps Development), incorporating a civilian E&T programmers into a military certification of M&S professionals (Mazal 2018). Indeed this initiative aims to develop a professional M&S Education and Training portfolio and certification process to enhance current capabilities. As a one of the latest reaction of University of Genoa to identified requirements and perspectives in mentioned field is the new master degree educational program named "STRATEGOS" that is focusing on this subject and it is proposed to International Community as an advance in this sector (Bruzzone 2018a).

CONCLUSION

The article deals with the analyses of contemporary trends and future needs in various areas (including defence and homeland security sectors). The discussion highlights that necessity as well as the opportunity to develop new approaches based on quantitative decision making processes and relying on innovative technologies.

Indeed the paper proposes some case studies to demonstrate that this vision, as well as practical demonstration of the potential, is already available, but there is a fundamental need to prepare a new generation of decision makers and analysts able to work together on this subject. The potential perspectives, solutions, architectures are proposed and the authors are working, even more, to develop a more extended analysis of this situation. Furthermore, it is proposed the new Master in Strategic Engineering that represents a practical example of study program devoted to design and implement these concepts. It is evident the necessity by International Organizations involved in complex decision making to follow up on the proposed guidelines as recently pointed out, during last CAX Forum (Bruzzone 2018b). In general, it will be necessary to properly work together among Academia, Services, Governmental Institutions and Industries to properly develop future E&T programs devoted to decision making, including that one addressing Executives, Staff as well as Scientists; indeed the evolution of the relative culture is probably the most critical aspect to succeed.

REFERENCES

Battle Command Training Program, Operations Group Charlie (2015) "The Operations Process, A Guide to the MDMP for Brigade and Battalion Staffs", Technical Report from Battle Command Training Program, Operations Group Charlie, May, militarydecisiongr.files.wordpress.com/2015/05/a-guide-to-the-mdmp.pdf

Bruzzone A.G. (2018a) "MS2G as Pillar for Developing Strategic Engineering as a New Discipline for Complex Problem Solving", Keynote Speech at I3M, Budapest, September

Bruzzone A.G. (2018b) "Strategic Engineering: How Simulation could Educate and Train the

Strategists of Third Millennium", Proc.of CAX Forum, Sofia, September

Bruzzone A.G., Massei M., Longo F., Cayirci E., di Bella P., Maglione G.L., Di Matteo R. (2016) "Simulation Models for Hybrid Warfare and Population Simulation", Proc. of NATO Symposium on Ready for the Predictable, Prepared for the Unexpected, M&S for Collective Defence in Hybrid Environments and Hybrid Conflicts, Bucharest, October 17-21

Bruzzone A.G., M. Massei, F. Longo, L, Nicoletti, R. Di Matteo, G.L.Maglione, M. Agresta (2015) "Intelligent Agents & Interoperable Simulation for Strategic Decision Making On Multicoalition Joint Operations". In Proc. of the 5th International Defense and Homeland Security Simulation Workshop, DHSS, Bergeggi, Italy

Bruzzone A.G., Massei M., Poggi S., Bartolucci C., Ferrando A. (2014) "IA for HBM as Support to Operations", Simulation and Modeling Methodologies, Technologies and Applications, Advances in Intelligent Systems and Computing, Springer, London, Vol. 319, pp 119-132

Bruzzone A.G., Tremori A, Sokolowski J, Banks C, Longo F, Casapietra A, Corso M, Ferrando A, Porro P, Dell'Acqua F (2013) "Innovative Models For Multi-Coalition Management", Proc. of the International Workshop on Applied M&S, Buenos Aires, Argentina, Nov 25-27

Bruzzone A.G. (2013) "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., Tarone, F., Madeo, F. (2011) "Intelligent agents driving computer generated forces for simulating human behaviour in urban riots", Int.Journal of Simulation & Process Modelling, 6(4), 308-316

Bruzzone A.G., Cunha, G., Elfrey, P., & Tremori, A. (2009) "Simulation for education in resource management in homeland security", Proc. of SCSC, Istanbul, Turkey, July, pp. 231-238

DARPA (2007) "BAA 08-09 Deep Green Broad Agency Announcement (BAA)", DARPA Technical Report, Washington DC

Dawson, D. (2018). The origins of Western warfare: militarism and morality in the ancient world. Routledge

Di Bella (2015) "Present and Futures Scenarios and Challenges for M&S terms of Human Behavior Modeling", I3M Keynote Speech, Bergeggi, IT

Gerasimov V. (2013) "The Value of Science is in the Foresight: New Challenges Demand Rethinking the Forms and Methods of Carrying out Combat Operations", Voyenno-Promysh-lennyy Kurier online, February 26

Howell, S. L., Williams, P. B., & Lindsay, N. K. (2003). Thirty-two trends affecting distance education: An informed foundation for strategic planning. Online Journal of Distance Learning Administration, 6(3), 1-18.

Luttwak, E. (2016). The Grand Strategy of the Roman Empire: From the First Century CE to the Third. JHU Press.

Machiavelli, N. (2009). Discourses on Livy. University of Chicago Press (reprint from 1539 edition in Italian, "Discorsi sopra la Prima Decade di Tito Livio")

Massei M., Poggi, S., Agresta, M., & Ferrando, A. (2014) "Development Planning Based on Interoperable Agent Driven Simulation", Journal of Computational Science, 5(3), 395-407

Mazal J., (2018) "MSG 152 Progress Report", Proc.of CAX Forum, Sofia, September

Mintzberg, H. (1994). Rethinking strategic planning part I: Pitfalls and fallacies. Long range planning, 27(3), 12-21.

Powell, T. C. (1992). Strategic planning as competitive advantage. Strategic Management Journal, 551-558.

NEW EDUCATIONAL PROGRAMS BASED ON M&S FOR STRATEGIC ENGINEERING

Agostino G. Bruzzone, Marina Massei
Simulation Team, University of Genoa, Italy
Email: {agostino, massei}@itim.unige.it
URL: www.itim.unige.it/strategos

Roberto Cianci,
DIME, University of Genoa, Italy
Email: roberto.cianci@unige.it
URL: www.unige.it

Alessandro de Gloria
Elios Lab, DITEN, University of Genoa, Italy
Email: adg@elios.unige.it
URL: www.diten.unige.it

Anna Sciomachen
DIEC, University of Genoa, Italy
Email: sciomach@economia.unige.it
URL:www.economia.unige.it

ABSTRACT
This paper proposes a new initiative, named STRATEGOS, devoted to promote Strategic Engineering as a new discipline to be taught in University and to prepare a new generations of engineers able to use new technologies for supporting decision makers on strategic issues.
This initiative is strongly based on the capability to combine different methodologies in real applications; the pillars of this discipline are represented by Modeling and simulation, data science, machine learning and smart optimization solutions. Also, the paper proposes applications and program as example for further developments.

Key Words: *Strategic Engineering, Simulation*

INTRODUCTION

In modern world we face many challenges that usually require efficient strategic decision making; therefore we assist, not rarely, to failures due to decreasing of trustiness in Institutions and Politics among the population. It happens similarly in military operations as well sometime in industry and business. These kinds of issues in supporting strategies have been addressed since centuries by classical writers, including Livy and Machiavelli, therefore, recently some pretty interesting reading about these subjects with special attention to complex scenarios and systems have published (Powell 1992 Mintzberg 1994; Galula 2002; Gordon 2017). Obviously, many books related to decision making and strategies are available, but a crucial element emerging as critical is the decision making capability (Summers 2009; Luttwak 2016; Payly 2017). This problem has two evident sides: decision makers along with their staff should acquire new capabilities. Nowadays we are experiencing the revolution of information age and many new data sources and resources are available; indeed also computational capabilities are much higher than before and AI (Artificial Intelligence) is demonstrating major advances (e.g. intelligent search, human profiling, communications, transportations, etc.) in complex scenarios (Massei et al.2014). So it is evident that today it turns possible to use enabling technologies and new methods into an integrated way to support decision makers, but, at the same time, it emerges the necessity to prepare a new generation of scientists, engineers and decision makers able to work using this new tools and related innovative approaches.
A promising solution to this challenge is provided by Strategic Engineering, a new discipline focusing exactly on these issues. The authors developed an new educational program, named STRATEGOS that is an example of new deal in this direction and could represent a way toward the necessary achievement in Strategic decision making (Bruzzone 2018b).

MODELS FOR STRATEGIC ENGINEERING: SOME EXAMPLES

Despite the highly innovative nature of Strategic Engineering, ideas about this capabilities have been considered since several years (DARPA 2007); furthermore it is evident that today multiple models are already available to be used; in the following few

examples based on Simulation Team achievement are listed (Bruzzone 2013; Bruzzone et al. 2009, 2011, 2014, 2015, 2016):

- ARPIAS: Augmented & virtual Reality for Population modeling based on Intelligent Agents
- BACCUS: Behavioral Advanced Characters & Complex Systems Unified Simulator
- CRIPEM: CRitical Infrastructure Protection in Extended Maritime framework
- Decision Theatre: SMARTCITY, Strategic Decision Making in Urban Environment
- DIES-IRAE: Disasters, Incidents & Emergencies Simulation & Interoperable Relief Advanced Evaluator
- MALICIA: Model of Advanced pLanner for Interoperable Computer Interactive Simulation
- MEGACITY Simulator
- MOSES: Modeling Sustainable Environments through Simulation
- SIMCJOH: Simulation of Multi Coalition Joint Operations involving Human Modeling - Virtual Interoperable Simulation & Virtual Interoperable Commander
- SO2UCI: Simulation for Off-Shore, On-Shore & Underwater Critical Infrastructure
- ST_CRISOM: Simulation Team Crisis Simulation, Organization and Management
- S4PT: Safety, Security Simulation System for Port Terminals
- T-REX:Threat network simulation for REactive eXperience

In these solutions apply Intelligent Agents and interoperable simulators, able to create a virtual framework where is possible to test strategies (Bruzzone & Massei 2017); indeed these simulators and virtual environments have to be even considered as major resources for E&T programs (Education and Training) in Strategic Engineering to organize classes, interactive experiences, exercises and role play games in realistic scenarios with experts (Di Bella 2015).

STRATEGIC ENINEERING INITIATIVES

Strategic Engineering is an emerging new discipline that was already promoted in different Initiatives by authors including Workshops, R&D Projects, Seminars, Webinars, etc. For instance recently several workshop, presentations or tracks were included in conferences such as :

- Future Forces Forum, Praha, October
- 11th Workshop in Applied Modeling and Simulation, Praha, October
    - *Strategic Engineering & Simulation Session*
    - *Serious Games for Strategy Session*
- 15th International Multidisciplinary Modeling & Simulation Multiconference, Budapest, September
- 8th International Workshop in Defense and Homeland Security Simulation, Budapest, September
    - *Track on Simulation for Strategic Engineering, Budapest, September*
- *Logistics Enhanced by Simulation Nowadays: Strategies and Guidelines for addressing New Opportunities & Challenges*, Invited Speech at TIDE, Think-Tank for Information, Decision and Execution Superiority, Spring 2018, organized by NATO ACT (Allied Command for Transformation)
- *Presentations* on the 3rd NASP International Workshop on Conflicts and Institutions

In addition there are active calls for Journals on this subject:

- *Special Issue on M&S and SG for Strategic Engineering*

STRATEGOS INITIATIVE

As anticipated, STRATEGOS represent a new initiative devoted to promote quantitative analysis and modeling for strategic decision making process (Bruzzone 2018a). Indeed along the years several qualitative approaches are emerged addressing management issues for companies and even qualitative engineering turned to be popular. The good performance of qualitative engineering in supporting professionals playing key roles, is strongly related to the necessity to take decision in presence of highly degree of uncertainty while facing complex systems that result not predictable and it could still have application for those who are confident with these approaches. Therefore many realized a strong change due to technological enablers: indeed, it results evident that new technologies allow to access, process and model huge amount of data, often obtained in quasi-real-time. It makes possible to perform quite effective quantitative analysis. The point is create engineers mastering these technologies in order to combine them together and obtain reliable and punctual quantitative results. In facts, STRATEGOS aims to create a new generation of engineers dealing with Strategic Thinking based on quantitative models and methodologies so that they might support Decision Makers. It is evident that these achievements strongly rely on specific techniques such as advanced Modeling & Simulation (M&S) and Mathematical Modeling (Cianci et al. 2016). Obviously several enabling technological and scientific areas supporting this approach are to be covered by STRATEGOS Program.

Figure 1 – STRATEGOS Programs, courses, workshops and project work

In facts, the term Strategy define the ability to deal with a variety of variables, considering uncertainty, extensibility, scalability, dependability as well as opponent reactions.

Also, it make sense to remind a major Strategist, Von Moltke, who defined "Strategy as a system of expedients; it is more than a mere scholarly discipline". He was used to add that "no plan of operations extends with any certainty beyond the first contact with the main hostile force" (Militarische Werke, 1871). These considerations are still valid today, however the Preußischer Generalfeldmarschall did not state “Strategic Planning is useless” but the opposite: the necessity to adopt a Dynamic and Fluid Strategic Approach that is exactly what we have to face nowadays. In facts, STRATEGOS does not deal with creating Strategists, but people mastering the techniques and technologies to create Dynamic and Fluid Aids to Strategic Decision Making based on current advances. So the main aim of STRATEGOS, Master in Engineering, is to prepare people to develop these new models and architectural solutions able to win the present and future competition within a wide spectrum of applications. From this point of view, it is possible to find a validation of this approach in many current initiatives; for instance, it makes sense to consider just one statement, among millions, that confirms the importance of Strategic Engineering: "If you want to grow, find a good opportunity. Today, if you want to be a great company, think about what Social Problem you could solve." (Ma Yun, alias Jack Ma, co-founder and executive chairman of Alibaba, in 2018: Personal Net Worth 42.2 GUSD; Alibaba 462th World Raking, 23.8GUSD Revenues, 6.2GUSD Profits, 56% Growth in Net Revenues, Stocks +15% within a single month). Indeed if we analyze major success in business (e.g. Facebook, Alibaba, Amazon, Booking, etc.) they are strongly addressing social issues and turning them into a business opportunity.

In facts, social factors play a major role in development of Strategies and the access to computational capabilities based on new quantitative models reproducing the dynamics of Complex Systems an using big data. It is interesting to outline that STRATEGOS initiative is among first ones worldwide and it specifically focuses on applications for industry, business and governmental agencies. A special attention will be devoted to Defense as well as other applications: organizational changes, finance, marketing, services, operations. The Master addresses

the requirements for developing capabilities for support to Strategy Planning and Development and the major pillars are Simulation, Artificial Intelligence, Mathematical Modeling Machine Learning, Innovative Operational Research & Data Analysis (Sciomachen et al. 2005; Bruzzone 2013). The STRATEGOS students are expected to learn how to design architecture for supporting decision process and how to combine the different methodologies in algorithms to be supported by Information and Communication Technologies (ICT). It is important to state that engineers are not just about to design new Systems and Products, but also to support Definition and Development of New Strategies. Obviously these aspects deal with the ability to define and implement New Processes, new Solutions and change Organizations able to guarantee the achievement of Strategic Goals. In facts new Systems have a quite long and risky Operational Lifecycle, strongly affected by many variables as well as by changing boundary conditions and general scenarios. STRATEGOS aims to provide the students with proper understanding of all these issues. As anticipated, up to now they are often roughly addressed by educational practices: for instance, by applying basic qualitative approaches or simplified static analysis methodologies to provide insights of complex systems.

THE EDUCATIONAL PROGRAM

The abovementioned new Engineering Master Program, MSc, deals with enabling technologies while combining different domains to address Strategic Decision Making.

STRATEGOS is a Joint Venture among different Engineering Departments, Faculty of Economics and Political Science as a new educational path providing deep Scientific Knowledge as well as Technical Engineering Skills combined with Strategic Planning and Decision Making Approaches in use for Business and International Affairs.

The final goal is to give a proper scientific background to those expected to work closely with decision makers with different backgrounds. The graduates will be capable to develop, tailor, propose and update strategies both on planning and development phase. The new Strategic Engineers will be able to use advanced quantitative methodologies and Models directly together with decision makers and executives for Strategy Definition, Innovative Solution Development and Capability Assessment. The details of the focus are under definition within the steering committee (international experts in different domains e.g. power, communications, defense, consultancy). Indeed the scope is to create a strong synergy between Academia and Industries as well as Governmental Institutions, Military Services and International Organizations. In this way the professionals generated as outcome of STRATEGOS will experience leading Institutions and Companies while their internship & project works to reinforce their capability to operate in a variety of application domains ranging from Manufacturing to Engineering, from Military Sector to Business, from Politics to Personal and Societal Development. They should be able to apply Strategies using the most appropriate Models, but also to finalize system requirements and to design new Methodologies, Techniques and Instruments for Strategic Planning and Management (Amico et al. 2000). Topics addressed in STRATEGOS include:

- Computational Methods
- Computer Programming
- Continuous Modeling and Simulation
- Crisis Management
- Cyber Physical Systems
- Cyber Warfare
- Decision Making
- Decision Support Methods
- Discrete Modeling and Simulation
- Game Theory
- Graphics Modeling and Simulation
- Human Behavior Modeling
- Hybrid Warfare
- International Relationships & Geopolitical Models
- Mining and Analyzing Big Data
- Modeling and Design of Complex System
- Modeling and Simulation of Maritime Systems
- Modeling for Monitoring and Diagnostics
- Models and Principles of Economy
- Operational Research
- Probabilistic System Design
- Social Network Modeling
- Software Systems Design Techniques

STRATEGOS program includes seminars and workshops open to selected audience addressing hot spots (e.g. Social Network Modeling, Demand Forecast, Modeling for B2C, Hybrid Warfare, Human Behavior Modeling, Cyber Warfare, Crisis Management, Anti-Access Area Denial A2AD, Agile C4I, CBRN, etc.). Indeed these subjects are pretty relevant and require use of modern scientific approach to be effective (Gerasimov, 2013) it worth to mention that current operational scenarios propose very interesting cases where strategies, despite big efforts, resulted in failures due to multiple causes that a Modeling approach could face (Jalali 2017; Di Bella 2015). The students will perform team working on simulators (figure 2) as MIPET students do (MIPET

is the 1st International Master Program of Genoa University in Industrial Plant Engineering and Technologies). Topics such as project management, construction, sustainability issues are addressed by experts from Industry using computer simulation to investigate alternatives and finalize virtual experience: innovative simulators such as SIMCJOH will be in use for this purpose (Bruzzone et al.2015). Moreover, STRATEGOS is an International Master open to student from worldwide, lectures are delivered in English language and optional courses will be offered also in other Languages to improve cultural background in soft skills (e.g. Project Management, Team Building) as well as in Language (e.g. Italian, English, Spanish, Chinese, Portuguese). The STRATEGOS program is currently organized over 2 years, where 3 semesters are focused on lectures, exercise, simulations, role play games and laboratory activities, while the latest is devoted to a project work within a Company or Institution; indeed it is possible also to spend some weeks in international initiatives to enhance the capabilities of the students.

ROLES FOR STRATEGIC ENGINEERS

The STRATEGOS Engineers could serve in multiple roles in Industry, Business, International Activities, Defense and Homeland Security; some examples are listed hereafter:

- Scenario Identification, Definition and Analysis
- Support Decision Makers by Quantitative Methodologies, Models and Analytical Approaches
- Strategic Analysis and Decision Support in Defense
- Development of Models, Processes and Analysis to support Governmental and International Institutions, Policy Makers and Public Authorities
- Support to Industry in Strategic Decision Making, Planning and Scenario Definition
- Development of Models of Complex Systems
- Data Farming by Simulation to extend, integrate and fuse Big Data for Data Analytics
- Development of New Algorithms, Models and Architecture devoted to model, simulate, anylize and support decisions in complex Systems
- Modeling, also through the capture of data and information conditioning, of the scenario in which the organization moves
- Supporting the management of an Organization, civil or military, in defining the objectives and planning the actions necessary to achieve them
- Simulation, through the implementation of self-built systems, of the evolution of events on the basis of planned actions to verify whether the objectives of the organization are likely to be achieved.
- Development of plans to defend and restore to normal operating conditions following attacks or major emergencies.

PLACEMENT OPPORTUNITIES

Modeling, analysis and strategy planning are some of the competences and skills expected to be usable for several applications. The expected target include large companies, but also Small Medium Size Enterprises (SMEs) given the typical current uncertainty in Industry and Business.

Specific competences, that are expected to be useful particularly for advanced business dealing with complex systems and closer to the world of the research, include discrete and continuous modeling, statistical techniques, scenario simulations, enabling ICT technologies.

Position in public/private research and management/administration centers is targeted as well as in Industries and Companies. Hereafter some examples:

- Support to the Board of Directors: Oil & Gas, Industrial Process Plants & Industries, Major Manufacturing Companies, Strategies for B2B, Strategies for Business to Consumers, Strategies for Communications Services, Strategies in Energy, Strategies in Resilience & Sustainability, Strategies in Investments, Retail, etc.
- Support to the Directors: Strategies on Operations for Major Industries, Strategies in Multi-Project Management in Companies, Operational Level and Grand Tactics devoted to implement Strategies, etc.
- Strategies for Specific Domains: Power, Constructions, Services, Logistics, Marine Sector, Airport Networks and new Air Traffic Control Solutions; New developments enabled by Autonomous Systems; Space & Aerospace (e.g.Micro Satellites and Enabling Technologies in Aerospace); Underwater Resources (e.g.Impact of advances in Underwater Robotic Systems), etc.
- Support to Defense & Homeland Security: Commander Decision Support in Operational Planning -Course of Action Definition, Quantitative Support to Negotiation and Consensus, Strategies for Homeland Security & Defense, New Programs and Simulation Based Acquisition, etc.
- Support to Agencies & Governmental Institutions (e.g. EDA, ONU, NATO): Strategies on International Affairs, Consensus, Strategies in Service to Society, Health Care & Strategies, etc.

- Models for Companies specialized in complex Systems and Plants, etc.
- Design, service and management companies (including Banks and Insurances) requiring scenario simulation and data processing and interpretation, etc.
- Companies (e.g., software houses, mechanical electrical and electronic components and systems, etc.) interested in Decision Making and Engineering, especially considering product/system/service strategy. This should concern also SMEs.

Figure 2- Interactive Class on PM in MIPET

STRATEGIC ENGINEERING SKILLS

STRATEGOS Engineers are expected to address models and algorithms development and carry out Scenario and System Analysis. In addition the Strategic Engineers are trained to identify the Target Functions in a Complex Systems, that is why Strategic Engineer Skills include among the others:

- Engineering and Mathematics applied for modeling complex systems
- Modeling and Simulation
- Data Farming and Data Analytics
- Artificial Intelligence, Intelligent Agents and Machine Learning
- Robotic Process Automation and Autonomous Systems and Heterogeneous Networks
- Mathematics, Information Technology and Engineering for the implementation of Simulators and for the Critical Analysis and Decision Making
- Economic and Political Analysis of Scenario and Operational Context and Feasibility Analysis of the Alternative Solutions
- Context Engineering for the Technical Sustainability of the Strategies developed and the Plans to implement Them
- AR, VR, Graphics and Visualization, to move results into an easily accessible and understandable, interactive, immersive and interoperable framework

STRATEGOS Degree is multidisciplinary, it aims to providing skills for addressing and coordinating complex systems such as that ones in Defense, Homeland Security and Industry. Simulation Team and Elios Lab provide a major support to promote the education activities of the Master making available their resources.

STEERING COMMITTEE

STRATEGOS Steering Committee involves Top Quality Experts and Scientists from Academia, Industry, Services and International Agencies in order to keep updated its contents and to guarantee continuous improvements. In addition, the engagement of Excellence Centers guarantee to enhance the opportunities for the STRATEGOS Students. Currently Agostino G. Bruzzone and Alessandro De Gloria serve as coordinators, however new organizations and institutions are expected to be involved into the process. Indeed Memorandum of Understanding, Patronage and Collaboration with many entities are foreseen, even considering Education & Training emerging needs (Mazal 2018).

DESIGNIN FLEXIBLE SELECTION PROCESS

The Selection process in this innovative program need to consider that different people could apply: new graduates with a BSc in Engineering, but also professional people such as officers or scientists working in this field and interested to develop strategic engineering skills; due to these reason STRATEGOS created a special Committee for selection including as observers representative of the Institutions and Companies involved in the Steering Committee. In addition STRATEGOS is designed as proposed in the general scheme, to develop and include specific workshops, seminars and preliminary classes devoted to provide credits to people applying for this MSc Program that don't have the titles to finalize the procedure; in this way the applicants will attend these initiatives and acquire missing credits.

In facts the admission to STRATEGOS is subject to the possession of specific curricular requirements and adequacy of personal preparation.

The verification of the preparation will be carried out as described in the academic regulations of the M.Sc.

Indeed for professional people with experience it will be possible to send applications to be evaluated by the selection Committee. The validation of such credits

will be obtained as result of the recognition of Professional knowledge, expertise and skills certified individually in accordance with current legislation
Other knowledge and skills gained through educational activities at university level is possible; obviously, considering the lectures and the educational material will be all in English, it is required to have adequate knowledge of the English language, with reference to disciplinary vocabularies, equivalent to B.2 or higher.

CONCLUSIONS

STRATEGOS focuses on developing an innovative framework for new generation engineers dealing with Strategic Engineering. The students will attend classes and labs to use modern M&S, MS2G (Modeling, interoperable Simulation, Serious Games) Machine Learning, Big Data, innovative ICT solutions (Bruzzone et a. 2009, 2018a; De Gloria et al. 2014). These "tools" have a great potential to support effectively strategic analysis for dynamic complex systems affected by emergent behaviors. In addition, STRATEGOS considers as a major *atout* the partnership with Institutions and Companies: this is a stronghold able to support this Master by means of valuable Internships and Excellent Placements.

REFERENCES

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

Bruzzone A.G. (2018a) "MS2G as Pillar for Developing Strategic Engineering as a New Discipline for Complex Problem Solving", Keynote Speech at I3M, Budapest, September 18-20

Bruzzone A.G. (2018b) "Strategic Engineering: How Simulation could Educate and Train the Strategists of Third Millennium", Proc.of CAX Forum, Sofia, September

Bruzzone A.G., Massei, M. (2017) "Simulation-Based Military Training", in Guide to Simulation-Based Disciplines, Springer, pp. 315-361

Bruzzone A.G., Massei M., Longo F., Cayirci E., di Bella P., Maglione G.L., Di Matteo R. (2016) "Simulation Models for Hybrid Warfare and Population Simulation", Proc. of NATO Symposium on Ready for the Predictable, Prepared for the Unexpected, M&S for Collective Defense in Hybrid Environments and Hybrid Conflicts, Bucharest, October 17-21

Bruzzone A.G., M. Massei, F. Longo, L, Nicoletti, R. Di Matteo, G.L.Maglione, M. Agresta (2015) "Intelligent Agents & Interoperable Simulation for Strategic Decision Making On Multicoalition Joint Operations". In Proc. of the 5th International Defense and Homeland Security Simulation Workshop, DHSS, Bergeggi, Italy

Bruzzone A.G., Massei M., Poggi S., Bartolucci C., Ferrando A. (2014) "IA for HBM as Support to Operations", Simulation and Modeling Methodologies, Technologies and Applications, Advances in Intelligent Systems and Computing, Springer, London, Vol. 319, pp 119-132

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

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

Bruzzone A.G., Cunha, G., Elfrey, P., & Tremori, A. (2009) "Simulation for education in resource management in homeland security", Proc. of SCSC, Istanbul, Turkey, July, pp. 231-238

Cianci, R., Bruzzone, A., & Sburlati, R. (2016) "A simulation of one dimensional contaminant transport". Proceedings of the Summer Computer Simulation Conference (p. 67). Society for Computer Simulation International.

DARPA (2007) "BAA 08-09 Deep Green Broad Agency Announcement (BAA)", DARPA Technical Report, Washington DC

De Gloria, A., Bellotti F., Berta R. (2014) "Serious Games for education and training." International Journal of Serious Games 1.1

Di Bella (2015) "Present and Futures Scenarios and Challenges for M&S terms of Human Behavior Modeling", I3M Keynote Speech, Bergeggi, IT

Galula, D. (2002). Pacification in Algeria, 1956-1958 (Vol. 478). Rand Corporation.

Gerasimov V. (2013) "The Value of Science is in the Foresight: New Challenges Demand Rethinking the Forms and Methods of Carrying out Combat Operations", Voyenno-Promysh-lennyy Kurier online, February 26

Gordon, R. J. (2017). The rise and fall of American growth: The US standard of living since the civil war (Vol. 70). Princeton University Press.

Jalali, A. A. (2017). A Military History of Afghanistan: From the Great Game to the Global War on Terror. University Press of Kansas.

Luttwak, E. (2016). The Grand Strategy of the Roman Empire: From the First Century CE to the Third. JHU Press.

Machiavelli, N. (2009). Discourses on Livy. University of Chicago Press (reprint from 1539 edition in Italian, “Discorsi sopra la Prima Decade di Tito Livio”)

Massei M., Poggi, S., Agresta, M., & Ferrando, A. (2014) "Development Planning Based on Interoperable Agent Driven Simulation", Journal of Computational Science, 5(3), 395-407

Mazal J., (2018) “MSG 152 Progress Report”, Proc.of CAX Forum, Sofia, September

Mintzberg, H. (1994). Rethinking strategic planning part I: Pitfalls and fallacies. Long range planning, 27(3), 12-21.

Pauly, R. J. (2017). Strategic Preemption: US Foreign Policy and the Second Iraq War. Routledge.

Powell, T. C. (1992). Strategic planning as competitive advantage. Strategic Management Journal, 551-558.

Sciomachen A., Tanfani E., Testi A. (2005) “Simulation Models For Optimal Schedules Of Operating Theatres” International Journal of Simulation: Systems, Science & Technology Vol. 6 No 12-13, Issn 1473-804x Online, 1473-8031 Print

Summers, H. G. (2009). On strategy: A critical analysis of the Vietnam War. Presidio Press.

DRAWEVA: A SERIOUS GAME FOR STRATEGIC COLLABORATION

Alessandro De Gloria[(a)], Riccardo Berta[(a)], Francesco Bellotti[(a)], Agostino Bruzzone[(b)]

[(a)]EliosLab, DITEN, University of Genoa, ITALY
[(b)] Simulation Team, DIME, University of Genoa, ITALY

[(a)]{riccardo.berta, franz, adg}@elios.unige.it
[(b)] agostino@itim.unige.it

ABSTRACT

Leadership and collaboration are key factors for decision making, particularly at strategy level. However, sharing goals, tasks and knowledge is difficult, in current organizations, and it is the subject of careful and expensive training programs. One tool that is being explored to support such training activities is given by serious games (SG). This paper presents Draweva, a multi-player 3D SG designed to coach decision makers to focus more on synergies with others and collaborate also beyond their own area of responsibility. The Draweva plot, set in a fantasy environment, requires players with different roles to communicate and collaborate in various tasks in order to achieve the final target of their adventure. In a preliminary qualitative tests, experts have positively assessed in terms of development flexibility and efficiency the technological solutions we have implemented to support Draweva.

Keywords: Serious Games; strategy; collaboration; decision making

1. INTRODUCTION

The Serious Game (SG) term is used to define games which provide a mental contest and are played with a computer in accordance with specific rules for government or corporate training, education, health, public policy, and strategic communication (Noghani, 2010). Serious games are not meant to replace traditional learning methods, they rather aim at integrating them and allowing users to learn and have fun at the same time (Arnab, 2012) and to contribute to the player's level of motivation (Bellotti, 2010).

Games are intrinsically related with strategy, as they typically require and spur a player to think of and implement a strategy in order to achieve the goal. SGs add to this the fact that they purposely target a goal which is not pure entertainment. For instance, describing the Wuzzit Trouble game, (Pope, 2015) write: "the game engaged learners in an iterative process of decision-making by calling for students to try, check, and revise their strategy as they played".

This paper presents Draweva, a SG stemmed from the observation that, today, people in organizations tend to work in what are called "invisible silos": they are only aware of their own targets. At the same time, they are often not aware of others and miss the opportunity to make relevant (strategic) decisions based on a general view of the entire organization. Draweva was developed with a view to help decision makers in organizations to focus more on synergies with others and collaborate beyond their own area of responsibility.

The primary audience of the game are leaders who want to lead high-performance team. The leaders can be from global, regional or local organizations, and can be from different leadership levels. Many multinational corporations and also small-to-medium enterprises set the focus on collaboration and teamwork, and these aspects will become even more important in the next years.

The game is embedded in a bigger frame, called Q Coaching Camp, which is an online platform for measuring, developing and sustaining behavior change. It is designed to be played in a specific time-frame by a set of people from an organization which is coached by the Q Challenge company specialists. The game is in its final stage of development and will be used in real Coaching Camps starting from Q1 2019.

This paper is organized as follows. Section 2 describe the related works in the context of SGs about knowledge and skills for business. Section 3 describes the relevant requirements and the relative design of the Draweva game. Finally, Section 4 reports some of the preliminary experimental results obtained.

2. RELATED WORKS

(Earp, 2014) argue that SGs can be considered suitable means to contribute to develop knowledge and skills for business. They highlight that SGs impact should consider both cognitive and affective/behavioral aspects and that SGs should allow appropriate personalization of learning paths.
Regular training of social skills in organizational settings is being ever more supported for an effective communication among members, which is important

particularly in emergency situations. (Haferkanmp, 2011) proposes a disaster communication methodology providing a SG which enables its users to train soft skills, also including group decision, in a virtual environment simulating under safe conditions. In a terror attack simulation, (Chittaro, 2015) shows that a SG for emergency preparedness is able to improve knowledge, self-efficacy and risk and severity perception. The authors explore psychological models, particularly the Protection Motivation Theory, that explain how people are motivated to protect themselves from danger. Testing a SG for environmental management, (Jean, 2018) argue its aid in crossing knowledge boundaries and supporting stakeholder collaboration. After surveying water-related SGs, (Aubert, 2018) propose many research opportunities for behavioral operational research as no SG exist that support preference elicitation compatible with multi-criteria decision analysis, which is used . An overview of SGs for decision making and strategy development for environmental and disaster management is provided in (Solinska-Nowak, 2018).

SGs have also been utilized to facilitate distributed requirements elicitation, by enhancing communication and collaboration between project members (Hadi-Ghanbari, 2015). Observing three SGs from L'Oréal, IBM, and Thales, (Oihab, 2017) propose a theoretical model with five distinct influence domains of serious games useful for collaborative open training: relations, culture, knowledge, innovation, and desire.
(Bellotti, 2014) presents a table template for the scouting of SGs for university-level entrepreneurship education and defining the most appropriate mix for their use in the courses, keeping into account targeted competences and skills, usability and pedagogical effectiveness. In the corporate training area, (Bacharova, 2012) discuss metrics for effectiveness, that is key to assess the impact of a SG.

In the defense area, systems to support Situational Awareness take increasingly advantage of data and information fusion techniques. (DeRosa, 2018) describe the Reliability Game, that was developed to characterize information source factors impact on human belief assessment.
(Westera, 2017) argues that Cognitive flow in serious games can be effectively modelled in computational models, that explain how different user strategies in serious games produce different learning curves. Generalizing the concept, we argue that these models might be used for identifying unexpected strategies that may arise in a gameplay. Concerning uses of M&S addressing Human Factors and Human Behaviors for Defense against Terrorism, it worth mentioning that researches successfully used SG in Education and Training even by web games (Bruzzone et al. 2009).

It is important to finally highlight that different research studies claim that specific design features should be carefully investigated since they may compromise the success of a collaborative-competitive SGs in terms of usage and learning (Buchinger, 2018). (Carvalho, 2015) have proposed a SG analysis and design support methodology that builds on the Activity theory to so support an in-depth analysis of how the combination of a SG's elements support its target pedagogical goals.

3. REQUIREMENTS AND GAME DESIGN

Requirements for the game design are provided by the Q Challenge experts in leadership coaching. In particular, the most important requirements are:

- **Observation and Search for Trends**: the decision maker needs a complete understanding of the industry/military context, trends, and business drivers. He has to routinely explore and synthesize the internal trends in his day-by-day work (e.g. pay attention to the issues that frequently arise in the organization).
- **Ask the right question**: questions are fundamental for strategy planning. By becoming curious, and looking at information from different points of view, the decision maker should be able to reduce the uncertainty and see different possibilities, approaches, and potential outcomes.
- **Collaboration**: the decision maker has to be proactive about connecting with colleagues and peers both in his organization and business context, in order to understand what happens and then share findings.
- **Non-realistic settings**: the decisions have to be taken in an abstract context, different from the one in which the user performs his activity. This is important in order to allow the training to be effective for various industrial/military contexts and to focus on the skills needed to strategic decision making instead of the details of a specific context.
- **Dilemmas and Pitfalls**: success is not a matter of absolute performance, but depends on how well the decision maker does relative to others (collogues and competitors). The best decisions must anticipate the moves of others. Some guidance comes from the game theory, with situations like the "prisoner's dilemma" or the "rock-paper-scissors" game, in which the winner is determined by the interaction of all players' decisions.
- **Planning**: people should be rewarded for evidence of thinking, not just for reaction. The organizational culture has to encourage the anticipation of opportunities and the avoidance of problems (e.g. managers have to be rewarded when they quickly propose solutions to problems with long-term benefits for the overall organization).

3.1. Technological architecture

Based on the stated requirements, we have implemented a first version of the Draweva game, developing a set of technical functionalities on top of the Unity Game Engine (Petridis, 2012). The main components are:

- A **3D fantasy scenario** implemented through the 3D graphics rendering of the Draweva 3D virtual world and where the player interaction is managed. The scenario consists of different naturalistic and fantasy places (e.g. rivers, mountains, caves, etc.) with a medieval castle in the center, in order to adhere to the "non-realistic landscape" requirement. The 3D world module leverages all the features already available in the Unity Game Engine (rendering, event management, scripting, etc.).
- A **multiplayer support** responsible for collecting events and information from game clients (used by the players) during the different game phases. The modules provides players with data about the internal state of the game to allow them maintain a complete version of the game world (e.g. current position and action of other players). This is important to allow collaboration between player.
- An **assessment component** which interprets the action performed by players during the game (e.g. make a right decision, collaborate or compete with others, etc.) and decides on the current evaluation of the user based on the Item Response Theory (IRT) (Bellotti, 2009). Based on information about performance, the game can provide feedback to the players using scores and badges.
- A **dialog manager module** responsible for allowing the user to interact in natural language with Non-Player Characters (NPCs). This gives the perception of a deeper involvement compared to traditional communication systems. The module allows the user to freely express his questions in textual form and provides the user with an adequate answer. This is developed to meet the "Ask the right question" requirements.
- A set of **points-of-decision** responsible to present the user with dilemmas and pitfalls during the game. For example, the player has to decide to use a tool alone or waiting for others, or he has to collect items in collaboration or in competition with other players. Actions performed by the players in all points-of-decision will have an impact on the final game outcome.
- An **online chat room** to allow players to communicate among each other in real-time during the game sessions. This can facilitate collaboration among peers. It is possible to set up different rooms in order to send messages to everyone or to a specific group of players.

Finally, we have implemented also a dashboard to allow the Q Challenge specialists to get data and metrics about the user progression during the game (e.g. how players are completing phases, how difficult levels are to complete, what score players receive upon completion, and how quickly they are completing the tasks). This is important to allow players and instructors to have an informed debriefing session after the gameplay.

3.2. Game plot

The Draweva game is played contemporaneously by three teams of seven players each, that go through the 3D fantasy scenario (Figure 1) with the major goal to kill a monster (Draweva), which lives in a castle in the center of the game map. This requires killing it in a special way and before a certain time. Each team is led to believe that it is fighting its own individual creature, so the strategic decisions during the game are related only to a part of the whole problem. There are a Vampire, a Werewolf and a Dragon. But, actually, the three monsters are just one creature composed of the three different personas. This represents the real big problem to overcome, which needs a complete strategic view.

Figure 1: Draweva Screenshots

3.3. Game roles

There are seven routes to the castle. Each team puts one member on each road, so that three members from each team are faced with the same task on each road. Every team member has his own task according to his road:

- the "Weapon Specialist" has to find in the virtual world the right weapon to kill the monster;
- the "Sourcing Specialist" has to support the Weapon Specialist by developing a special additive for the weapon, to make it lethal;
- the "Logistical Specialist" has to find the best way to move towards the castle bringing the weapon;
- the "Safety Specialist" has to find ways to protect the entire team from the monster;
- the "Creature Specialist" has to find a way to organize the team to have a good collaboration while fighting with the monster;

- the “Bodyguard” has to find the best attack methods to weaken the monster;
- the “Team Leader” has to lead the team in terms of decision making about overall strategy.

3.4. Game Phases

The game is divided into five phases, in which the players are faced with different tasks that simulate regular decision-making situations in an international company. The task completion is evaluated using an ad-hoc designed assessment method (which assesses player learning, engagement and satisfaction from patterns of usage based on quantitative data collected during the game play) in order to provide feedback to the players about their achievements. The positions of players are shared between clients leveraging a multiplayer server, apart from the team leader, who has to overlook the actions of his team and make strategic decisions based on the information he gets from his team members. His main task is to manage the limited budget and the time.

The phases for the other six players are the following.

- Phase 1 (**Collecting information**). The player has to collect information according to his specialty by posing questions to different Non-Player Characters (NPCs). The player has to take decisions in order to collect relevant information, focusing on the overall team objective. Information to make a right decision frequently comes from several different stakeholders, and it is underestimated how important this aspect is for the success of the organization.
- Phase 2 (**Empowerment**). The player has to ask for help from other team members for information he cannot get himself. Since he will get also requests from others, he has to collect information in order to help others in the right way as well. In this phase, players chat together using an instant messaging feature embedded in the game. Breaking down silos also means reaching out others and asking for help.
- Phase 3 (**Challenge with rivals**). The players will get to a point in the virtual world which is only passable once, independent of how many players actually pass. If a player arrives before the others and passes, he later finds out that he has to go back to help the others cross. In daily business life, workers are constantly benchmarked and should also rely on others to ensure goal achievement .
- Phase 4 (**Synergies**). The players arrive in front of a castle. But, to get in, they have to pay guardians with diamonds that can be found nearby. There is the possibility for the teams to share diamonds and pay only one guardian, in order to save a lot of time. This is a crucial point to show that strategic decisions should consider an exploitation of synergies.
- Phase 5 (**Killing**). The players confront with the monster while realizing that it is one creature. They have to use all information and items collected earlier to kill Draweva. In this phase it is critical to achieve the goal in the right time.

4. PRELIMINARY RESULTS

Draweva is currently in the testing phase and will be used with real users in real contexts of use starting from 2019 Q1. We are planning extensive user test in order to access its impact on decision-making skills.

By now, we have evaluated the technical architecture consisting of the previously described modules (the fantasy 3D scenario, the multiplayer support, the assessment component, the dialog manager module, the points-of-decision and the online chat room), that were designed to support versatility, maintainability and extensibility.

In order to have a qualitative assessment of the benefits of such technological support, in terms of development efficiency and usability, we piloted an advanced-development Draweva prototype. The pilot took place in a time frame of six months, from September 2017 to February 2018.

Three game developers from Wondertech SRL (the company who developed Draweva) participated in the pilot. The participants were asked to develop one phase of the game, using the available components, and then report on advantages and disadvantages of the technological solution provided as the basis for the development.

The responses highlight that all the programmers correctly understood the meaning of the components and the rules for leveraging them for the implementation of the game phase.

In the future, more tests are necessary for a clearer assessment. However, this first session allowed us to confirm the validity of the approach, that we argue could be extended to other games as well.

5. CONCLUSIONS

The Draweva game was designed to help leaders in organizations develop leadership and collaboration skills, that are key factors for decision making, particularly at strategy level.

In order to implement the game, we have designed a set of game modules to meet the main requirements coming from experts in strategic thinking teaching.

Based on this experience, we argue that our technological solution is able to provide SG developers with significant benefits, particularly in terms of development flexibility and efficiency. Preliminary tests showed that the proposed architecture can be fruitfully adopted for designing SGs. The next step of our research will involve the test of Draweva in its real context of use.

ACKNOWLEDGMENTS

We thank Pat Micalizio and Jan-Schaumburg of QChallenge Jurney Ltd for sharing their ideas, comments and design of the Draweva game during the course of this research. We also thank Ivan Carmosino, Lara Galanti and Alessandro Sartori of Wondertech SRL for their work with early prototypes of software services.

REFERENCES

Allal-Chérif, O., Bidan, M. Collaborative open training with serious games: Relations, culture, knowledge, innovation, and desire, Journal of Innovation & Knowledge, Volume 2, Issue 1, 2017, Pages 31-38,

Arnab S., Berta R., Earp J., de Sara F., Popescu M., Romero M., Stanescu I., Usart M. "Framing the adoption of serious games in formal education" (2012) Electronic Journal of e-Learning, 10 (2) , pp. 159-171.

Aubert, A., Bauer, R., Lienert, J. A review of water-related serious games to specify use in environmental Multi-Criteria Decision Analysis, Environmental Modelling & Software, Volume 105, 2018, Pages 64-78,

Bachvarova, Y., Bocconi, S., van der Pols, B., Popescu, M., Roceanu, I. Measuring the Effectiveness of Learning with Serious Games in Corporate Training, Procedia Computer Science, Volume 15, 2012, Pages 221-232

Bellotti F., Berta R., De Gloria A., & Primavera L. (2009). Adaptive experience engine for serious games. IEEE Transactions on Computational Intelligence and AI in Games. Vol. 1(4), 264-280.

Bellotti F., Berta R., & De Gloria A. (2010) Designing Effective Serious Games: Opportunities and Challenges for Research. International Journal of Emerging Technologies in Learning, vol. 5, 2010, 22-35.

Bellotti, F., Berta, R., De Gloria, A., Lavagnino, E., Antonaci, A., Dagnino, F., Ott, M., Romero, M., Usart, M., Mayer, I. Serious games and the development of an entrepreneurial mindset in higher education engineering students, Entertainment Computing, Volume 5, Issue 4, 2014, Pages 357-366

Bruzzone, A., Tremori, A., Massei, M. (2009). Serious games for training and education on defense against terrorism. Meeting Proceedings RTO-MP-MSG-069 Modelling and Simulation Group Symposium, Brussels, Belgium, October 15-16

Buchinger, D., da Silva Hounsell, M., Guidelines for designing and using collaborative-competitive serious games, Computers & Education, Volume 118, 2018, Pages 133-149,

Carvalho, M., Bellotti, F., Berta, R., De Gloria, A., Islas Sedano, C. Baalsrud Hauge, J., Hu, J., Rauterberg, M. An activity theory-based model for serious games analysis and conceptual design, Computers & Education, Volume 87, 2015, Pages 166-181

Chittaro, L., Sioni, R., Serious games for emergency preparedness: Evaluation of an interactive vs. a non-interactive simulation of a terror attack, Computers in Human Behavior, Volume 50, 2015, Pages 508-519

de Rosa, F., Jousselme, A.-L., & De Gloria, A. (2018). A Reliability Game for Source Factors and Situational Awareness Experimentation. Int. Journal of Serious Games, 5(2), 45 - 64.

Earp, J., Ott, M., Popescu, M. Romero, M., Usart, M. Supporting Human Capital development with Serious Games: An analysis of three experiences, Computers in Human Behavior, Volume 30, 2014, Pages 715-720

Ghanbari, H., Similä, J., Markkula, J. Utilizing online serious games to facilitate distributed requirements elicitation, Journal of Systems and Software, Volume 109, 2015, Pages 32-49

Haferkamp, N., Kraemer, N., Linehan, C., Schembri, M. Training disaster communication by means of serious games in virtual environments, Entertainment Computing, Volume 2, Issue 2, 2011, Pages 81-88

Jean, S., Medema, W., Adamowski, J., Chew,C., Delaney, P., Wals, A. Serious games as a catalyst for boundary crossing, collaboration and knowledge co-creation in a watershed governance context, Journal of Environmental Management, Volume 223, 2018, Pages 1010-1022

Petridis, P., Dunwell, I., Panzoli, D., Arnab, S., Protopsaltis, A., Hendrix, M., & de Freitas, S. (2012). Game engines selection framework for high-fidelity serious applications. International Journal of Interactive Worlds, 1-19.

Pope, H., & Mangram, C. (2015). Wuzzit Trouble: The Influence of a Digital Math Game on Student Number Sense. International Journal of Serious Games, 2(4).

Solinska-Nowak, A., Magnuszewski, P., Curl, M., French, A., Keating, A., Mochizuki, J., Liu, W., Mechler, R. An overview of serious games for disaster risk management – Prospects and limitations for informing actions to arrest increasing risk, International Journal of Disaster Risk Reduction, Volume 31, 2018, Pages 1013-1029

Westera, W. How people learn while playing serious games: A computational modelling approach, Journal of Computational Science, Volume 18, 2017, Pages 32-45,

AUTHORS BIOGRAPHY

Riccardo Berta is currently an Assistant Professor with the ELIOS Lab (DITEN), University of Genoa. He has authored about 100 papers in the international journals and conferences. His main research interest is about applications of electronic systems, in particular in the fields of serious gaming, technology-enhanced learning, and Internet of Things. He is a Founding Member of the Serious Games Society in 2006. He has been involved in the Editorial Team as a Section Editor of the International Journal of Serious Games and in the Program Committee of the GALA Conference.

Alessandro De Gloria is full professor in electronics engineering at the University of Genoa. He currently teaches: Computer Graphics Games and Simulation. His main research interests concern Embedded Systems, Applications for Smartphone and Tablet, Vehicular Cooperation and Safety, Human-Computer Interaction, and Serious Games. He has been international or local responsible for 10+ EU research projects in the last 15 years, in particular he was the coordinator of the Game and Learning Alliance (GALA), the Network of Excellence (NoE) on Serious Games founded by the European Union (EU) in FP7. Prof. De Gloria is the founder of the Serious Games Society (SGS), a cultural association that was born in 2012 as a spin-off of the GALA NoE and that is continuing its aims after the end of the EU funding. Prof. De Gloria authored 200+ papers in peer-reviewed international journals and conferences.

Francesco Bellotti is Associate Professor with the Department of Electrical, Electronic, Telecommunication Engineering and Naval Architecture, University of Genova, Italy, where he teaches cyber-physical systems and IoT at the M.Sc. Program in electronic engineering. He has led WPs in several industrial research projects and has authored 200+ journals/conference papers. His main research interests include info-mobility systems, HCI, signal processing, machine learning, and technology-enhanced learning. He is the president of the Serious Games Society, which publishes the International Journal of Serious Games and manages the Games and Learning Alliance (GaLA) Conf.

Agostino Bruzzone is full Professor at DIME University of Genoa and he is President of MIPET (Master in Industrial Plant Engineering and Technologies), the 1st International Master of Genoa University. He is President of Simulation Team and Liophant Simulation; he has served as Vice President in the SCS and MIMOS and has developed, as Project Leader, the new research track on *Marine Simulation* in the Science and Technology Organization of NATO.
He works since long time in innovative technologies such as M&S, IA, AI, VR, AR, directly applied in Industries, International Organizations, Agencies, Services, Defense and Homeland Security.

LEARNING DECISION MAKING PROCESSES AT STRATEGIC LEVEL BASED ON VR & AUGMENTED REALITY

Agostino Bruzzone, Marina Massei
DIME, University of Genoa
Email: {agostino.bruzzone, marina.massei}@simulationteam.com
URL: www.itim.unige.it

Francesco Longo
MSC-LES, UNICAL
Email: francesco.longo@simulationteam.com
URL: www.msc-les.org

Riccardo Di Matteo
SIM4FUTURE
Email: riccardo.dimatteo@simulationteam.com
URL: www.sim4future.com

Kirill Sinelshchikov
Simulation Team
Email: kirill@simulationteam.com
URL: www.simulationteam.com

ABSTRACT
This paper proposed the potential use of innovative immersive techniques to support decision making over complex problems. In particular the paper addresses the problem of strategic decision making and it is evaluating the potential of using Virtual Reality and Augmented Reality as enablers to improve understandings in this context; situation awareness, variable correlations as well as impacts could be better understood by this approach and in facts the paper proposes a large set of examples where MS2G (Modelling, interoperable Simulation and Serious Games) could be readapted to support decision makers into finalizing strategic planning as well as supporting Strategic Management

Keywords: *Virtual Reality, Augmented Reality, Strategic Decision Making, Simulation*

INTRODUCTION

Virtual and Augmented Reality are evolving since many years, the progress in this sectors are quick, but probably less that most people expect (Bruzzone et al.2017a); in facts, we are waiting from decades the diffusion of HDM (Head Mounted Displays); in Simulation Labs of Genoa University we experimented first HDM for application with different Virtual Environment over 20 years ago for applications in Defense, Aerospace, Marine sector and Emergency Management (Mosca et al.1995; Bruzzone et al.1997). However, these systems were limited by many aspects including costs, reliability, usability, etc. (Pimentel et al. 1992).

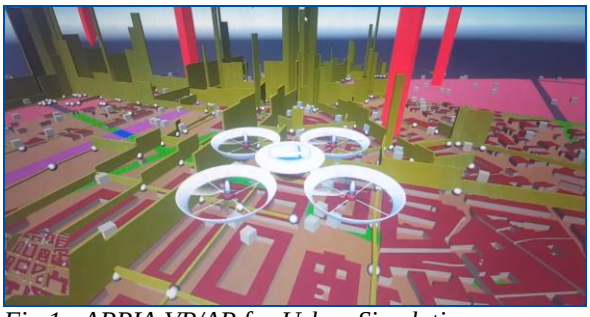

Fig.1 - ARPIA VR/AR for Urban Simulation

Much more recently, people experienced a big expectation for Google Glasses or for Oculus Rift, with pretty limited results.
Therefore, it is evident that these technologies are quickly evolving and it is possible to observe radical improvements year by year (Chafkin 2015; Scudellari 2016).
It is evident that in this sector there is a growing demand to move from unreliable solutions used just to create interests within games and fancy applications to reliable environments to be used continuously; indeed, the VR & AR (Virtual & Augmented Reality) applications and their potential continue to advance and are promising for being used in many fields (Wagner 2016).
The authors have worked on several initiatives devoted to use the new advances in combination to other technologies to develop reliable, usable and convenient solution in different areas (Bruzzone et al., 2016a, 2017a).
This paper proposes the use of AR and VR to support decision making with special attention to strategic issues. Indeed, virtual and augmented reality could be

effective in addressing the difficulties experienced since long times into engaging executives, thanks to their ability to present the opportunity to see and interact with *realistic models* by operating in virtual worlds.

VIRTUAL AND AUGMENTED EXPERIENCES

There are very interesting researches about how to use VR and AR in new fields in relation to many different aspects, including among others education & training, service, maintenance, remote tutoring and troubleshooting (Thomas et al. 2000; Burdea 2003; Rizzo 2009; Seidel et al. 2013; Spanu, 2016; Mazal 2018); there are many applications for safety and emergency management (Fabiano et al. 2015; Palazzi et al. 2017; Tatić et al.2017; Bruzzone et al. 2018a). The authors have created many applications in this sector including the development of a new generation of compact low cost CAVE (Cave Automatic Virtual Environment), named SPIDER (Simulation Practical Immersive Dynamic Environment for Reengineering) that is interoperable and interactive and where it is possible to combine AR & VR into new Mixed Reality (MR) solutions.

In facts, the SPIDER is specifically designed to develop solutions adopting innovative MS2G paradigm (Modeling, interoperable Simulation and Serious Games).

These applications allow to use the SPIDER, as an efficient and effective environment able to support collaborative work among several users acting live and federated with other models and people locally and remotely (Bednarz et al. 2015; Bruzzone et al.2015a). In facts there are many several interesting solution for cooperation and remote assistance in industrial field utilizing VR based on CAVE (Bruzzone et al., 2011a; Dai 2012).

Other cases addressed mining where VR and AR have been used to improve safety and productivities on the field both in the mine and during transportations by supporting training and orientation underground (Benes & Kodym 2014). Also constructions are enlisted among application fields in terms of training for improving safety (Le et al. 2015, Perlman et al. 2014).

DECISION MAKING vs. AR & VR

Decision Making, especially in strategic planning and management, it is a complex process that requires to evaluate the current situation in terms of real data and hypotheses, to define possible actions and to analyze the alternative Course of Actions (COA), even considering boundary condition evolution. Based on these activities it is often very useful to simulate the COAs and to create a short list to be refined in order to finalize the final decision. As it is evident from this process, the necessity to acquire a reliable situation awareness is a key point that requires even to consider intelligence reports and generic hypotheses that could be quite vague and affected by uncertainty; even the scenario evolution could be heavily affected by stochastic factors, while the system itself could be complex and very difficult to be predicted in terms of his future evolution respect our decisions. All these elements suggest the use of M&S, therefore usually this is not so common for a set of reasons that include among the others (Amico et al.2000):

- Difficulties in engage decision makers
- Lack of trustiness in pretty complex models
- Difficulty to acquire and certify all input data
- Complexity on model verification and validation
- Difficulty to understand the multivariable output

In facts most of these elements are related to the VV&A (Verification, Validation and Accreditation) and it should be also stated that the complexity of most simulation system in the past required long times for installation and settings and specific skills in analyst to use them as well as hard work to refine and modify the scenarios (Balci 1997).

Currently the new paradigm MS2G provides new opportunities allowing to setup quickly the simulators based on Lean Simulation approach (Bruzzone & Saetta 2002; Bruzzone et al.2014a)

Indeed, using MS2G in combination with VR and AR, it could be possible to directly involve decision makers into the VV&A not only of simulation logic and entity behaviors but also respect input and output data that could turn into an interactive immersive environment (Bruzzone et al.2017a; Bruzzone 2018).

A proper approach based on MS2G could enable to keep the new solutions open to be operated from a SPIDER as well as from a smartphone and to allow distributed use and interoperability with other models; in this way these systems could be integrated with other solutions and interconnected with Data Farms and Smart Devices to be immediately fruitful by executives and decision makers.

It is evident that Mixed reality, combining VR and AR, for this kind of user could be different and rely more on software solutions to make immersive the world (eventually even from a smart phone) respect classical hardware (Sherman and Craig 2003; Lindgren et al. 2016); indeed, in this field there are many alternative solutions and technologies to make MS2G available to users including regular Computers and Laptops, Head Mounted Displays, Smart Glasses, CAVEs, Smartphones and mobile devices (Quero et al. 2012; Perez-Ara et al.2013).

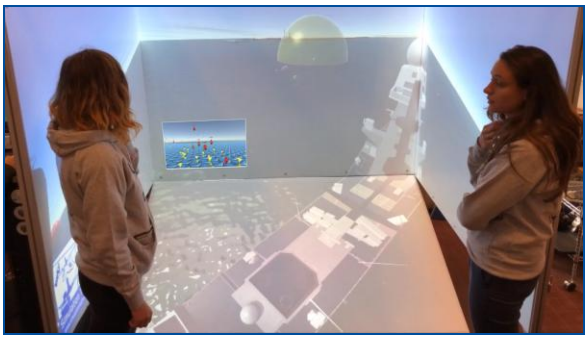

Fig.2 – JESSI combining physical and Cyber Layers

Therefore, it should be considered that the new generation of executives will be, in few years, completely open to experience the new Mixed reality adventure, while the related technologies are expected to be much more effective and less invasive within the same period.

In addition, these technologies allow to operate remotely and enter and cooperated in virtual worlds as anticipated (Alzahrani et al.2014; Zhang et al. 2014; Safir et al. 2015). In facts, the authors experienced this for instance in remote planning at strategic and operational level for fleet of ships in Oil & Gas sector (Bruzzone et al., 2011a).

Educational distribute worlds are another interesting approach to support to develop education and training classes and exercise for decision makers (Bower et al. 2016); it should be stated that up to now there are still concerns on the effectiveness of virtual classes, therefore even this point is supposed to be overpassed at some point into the future (Seidel & Chatelier 2013).

REAL EXAMPLES & PROOF OF CONCEPTS

Many applications have been developed by the authors to address specific sectors, even strategic planning (Bruzzone et al. 2016d, 2017b, 2017d; a very good example is the case of SIMCJOH expressively dedicated to Commander Strategic Decision making during crisis using AR and VR in immersive interactive environments (Bruzzone et al.2015a; Di Bella 2015).

In facts, there are several of these applications, often based on MS2G paradigm, and most of them result almost ready to be used in support of strategic decision making in different ways (e.g. education, training, operational planning, operation support, etc.).

To illustrate better these considerations, in the following are proposed several examples based on simulators developed by Simulation Team under patronage of Liophant Simulation (www.liophant.org/projects).

ARPIAS & Decision Theater

These simulation systems have developed to support Strategic Planning by town authorities; in particular Decision Theater project involve the tailoring of a NCF (Non Conventional Framework) for HBM (Human Behavior Models) based on IA-CGF (Intelligent Agent, Computer Generated Forces) by Simulation Team; in this case the simulator represents the capability to use agents to reproduce the population of an entire city and its reactions to investments and activities carried on the town (e.g. road constructions, new infrastructures, new services); the simulator is interoperable by HLA (High Level Architecture) and represent an example of constructive simulator based on discrete event stochastic simulation (Massei et al.2014; Bruzzone et al. 2017a, 2018b). This simulator is connected with ARPIA (Augmented & virtual Reality for Population modeling based on Intelligent Agents), which represents a virtual world where all dynamic variables are virtually proposed by means of interactive objects placed on top of the real city representation; in this way input and output variables as well as evolution of the situation is proposed within a 3D representation of the town and it is even possible to interact with this world by using various human-machine interfaces.

In this way the user is entitled to explore the virtual environments and to interact with nodes of various networks, buildings, different componentss and areas, in order to depict in Augmented Reality different variables such as occupation level, traffic density, delays, level of satisfaction.

These variables are expressed in terms of their dynamic evolution during simulation run and provide great insight on the Town evolution respect the strategic decision on its development. In figure 1 is proposed a virtual flight over a town where different strategic decision have been implemented, it is possible to see tall bars and walls corresponding to AR showing values for traffic indicators as well as for occupancy of attractions and public services in their dynamical evolution over a day or cumulative over a time window of a week or month This is a classic example where the development of a simple and intuitive interface as well as the presentation in immersive environments could provide great advantage for understating the situation to decision makers that could get the situation awareness within a realistic 3D representation. Indeed in this case it was defined also an approach to provide to population the possibility to test and verify interactive the town development plan of authority versus other solutions, including individual proposals; this mode could allow also authorities to browse among solutions provided by population and collect good ideas to improve the strategic plan; indeed such approach requires new

political view on decision making and relies on the innovative concept of crowd sourcing (Bruzzone 2014b).
Therefore, it is evident that by this mode it could be possible to recreate trust on Institution and Authorities and to reinforce the connection with people based on common simulation environments used to test alternative solutions.

CRIPEM

CRIPEM is an HLA federation devoted to combined different models to address the topic CRitical Infrastructure Protection in Extended Maritime framework. In this context is common to remind that there are many available models (Massei et al. 2013; Bruzzone et al.2015b). If we consider the case of Deep Water Horizon it is symptomatic to realize that despite the availability of helicopter simulator for landing on Off Shore Platforms, control room simulator of the platform, tug and firefighting simulation, oil spill simulation and ROV simulation, there was not available any combined simulation based on interoperability. In practice, all elements were available, but nobody never consider to simulate a global crisis. Now CRIPEM approach could include also VR and AR allow decision makers to investigate how to develop investments at sea in terms of correlation with data analysis, exploration planning, extraction development and safety issues. Indeed, in this context it could be consider to use VR and AR as support for the simulator SO2UCI (Simulation for Off-Shore, On-Shore & Underwater Critical Infrastructure) currently in use to evaluate security procedures as well as to test new technology in this context and to train operators (Bruzzone et al.2016c). For strategic decision making SO2UCI could be enhanced by providing general performance and KPIs (Key Performance Indexes) necessary at that level. SO2UCI has widely used on SPIDER as well as on HDM and glasses.
In this context another interesting simulator to federate is S4PT (Safety, Security Simulation System for Port Terminals) that uses a different technology, but allows to reproduce safety and security in ports; in this case the approach could be similar (Massei et al.2013).

DIES IRAE

This simulator, named DIES IRAE (Disasters, Incidents & Emergencies Simulation & Interoperable Relief Advanced Evaluator), is devote to analyze operations in disaster relief and humanitarian operations; the solution was designed based on MS2G paradigm and tested over different platforms; it is interesting to state that this approach provide immediate virtual representation of camps size and logistics that are generated and updated dynamically in the 3D world by the simulator (Bruzzone et al.2016d, 2017c). Originally this system has been developed to support training and planning of operations. Therefore, DIES IRAE could be used to investigate alternative COAs as well as to finalize scenario awareness and capability assessment respect strategic issues related to the specific zone.

JESSI

JESSI (Joint Environment for Serious Games, Simulation and Interoperability) is a powerful and innovative simulation environment, developed by Simulation Team and based on MS2G Paradigm, that supports interoperability among assets, platforms and models operating in multiple domains such as air, sea surface, underwater, land, space and cyberspace (Bruzzone & Massei 2017b). Indeed, JESSI includes many different models to recreate large and complex heterogeneous networks as well as operational scenarios with their entities and corresponding interactions & ROE. JESSI simulation relies on use of Intelligent Agents that drive all entities and units not operated by human players. In this way it is possible to conduct completely automated simulation runs or to create interactive sessions with users. In facts, the IA-CGF direct not only single entities, but also all individuals composing the entire population and they are in charge to reproduce social networks, human factors & autonomous system behaviors. JESSI has been extensively used in relation to industrial, defense and homeland security complex Scenarios and have possibility operate over multiple platforms (e.g. IoT, cloud, computers, SPIDER) being ready to be federated with other models & simulators in HLA.
Considering its own nature, JESSI have demonstrated its potential in After Action Review of exercise by collaborative teams as proposed in figure 2 where AR, VR are presented within SPIDER.
Indeed, JESSI is an example of a MS2G ready to be used to address strategic decision making in order to address complex and extended scenarios.
In facts JESSI acts as a work environment where it is possible to conduct virtual experimentation and finalize scenario awareness on real on line data or during dynamic evolution of alternative COAs; the simulator considers technological factors, but could even act based on high level orders assigning execution details to IA (Intelligent Agents), providing possibility to finalize complex risk analysis in automated way.

MEGACITY & MOSES

MEGACITY is born as instrument to study development and impact of alternative choice on big cities; indeed, a Megacity is a town overpassing 10

million inhabitants and the model has been used in multiple applications for International Organization and Research Centers in Europe and Asia (Bruzzone et al. 2014a). Megacity adds to a virtual city specific facilities and commodities in terms of ground occupation, infrastructure constraints and 3D virtual representations; this means that in relation to energy issue, by defining the statistical characteristics of population and power grid (e.g. consumption profile of people, import and export of power, energy production sharing among local generation sources) MEGACITY create a set of power plants with their fuel storage (e.g. oil tanks, gas storage or coal yards based on preferences of the town) as well as wind farms at sea or on-shore. MEGACITY addresses three main aspect: power generation, logistics and transportation. The result is to get an immediate and understandable immersive representation on the town of the impact of alternative decision, so it is possible to understand what it means to use more solar or wind generation by realizing the extensions and investments required virtually added to the 3D city; by the way for each kind of plant it is possible to specify the preferred details in that town (e.g. dimension of the wind turbine, type of installation, technology, etc.). This simulator has been investigated also as part of a crowdsourcing initiative devoted to provide clear understanding to population by allowing people to virtually visit a town that adopted alternative technological solutions. It is evident that MEGACITY could provide very interesting experimentation opportunities for VR/AR use at strategic level both for executives as well as pilot on having common people and decision makers virtually interacting on this common virtual picture about alternative solutions.

MOSES (Modelling Sustainable Environments through Simulation) is another simulator that has been developed in cooperation with Dupont and other industries to address the complex issues related to sustainability in planning big plant investments within a town; the simulator provide a comprehensive evaluation of the installation of a new plant into a town as well as the review of the overall area destination (e.g. industrial areas, commercial areas, green spaces, development of local activities); usually MOSES is used for educational and training purpose allowing two opposite teams (public authority in charge of authorization vs. private investor of the new plant) to develop a plan, finalizing an agreement on the installation of the new power plant, offset definition and town future development (Bruzzone et al. 2013). Indeed, MOSES has been used extensively in MIPET, the 1st International Master on Industrial Plant Engineering and Technologies, organized by Genoa University since ten years; in this case the class is divided in two groups and industrial and academic experts direct the role play game using MOSES as working tool. Indeed, the model consider impact on other activities, health care, environment, occupation, salaries, etc. Currently the graphics are proposed based on simplified maps of the region and interactive icon graphs where the user could simply observe changes in an intuitive way; it could be interesting to combine MOSES and MEGACITY to provide opportunities to players to observe virtually he effect on sustainability overlapped to the virtual city. Obviously in future this system could be moved also to real decision making allowing to see a real town representation augmented with the information provided by the simulator in relation to consequences of strategic decisions.

DIEM-SSP & ST_CRISOM

CRISOM (Crisis Simulation, Organization and Management) has evolved over different releases to support crisis management; the Simulator has been developed by Simulation Team to be used both for civil that military users with special attention to civil protection and disaster relief (Bruzzone et al.2018c).

Recently this solution was reframed as ST_CRISOM (Simulation Team CRISOM) and enabled to operate in HLA standard for guarantee interoperability v with other simulator or systems. Indeed, the simulator includes models about different kinds of crisis as well as virtual humans derived by IA-CGF to reproduce population behavior and first responders; the simulation allows to identify people to be evacuated, risky areas, possible contaminated areas, etc.

Currently ST_CRISOM operates stand alone or could be federated with ARPIA to have a 3D representation of town, population and crisis as well as of their dynamics. This connection could be a way to provide framework to use VR and AR on crisis management as well as on strategic decision making process related to preventing or mitigation decisions on this subject. Therefore, it is interesting to mention the DIEM-SSP (Disasters and Emergencies Management for Safety and Security in industrial Plants) environment created by a joint cooperation of Simulation Team with other Universities to have a training environment for crisis management in Industrial Plant (Bruzzone et al. 2016f); DIEM-SSP includes virtual simulation adopting MS2G paradigm and constructive simulation for procedural and high level operational decisions. It is evident that coupling ST_CRISOM with DIEM-SSP could create a virtual interactive environment to evaluate risk over towns and to develop strategic plan about procedures, standing operations, equipment and infrastructures as well as town development plans; this could be supported by Virtual interactive representations as

well by augmented reality used to demonstrate the scenario evolution directly over the real town; the system could result into a very reliable approach to support decision on new installation in urban areas (e.g. LNG in a Port bordering a town).

T-REX

Last but not least the T-REX (Threat network simulation for REactive eXperience) has been one of first models dealing with actual and complex problem of Hybrid warfare (Bruzzone 2016). The Hybrid Warfare is an evolution of different well know approaches to war that had recent fortune thanks to enabling factors (e.g. mobile technologies, social media, cyberspace); so this kind of warfare is an actual activity on going on existing scenario that was used, with different declination, also in past times (Lamb & Stipanovich 2016). Today, considering the cases of hybrid Warfare, it is very important to study this subject considering its impact on multiple aspects (e.g. public opinion, finance, diplomacy, coalition reliability, etc.) and different alternative approaches (McCuen 2008; Weitz 2009; Gerasimov 2013; Bachmann & Gunneriusson 2014; Davis 2015; Bruzzone & Cayirci 2016b). T-REX is one of first and major simulators acting on this subject and it has been used for multiple investigations and researches by International Organizations; furthermore, T-REX is based on MS2G (Modeling, interoperable Simulation & Serious Game) paradigm and it includes a stochastic discrete event simulation able to be used in stand-alone way as well as federated with other HLA simulators both in real time (training) or fast time (experimentation). Furthermore, by Monte Carlo techniques T-REX allows to apply DOE (Design of Experiments) to complete capability assessment, vulnerability reduction and to investigate alternative doctrine, policies and technological solutions for addressing Hybrid Warfare open issues (Bruzzone et al.2016e). The public domain scenario of T-REX is related to a desert region facing the sea that includes five different towns and relies on oil and gas extraction as well as on desalination facilities to survive.

T-REX simulator covers different layers of this scenario with special attention to population; this element is simulated in terms of people and social networks at physical and web levels as well as as interest groups such as business sectors, religious groups, local leaders, behaviors of single individuals.

Indeed the behaviors of the agents reproducing population are based on various parameters, for instance on educational background, social status, age and gender etc.; all these layers are dynamically evolving during the simulation due to their own regular behaviors as well as based on their perception on scenario and boundary condition evolutions; the approach used to reproduce these elements is based on AI (Artificial Intelligence), IA and FAM (fuzzy allocation matrices) to reproduce attitude and intensity over the different relationship at individual level, between people and interest groups as well as among such groups. T-REX covers also many other layers by including different models and it is open to integration by means of HLA of external simulators dedicated to specific domains (e.g. economy or traditional force to force war gaming); in facts, the simulation reproduce social media and traditional media as well as activities carried out by threat networks, simulation of Entity & Units reproducing military units and other assets that have an impact on the scenario (e.g. ELINT ELectronic-signals INTelligence, IED Improvised Explosive Device, UxV Unmanned every domain Vehicles) and able to influence directly or indirectly population behaviors.

T-REX reproduce the whole cyberspace by creating virtual cyber twins of virtual assets in order to be able to evaluate mutual interaction between physical and cyber worlds; in facts each node and link of the simulated cyberspace is defined in terms of availability, integrity and/or confidentiality, so it is possible to conduct offensive and defensive actions (e.g. preventive or restoring activities) that impact on the correspondent assets and on procedures and evolution of physical world (Bruzzone et al.2016e).

The scenario has multiple potential targets including power grid, global service, water resources, oil and Gas assets and market, communication network, etc. It is possible to assign to IA-CGF high level task devoted to protect the area or to conduct aggressive cyber warfare or hybrid warfare actions, even coordinated. By this approach it is possible to run complex scenario autonomously and by the virtual representation to present the situation to decision makers to evaluate different approaches and strategies. In addition, the use of additional information on the graphical representation over the virtual world (e.g. KPI, Cyber layer, Communications, Compromised Elements, Population Reactions) is a very good example of AR applied in the field of understanding and evaluating strategic aspects related to Hybrid Warfare.

CONCLUSIONS

In conclusion, it emerges that the new immersive technologies could enhance the capability of innovative simulators to be used in decision making at strategic level. It resulted that many simulators with proper capabilities are already available and could be tested on the field operating side by side with experts and companies.

Indeed, actually, there are favorable conditions to implement and develop models to support new critical area where the new MS2G could provide a strategic advantage, such as happen in the case of Hybrid Warfare; in this field the T-REX has a great potential and the experimentations carried out suggest to continue in this direction; similar considerations are also valid for other solutions, especially for JESSI, applied to all kind of Joint Operations or SIMCJOH

Based on these considerations the authors are working on several concurrent project to test operationally with decision makers the enabling capabilities of introducing proper modeling approach.

In this area critical infrastructure protection and Cyber warfare are just two additional elements pretty critical, but it is evident that concurrently with practical experimentation it will be fundamental to develop the new generation of engineers and scientists able to interact with future executives.

REFERENCES

Alzahrani, A., Callaghan, V., & Gardner, M. (2014) "Towards the Physical Instantiation of Virtual People and Components in Physical Mixed-Reality Tele-Presence Environments", Proc. of Intelligent Environments Workshops, pp. 285-294, July

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

Bachmann, S. D. O. V., & Gunneriusson, H. (2014) "Terrorism and cyber attacks as hybrid threats: defining a comprehensive approach for countering 21st century threats to global risk and security", The Journal on Terrorism and Security Analysis.

Balci, O. (1997, December). Verification validation and accreditation of simulation models. In Proceedings of the 29th conference on Winter simulation (pp. 135-141). IEEE Computer Society.

Bednarz, T., James, C., Widzyk-Capehart, E., Caris, C., & Alem, L. (2015). "Distributed collaborative immersive virtual reality framework for the mining industry" in Machine Vision and Mechatronics in Practice. Springer Berlin Heidelberg. pp. 39-48

Benes F., Kodym O. (2014) "Application of Augmented Reality in Mining Industry", Proc. 14th SGEM GeoConference on Informatics, Geoinformatics & Remote Sensing, Vol. 1, 1-35

Bower, M., Lee, M. J., & Dalgarno, B. (2016) "Collaborative learning across physical and virtual worlds", British Journal of Educational Technology

Bruzzone A.G. (2018) "MS2G as Pillar for Developing Strategic Engineering as a New Discipline for Complex Problem Solving", Keynote Speech at I3M, Budapest, September

Bruzzone, A. G., Massei, M., & Di Matteo, R. (2018a). Modeling, Interoperable Simulation and Serious Games (MS2G) for healthcare and first responders in disasters within industrial plants. In Proceedings of the 50th Computer Simulation Conference, SCS, Bordeaux,July

Bruzzone A.G., Massei M., Sinelshchikov K., Di Matteo R. (2018b) "Population Behavior, Social Networks, Transportations, Infrastructures, Industrial and Urban Simulation", Proc. of EMSS, Budapest September

Bruzzone A.G., Massei M., Di Matteo R., Agresta M. (2018c) "Simulation of Crisis Affecting Critical Infrastructures and Industrial Plants", Proc. of DHSS, Budapest, September

Bruzzone A.G., Massei M., Nicoletti L., Sinelshchikov K., Di Matteo R., Cardelli M., Kuman Kandunuri P. (2017a) "Immersive, Interoperable and Intuitive Mixed Reality for service in Industrial Plants", Proc. of MAS, Barcelona, Spain, September

Bruzzone A.G., Massei, M. (2017b) "Simulation-Based Military Training", in Guide to Simulation-Based Disciplines, Springer, pp. 315-361

Bruzzone A.G., Massei, M., Bella, P. D., Giorgi, M., & Cardelli, M. (2017c) "Modeling within a synthetic environment the complex reality of mass migration", Proc. of the Agent-Directed Simulation Symposium, Virginia Beach, VA, April

Bruzzone A.G., (2016) ""New Challenges & Missions for Autonomous Systems operating in Multiple Domains within Cyber and Hybrid Warfare Scenarios"", Invited Speech at Future Forces, Prague, Czech Rep.

Bruzzone A., Longo F., Nicoletti L., Vetrano M., Bruno L., Chiurco A., Fusto C., Vignali G. (2016a). Augmented reality and mobile technologies for maintenance, security and operations in industrial facilities. 28th European Modeling and Simulation Symposium, EMSS 2016, pp. 355.

Bruzzone A.G., Cayirci E. (2016b) "T-REX About Hybrid Warfare" Invited speech, CAX Forum, Munich, Germany, September

Bruzzone A.G., Massei M., Maglione G.L., Di Matteo R., Franzinetti G. (2016c) "Simulation Of Manned & Autonomous Systems For Critical Infrastructure Protection ", Proc. of I3M, Larnaca

Bruzzone A.G., Massei M., Di Matteo R., Agresta M., Franzinetti G., Porro P. (2016d) "Modeling, Interoperable Simulation and Serious Games as an Innovative Approach for Disaster Relief", Proc. of I3M, Larnaca, September

Bruzzone A.G., Massei M., Di Matteo R., Maglione G.L. (2016d) "Model of Advanced Planner for Interoperable Computer Interactive Simulation", Proc. of I3M2016, Larnaca, September

Bruzzone A.G., Massei M., Longo F., Cayirci E., di Bella P., Maglione G.L., Di Matteo R. (2016e) “Simulation Models for Hybrid Warfare and Population Simulation”, Proc. of NATO Symposium on Ready for the Predictable, Prepared for the Unexpected, M&S for Collective Defence in Hybrid Environments and Hybrid Conflicts, Bucharest, Romania, October 17-21

ruzzone A.G., Massei M., Agresta M. et al. (2016f) "A Decision Support System For Disaster Prevention In Urban Areas" Proc.of I3M2016, Larnaca, September

Bruzzone A.G., M. Massei, F. Longo, L, Nicoletti, R. Di Matteo, G.L.Maglione, M. Agresta (2015a) "Intelligent Agents & Interoperable Simulation for Strategic Decision Making On Multicoalition Joint Operations". In Proc. of the 5th International Defense and Homeland Security Simulation Workshop, DHSS, Bergeggi, Italy

Bruzzone A.G., Massei M., Tremori A., Di Matteo R., Maglione G.L. (2015b) "Synthetic Environment For Interoperable Advanced Marine Simulation, Proc. of EMSS, Bergeggi, Italy, September

Bruzzone A.G., Massei M., Agresta M., Poggi S., Camponeschi F., Camponeschi M. (2014a) "Addressing strategic challenges on mega cities through MS2G", Proceedings of MAS2014, Bordeaux, France, September

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", Proc. of WAMS, Istanbul, September

Bruzzone A.G., Massei M., Poggi S., Dallorto M., Franzinetti G., Barbarino A. (2013) "Quantitative simulation of comprehensive sustainability models as game based experience for education in Decision Making", Proceedings of I3M, Athens, Greece

Bruzzone A., Massei M., Longo F., Madeo F., (2011a). Modeling and simulation as support for decisions makers in petrochemical logistics. Proceedings of the 2011 Summer Computer Simulation Conference, pp. 130.

Bruzzone, A., & Saetta, S. (2002). LESNEX: Lean simulation network of excellence. Proc. of MAS2002, Bergeggi, SV, Italy, October 3-5

Bruzzone A.G., Cotta G., Cerruto M. (1997) “Simulation & virtual reality to support the design of safety procedures in harbour environments” Proceedings of ITEC97, Lausanne, Switzerland

Burdea, G. C., & Coiffet, P. (2003). Virtual reality technology. John Wiley & Sons, NYC

Chafkin M. (2015) "Why Facebook’s $2 Billion Bet on Oculus Rift might one day connect Everyone on Earth", Vanity Fair Hive, October

Dai, F. (Ed.). (2012) “Virtual reality for industrial applications”, Springer Science & Business Media

Davis J.R. Jr (2015) “Continued Evolution of Hybrid Threats”, The Three Sword Magazine, N. 28

Di Bella P. (2015) “Present and Futures Scenarios and Challenges for M&S terms of Human Behaviour Modeling”, Invited Speech at I3M2015, Bergeggi, Italy, September

Fabiano, B., Parentini, I., Ferraiolo, A., Pastorino, R. (1995) "A century of accidents in the Italian industry", Safety Science, 21, 65-74

Gerasimov V. (2013) "The Value of Science is in the Foresight: New Challenges Demand Rethinking the Forms and Methods of Carrying out Combat Operations", Voyenno-Promysh-lennyy Kurier online, February 26

Lamb C., Stipanovich S. (2016) “Back to Basics on Hybrid Warfare in Europe A Lesson from the Balkans”, in Joint Force Quarterly, 81, March 29

Le, Q. T., Pedro, A. K. E. E. M., Lim, C. R., Park, H. T., Park, C. S., & Kim, H. K. (2015) “A framework for using mobile based virtual reality and augmented reality for experiential construction safety education”, International Journal of Engineering Education, 31(3), 713-725

Lindgren, R., Tscholl, M., Wang, S., & Johnson, E. (2016) "Enhancing learning and engagement through embodied interaction within a mixed reality simulation". Computers & Education, 95, 174-187

McCuen, J. J. (2008). “Hybrid Wars”, Military Review, 88 (2), 107

Massei M., Poggi, S., Agresta, M., & Ferrando, A. (2014) "Development Planning Based on Interoperable Agent Driven Simulation", Journal of Computational Science, 5(3), 395-407

Massei, M., Tremori, A., Poggi, S., & Nicoletti, L. (2013). HLA-based real time distributed simulation of a marine port for training purposes. Int.Journal of Simulation and Process Modelling, 8(1), 42-51.

Mazal J., (2018) “MSG 152 Progress Report”, Proc.of CAX Forum, Sofia, September

Mosca, R., Giribone, P., & Bruzzone, A. G. (1995). Al Techniques to Optimize the Distribution of Fire-Fighting Squads During an Accident. Simulation Series, 27, 321-321.

Palazzi, E., Caviglione, C., Reverberi, A.P., Fabiano, B. (2017) "A short-cut analytical model of hydrocarbon pool fire of different geometries, with enhanced view factor evaluation”, Process Safety and Environmental Protection, August

Pérez-Ara, M. A., Quero, S., Navarro, M. V., Botella, C., & Baños, R. M. (2013) “Augmented Reality for Safety at Work: Needs Analysis of the Priority Risks for Safety”, Proc. of Health Context in Spain, INTED, pp. 812-817

Perlman, A., Sacks, R., & Barak, R. (2014). "Hazard recognition and risk perception in construction". Safety science, 64, pp. 22-31.

Pimentel, K., Teixeira, K. (1992) "Virtual reality: through the New Looking Glass", TAB Books, NYC

Quero, S., Botella, C., Pérez-Ara, M. A., Navarro, M., Baños, R. M., Maciá, M. L., & Rodríguez, E. (2012). The use of Augmented Reality for safety in health: The European Project ANGELS. In ICERI2012 Proceedings (pp. 215-218). IATED.

Rizzo, A. A., Bowerly, T., Buckwalter, J. G., Klimchuk, D., Mitura, R., & Parsons, T. D. (2009). A virtual reality scenario for all seasons: the virtual classroom. Cns Spectrums, 11(1), 35-44.

Safir, I. J., Shrewsberry, A. B., Issa, I. M., Ogan, K., Ritenour, C. W., Sullivan, J., & Issa, M. M. (2015). Impact of remote monitoring and supervision on resident training using new ACGME milestone criteria. Can J Urol, 22, 7959-7964

Scudellari M. (2016) "Google Glass Gets a Second Life in the ER", IEEE Specturm, May 25

Seidel, R. J., & Chatelier, P. R. (Eds.). (2013). "Virtual reality, training's future? Perspectives on virtual reality and related emerging technologies". Springer Science & Business Media.

Sherman, W. R., & Craig, A. B. (2003) "Understanding Virtual Reality—Interface, Application, and Design. Presence", Morgan Kaufmann Publisher, SF, 12(4)

Spanu S., Bertolini M., Bottani E., Vignali G., Di Donato L., Ferraro A., Longo F., (2016). Feasibility study of an augmented reality application to enhance the operators' safety in the usage of a fruit extractor. International Food Operations and Processing Simulation Workshop, FoodOPS 2016, pp. 70.

Tatić, D., & Tešić, B. (2017) "The application of augmented reality technologies for the improvement of occupational safety in an industrial environment", Computers in Industry, 85, 1-1

Thomas, B., Close, B., Donoghue, J., Squires, J., De Bondi, P., Morris, M., & Piekarski, W. (2000, October). ARQuake: An outdoor/indoor augmented reality first person application. In Wearable computers, the fourth international symposium on (pp. 139-146). IEEE

Wagner K. (2016) "Two Years Later: Facebook's Oculus Acquisition Has Changed Virtual Reality Forever", Recode, March 24

Weitz, R. (2009) "China, Russia, and the Challenge to the Global Commons", Pacific Focus, 24(3), 271-297.

Zhang, J., Hou, H. T., & Chang, K. E. (2014) "UARE: Using reality-virtually-reality (RVR) models to construct Ubiquitous AR environment for e-Learning context", Proc. of IEEE Science and Information Conference (SAI), August, pp. 1007-1010

MULTI LAYER APPROACH WITH HUMAN BEHAVIOUR MODIFIERS TO SIMULATE FOOD SUPPLY CHAIN

Agostino G. Bruzzone [(a)], Matteo Agresta [(b)], Jen Hsien Hsu (c)

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

[(b)] Department of Strategic Management and Marketing, De Montfort University, UK

[(a)] agostino@simulationteam.com, [(b)] matteo.agresta@simulationteam.com, [(c)] jen.hsu @dmu.ac.uk

ABSTRACT

Social Network Interactions are extremely powerful in the opinion formation. The propagation of the information is extremely interesting in many different domains and simulation is a powerful instrument to capture many aspects of this phenomenon. This paper presents a large scale-Agent Based Simulation devoted to reproduce human behaviour in urban context by making use of a multi-layer approach. This solution allows to simulate the population as a system of interacting agents where each agent is a single entity characterized by a set of attributes based on real open data available. The daily behaviour of each single individual is simulated in time and it is used for estimating the probability for each agent to have social interaction with the other people. The word-of-mouth phenomena is simulated in the form of "Opinion Exchange" during the simulation time. The solution proposed allow to weight social interaction based on the influence of agent with a other one. Finally, the model proposed is applied for testing a food choice model based on the probability to buy ethical v.s. standard food by considering three main parameters: price, accessibility and Opinion

Key Words: *Agent Based Simulation, Green Products Consumption Simulation, Social Networks Simulation, Word of Mouth*

1 INTRODUCTION

Understanding the propagation of an idea or an opinion among social networks have always been extremely challenging (Bruzzone et al.2014a, 2017). Nowadays this task become more and more complex since people is constantly connected to the web by means of smartphone and other devices.

Despite there are discordant opinions on the use of the smartphone, depending also from the country and from the user profile, recent estimation on the use of social network declare that we spend more than one hour per day on application like Facebook, Twitter and Snapchat with an increasing trend. For example, Facebook user are over 2.23 billion monthly active Facebook users for Q2 2018 (Facebook MAUs) which is an 11 percent increase year over year. Data from social media like Facebook, Twitter, You Tube, allow to share feeling, pictures and videos that have a great potential to influence individual Opinion (Sharma et al, 2018; Koulompis et al, 2001).

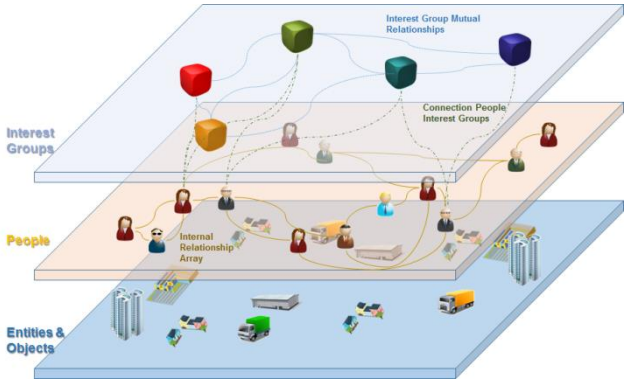

Figure 1: Multi Layer Approach for simulating Individual

It is also important to underline that each individual with an internet access is both a "receiver" and an "emitter", indeed it doesn't limit to receive and look for information but he also publish his opinion, feedback and sentiments to his network. Such process generates viral loops of reading- publishing the popular web content (Bruzzone, Agresta, Hsu, 2017).

2. AGENT BASED MULTILAYER SIMULATION

The aim of this paper is twofold: the first objective is to build an agent based multi-layer simulation able reproduce the individual activities of the population of an entire city for estimating their probability to get in touch with other agents. Secondly, an Opinion function is defined in order to capture the word-of-mouth phenomena in ethical food consumption. A choice model for estimating the standard food choice v.s. the ethical food choice is defined and assumed to be dependent on three parameters: price, accessibility of the shops and and "Opinion Function".

This approach is able to reproduce how a consumer's social network interaction cam modify his opinion and is market choice considering stochastic factors as well as human behaviour modifiers (Bruzzone et al. 2011). The contribution of this paper is mainly twofold: firstly, it is devoted to contribute to the ethical marketing literature regarding the moderation role of social network position and other communication channels on consumer's perception about the social values of ethical products.

By identifying this, it is likely to capture how social values of are weighted among different types of consumers and to provide implications to marketing practitioners regarding how to present the social values of

ethical products. Second goal is to analyze and demonstrate the potential of M&S (Modeling & Simulation) as support for marketing scientist in testing and validating their hypothesis within a synthetic environment. Indeed social systems, communication channels and time are proved to be, at least, three of the four main key drivers required to analyze the diffusion of new product in marketing science (Mahajan, Muller & Bass, 1991).

3 ETHICAL FOOD CHOICE

The proposed approach and this model have been investigate by the author in previous research defining the general architecture (Bruzzone, Agresta, Hsu, 2017). Obviously there are many different alternative hypotheses about the modern drivers of consumer demand and the growing influence of ethical and environmental issues since over 20 years (Strong 1996; Crane 2001; Peloza et al. 2013); indeed the food industry is even further sensitive to these elements and there are interests in investigating these aspects to develop new models (Jensen et al. 2011). The complexity of this context touches many different issues, from operational ones (e.g. logistics and production processes) to marketing and promotion often dealing with human factors (Schröder et al. 2004; Siro et al. 2008; Bruzzone et al. 2009a). It is evident that the complexity of each of these elements and their mutual interactions with human factors make it very challenging to develop quantitative analysis on this framework, therefore the importance to create models and simulators dealing with these issues results to be a strategic advantage for planner and decision makers (Bredahl et al. 1998; Vermeir & Verbeke 2006; Bruzzone et al. 2009b). Due to these reasons, the authors propose the development of an agent based simulation able to model this context and support analysis of green product consumptions. Despite the widespread attention in ethical consumption is receiving, consumers show little interests in actually purchasing ethical products, such as organic or fair-trade produces. For instance, Futerra (2005) found that whilst 30% of consumers claims themselves to be ethical consumers whereas only 3% of them actually put into practices. Such intention-behaviour gap reflects the situation that the benefit of product ethicality is at a lower hand against the practical concerns, such as price, accessibility, and quality issues, in the decision-making process (Devinney, Auger, & Eckhardt, 2010). Yet, there is an increasing evidence suggesting impression management reasons as main key factors to promote ethical consumption. For instance, Griskevicius, Tybur, and Van den Bergh (2010) demonstrated that eliciting consumers' status motives increase their desire for green products. The use of social norms (e.g., joining fellow citizens to save waters) increase also the likelihood for pro-social choices (Goldstein, Cialdini, & Griskevicius, 2008; White & Simpson, 2013). These empirical findings raise a question for investigation "*what type(s) of consumers will appreciate the social benefits of ethical products more than other consumers*?"

Based upon an instrumental altruism perspective, the authors conjecture is that consumer's social network position (e.g., how many connections they have and how central and active they are in the network) affects to what extent they will appreciate the social values of ethical products (Andreoni, 1990; Kahneman & Knetsch, 1992; Zahavi, 1975). Firstly, people who are at the central positions within their social network generally play as the roles of opinion leaders or lead users, which involve them having frequent social interactions with other members within their social node (Kratzer & Lettl, 2009). So, these types of consumers would have a higher need for impression management whereas the engagement in ethical consumption results to be one of major means that consumers do frequently (Crane & Matten, 2016). In facts agent based modeling has been applied in different area of marking to capture the aggregate dynamics originated from interactions among individual consumer (Delre et al. 2007; Goldenberg, Libai, and Muller 2010) as well as to examine these impacts on consumer's choice (Haenlein & Libai, 2013). The authors decided to simulate the complex behaviour of such social systems by using agent driven simulation,

Table 1:Point of Interest (PoI) in the simulator

#	PoI	Icon	Type
1	Commercial Centres		real data
2	Hospital		real data
3	Fire Fighters		real data
4	Police Stations		real data
5	Small Shops		generated
6	Parking Areas		Generated
7	Stadium		real data
8	Cinema		real data
9	Theatre		real data
10	Museums		real data
11	Bar		Generated
12	Households		real data
13	Parks		real data
	Schools/Universities		real data

4. SIMULATION

The authors used agent driven simulation paradigm based on Intelligent Agent Computer Generated Forces (IA-CGF) libraries that have been developed by Simulation Team along the years (Bruzzone et al. 2011).

By this approach the population is simulated as composition of single intelligent individuals living in a simulated town or region, all interconnected in social networks and related with interest groups; these entities are defined people objects or virtual persons and are interacting each other, as well as with their interested group (e.g. green movement, youth, universities students etc.) as well as to entities and objects that operate on the field (e.g. radio station, supermarket, etc.) as proposed in Table 1. Obviously the Simulation of population requires to consider the impact of HBM (Human Behaviour Modifiers) devoted to affect the actions and reactions of

people; from this point of view the authors adopted for conceptual models the structure developed by Simulation Team present in Intelligent Agents Computer Generated Forces, as anticipated; this models consider different data sets of HBM as well as different factors (Bruzzone et al. 2011); the first data set deals with individual characteristics and it is related t individual parameters with special attention to psychological factors such as: stress, fear, fatigue and aggressiveness; so it is evident that based on these parameters that evolve dynamically during simulation based on specific algorithms devoted to reproduce these phenomena considering the hysteresis characteristics suggested by SME (Subject Matter Experts); in this way it turns possible to observe reaction to a case of supply chain contamination (e.g. avian influenza) as well as to phenomena related to specific media campaign to solicit specific aspects (Bruzzone et al.2014b). Another set of crucial HBM is related to the social network links connecting different agents reproducing different people of the virtual population; it is evident that this affects the social behaviour in terms of food choice and it has been investigated in previous experimentation by Simulation Team and Harvard Medical School within BACCUS initiative (Massei et al. 2013). Individual preferences and choices are also related to the links between the virtual persons and the interest groups corresponding to their interests (e.g. age/generation, gender, religion, etc.); in these cases it was supposed, in studies related to media actions influencing population, the possibility to have an influence of simulation events on agents affecting the reliability of the connection to consider attitude shifts (Bruzzone 2013). In facts based on this approach it turn possible to consider the dynamics of food preferences during simulation runs based on actions and changes on boundary conditions.

5 SOCIAL NETORK & PEOPLE MODELS

As anticipated the HBM are crucial element in this simulation and hereafter it is described the process for generating individual, families & social network before the simulation start. Indeed the simulator generates single individuals, at first, and then it aggregates each one into families and social network, based on a weighted graph.

5.1 Individual Layer Definition

Each individual is characterized by the following parameters, assumed to be known, based on statistical distribution:

a) Individual Parameters:
   - Age
   - Sex (M/F)
   - Level of Education
   - Religion
   - Area of the city where he/she lives
   - Area of the city where works/go to school
   - Area of the city for extra activities, leisure, free time
   - Incomes
   - Occupation Type(e.g., white collar, blue collar, etc.)
   - Political orientation
   - Ethnic group

b) Individual Human Modifiers

   Stress Fatigue
   Fear Aggressiveness

The simulator computes and updates the value of specific individual human modifiers that are resulting from the scenario evolution, individual perceptions as well as from his previous history and current emotional status. Simulation Team have developed these models for military and civilian domains by correlating human feelings like fear, stress, aggressiveness, fatigue and trustiness with different events and actions.
for instance these have been applied in case of urban riots, social tension escalation, fear diffusion, and political consensus (Bruzzone et al.2011). These values are constantly updated and vary according to events that occur during the simulation run and according to the information exchange among each node and the network; these human factors could be evaluated both at individual level as well as aggregate level. For the aim of this paper in the following are reported main relationships.

5.1 Family generations: Strong Relationships

In this phase the individuals are aggregated stochastically in a graph according to their family components; such operation is based on compatibility algorithms and it could be also performed by using real data about families, if available. Once the families are generated, the system calculates some interesting indicators useful for validation and to check family characteristics such as :

- **Number of Sons**
- **Family incomes** as sum of the incomes of the different individual composing a family

These relationships are represented by means of graph theory, where each node represents an individual and each arc represents a connection. In particular the weighted graph has been used in order to define Stronger and Weaker connections. Familiar connection are obviously stronger and have more influence compared to other ones

5.2 Social Layer generations: Weaker Relationships

In this phase, the individuals are grouped in the social networks by means of a compatibility algorithm. Obviously the system is open to receive real data from social networks, but currently the social network is just stochastically generated among the different individuals.
Each individual is characterized by several parameters that are stochastically generated based on its Individual and Social Characteristics.
In this modelling approach the focus is in particular on following characteristics:

a) Social media number of Connections
b) Social media activeness, defined as “to what extent they share their personal life on social media”
c) Media and other information channels

In this layer the individual are connected to the information channels that are represented by nodes. Each individual is considered connected to such networks, by a specific weight according to its individual parameters.

6 MODELLING INDIVIDUAL CONSUMER CHOICES

Discrete Choice Models are useful to analyze and predict the individual choices when the set of choice is constituted by a finite number of alternatives. Such Models make use conventionally by Random Utility Model (RUM) that have been proposed for the first time by (Block & Marschak, 1960). These disaggregate models have been widely used for the simulation of individual choices in particular for what concern transportation and travel choices. (Ben Akiva & Lerman, 1985; Ben Akiva & Biedlare, 2003).

Considering the consumer choice, such models have been widely applied, also considering the Behavioral Decision Theory (BDT). (Swait & Adamowicz, 2001).

In general discrete choice model Discrete are derived from utility theory and in this case is applied a simple binary Logit is applied (Matejka et al.2014); the common requirements for discrete choice models are:

- The set of alternatives must be collectively exhaustive; this imply that each individual and group of similar individuals have its own set of alternatives from where to choose
- The alternatives must be mutually exclusive
- The set must contain a finite number of alternatives

Each individual is expected to maximise its *utility* derived from the different options that are available among the possible choices in set C. In this case each individual i has option among 2 choices:

a: Standard Food
b: Ethical Food

Each of these options provide to the single individual the *utility* from the two options: U_a and U_b with:

$$U = V + \varepsilon$$

$V =$ Systematic Utility
$\varepsilon =$ Error Term (Assumed to have a logistic distribution) for simulating the error on perception of each single individual and irrational behaviour.

So the probability of choosing an alternative n for each individual i is given by:

$$P_{i,n} = \mathrm{G}(x_{i,a}, x_{i,b}, \underset{*}{\gamma_{i,}}, \beta_i)$$

$x_{i,a}$ is a vector of attribute of alternative a
$x_{i,b}$ is a vector of attribute of alternative b
$\underset{*}{\gamma_{i,}}$ is a vector of characteristic of person i
β_i is a set of parameters giving the effect of variables on probabilities

$$U_{i,n} = \beta_{i,n} \cdot \underset{*}{\gamma_{i,n}} + \varepsilon$$

$$V_{i,n} = \beta_{i,n} + \underset{*}{\gamma_{i,n}}$$

So, the probability of choosing a green product a, and/or a standard product b, for each individual i is defined by:

$$P_{a,i} = \Pr(-V_{a,i} + \varepsilon_{a,i}) > \Pr(-V_{b,i} + \varepsilon_{b,i})$$
$$P_{b,1} = \Pr(-V_{a,i} + \varepsilon_{a,i}) < \Pr(-V_{b,i} + \varepsilon_{b,i})$$
$$P_{a,i} = \frac{1}{1 + \exp(-\beta_i \cdot V_{a,i})}$$
$$P_{b,i} = \frac{1}{1 + \exp(-\beta_i \cdot V_{b,i})}$$

Table 2: Information Channels

Media Channel	Probability	Description
Radio	Probability to hear it	Probability to see television according to his day life
Television	Probability to see it	Probability to see television according to his day life
Social Networks	Individual network Influence	Structure of the social network in time
Advertising Board	Probability to see it	Location of the Advertising Board in the city and probability to pass in this street calculated by means of simulation

For modelling customer green choices, the authors have considered the following parameters that have been correlated to each single individual:

$\gamma_{i,n} = \beta_1 * \mathrm{Inc} + \beta_2 * (\mathrm{GrP} - \mathrm{SP}) + \beta_3 * \mathrm{Of} + \beta_3 * (\mathrm{AsP} - \mathrm{AeP})$

Where:
Inc = Individual Income
GrP = Green Product Cost
SP = Standard Product Cost
Of = Opinion Function
Ac = Accessibility of Standard Product
AEP = Accessibility of Ethical Product

These parameters have been hypothesized considering specific assumptions and the choice manipulation is based on the following parameter:

- Price gap among (Ethical food and Standard Food)
- Accessibility of the ethical food based on a set of assumptions as proposed hereafter

Indeed, all other parameters are assumed known, based on the following considerations:

- Social media activeness
  - Definition: to what extent people share its own personal life on social media
  - Hypothesis: a positive significant relationship between social media activeness and green consumption owing to the need of showing-off or impression management (Griskevicius et al., 2010)
- Green Value (Haws, Winterich, & Naylor, 2014)
  - Definition: The tendency to express the value of environmental protection through one's purchases and consumption behaviour.
  - Hypothesis: a positive significant relationship between social media activeness and green consumption.
- Price sensitiveness (Lichtenstein, Ridgway, & Netemeyer, 1993)

    - Definition: the degree to which the consumer focuses exclusively on paying low prices.
    - Hypothesis: a negative significant relationship between social media activeness and green consumption.
- "Willingness to spend on food"
    - Within a person's budget living expenses, there is a need to prioritise how much he/she would spend on foods, clothing, entertainments, etc.
    - This parameter is complementary to price sensitiveness
- Citizens (of different social status categories) are be "centred" into particular zones (work place & residential area)

7 A PRELIMINARY CASE STUDY

For this first experiment have been performed a simulation with real data from the city of Genova, in particular have been considered:

- 10 zones of the city
- 10'000 individual
- Around 6.000 families
- 3 New Ethical Shops
- 145 Standard Food Shops

Each individual has been defined by its own parameters generated stochastically based on aggregated open data available from Genoa databases; the family and social networks have been created based on compatibility algorithms in consistency with the reference parameters.

Simulation duration have been to one 1 month. The simulator allows to evaluate the green consumption level of the different members of the families and the probability to buy ethical food respect different accessibility levels and different prices. Obviously a very critical aspect in developing this model is to finalize the VV&A (Verification, Validation and Accreditation) processes. it is evident the critical aspect devoted in validating these issues in real and historical cases and in checking data reliability; due to these reasons the author are actually conducting dynamic virtual experimental campaigns on numerical case to achieve preliminary validation of the proposed approach; ANOVA technique and experimental error temporal evolution analysis are the methods to be used to check consistency of the stochastic factors included in the models (Montgomery 2008). In facts up to now the validation and verification is still based on SME (Subject Matter Experts) face validation.

8 CONCLUSIONS

This paper proposes a preliminary investigation devoted to match intelligent agents with social network simulation in real cases respect green food product consumption. It is evident the complexity of the phenomena related to this context as well as the uncertainty affecting the human factors and, consequently, the efforts required to fine tuning the model parameters. Therefore it is important to outline that the adopting of agent driven simulation based on stochastic discrete event approach enables to model these complex scenarios and could result an interesting support to improve the understanding of this context. As anticipated, the authors are working on VV&A and it is expected that these new models, as soon as validated, could emerge as a strategic advantage in supporting decisions in these application areas. Currently the authors are working on finalizing the certification of numerical data sets for the proposed scenario based on examples inspired by real historical case studies; these data will be used to complete dynamic and statistical VV&A of the proposed simulator with support of SME (Subject Matter Experts).

REFERENCES

Andreoni, J. (1990). Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving. The Economic Journal, 100(401), 464-477

Ben-Akiva, M. and M. Bierlaire (2003) Discrete Choice Models With Applications to Departure Time and Route Choice The Handbook of Transportation Science, 2nd ed., (eds.) R.W.

Ben-Akiva, M. E., & Lerman, S. R. (1985). Discrete choice analysis: theory and application to travel demand (Vol. 9). MIT press

Block, H. D., & Marschak, J. (1960). Random orderings and stochastic theories of responses. Contributions to probability and statistics, 2, 97-132.

Bredahl, L., Grunert, K. G., & Frewer, L. J. (1998). Consumer attitudes and decision-making with regard to genetically engineered food products–a review of the literature and a presentation of models for future research. Journal of consumer Policy, 21(3), 251-277.

Bruzzone, A.G., Agresta M., M. Agresta, J.Hsien Hsu (2017) "Human Behavior and Social Influence: an application for Green Product Consumption Diffusion", Proc.of WAMS, Florence, September

Bruzzone, A.G., M. Massei, M. Agresta, G. Murino. (2016). "A decision support system for disaster prevention in Urban Areas " In proc. of. 4th International Workshop on Simulation for Energy, Sustainable Development and Environment

Bruzzone, A., Massei, M., Longo, F., Poggi, S., Agresta, M., Bartolucci, C., & Nicoletti, L. (2014a). Human behavior simulation for complex scenarios based on intelligent agents. In Proceedings of the Annual Simulation Symposium (p. 10). Society for Computer Simulation International.

Bruzzone, A. G., Longo, F., Massei, M., Nicoletti, L., & Agresta, M. (2014b). Safety and security in fresh good supply chain. International journal of food engineering, 10(4), 545-556.

Bruzzone, A. G. (2013) "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., Novak, V., & Madeo, F. (2012) "Obesity epidemics modelling by using intelligent agents", SCS M&S Magazine, 9(3), 18-24

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

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., Massei, M., & Bocca, E. (2009a). Fresh-food supply chain. In Simulation-based case studies in logistics. Springer London. pp. 127-146

Bruzzone, A. G., Tremori, A., Massei, M., & Tarone, F. (2009b). Modeling Green Logistics. Proceedings of AMS, Third IEEE Asia International Conference on Modelling & Simulation, May, pp. 543-548

Can, F., Özyer, T., & Polat, F. (Eds.). (2014). State of the art applications of social network analysis. Springer.

Crane, A. (2001). Unpacking the ethical product. Journal of Business Ethics, 30(4), 361-373.

Crane, A., & Matten, D. (2016). Business ethics: Managing corporate citizenship and sustainability in the age of globalization. Oxford University Press.

Davidsson, P. (2002). Agent based social simulation: A computer science view. Journal of artificial societies and social simulation, 5(1).

Delre, S. A., Broekhuizen, T. L. J., & Bijmolt, T. H. A. (2016). The Effects of Shared Consumption on Product Life Cycles and Advertising Effectiveness: The Case of the Motion Picture Market. Journal of Marketing Research, 53(4), 608-627. doi:10.1509/jmr.14.0097

Devinney, T. M., Auger, P., & Eckhardt, G. M. (2010). The Myth of the Ethical Consumer. Cambridge: Cambridge University Press.

Futerra, S. C. L.: 2005, The Rules of the Game: The Principals of Climate Change Communication (Depart- ment for Environment, Food and Rural Affairs, London, UK).

Goldenberg, J., Libai, B., & Muller, E. (2001). Using complex systems analysis to advance marketing theory development: Modeling heterogeneity effects on new product growth through stochastic cellular automata. Academy of Marketing Science Review, 2001, 1.

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels. Journal of Consumer Research, 35(3), 472-482.

Griskevicius, V., Tybur, J. M., & Van den Bergh, B. (2010). Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation. Journal of Personality & Social Psychology, 98(3), 392-404.

Haenlein, M., & Libai, B. (2013). Targeting revenue leaders for a new product. Journal of Marketing, 77(3), 65-80.

Jensen, K. D., Denver, S., & Zanoli, R. (2011). Actual and potential development of consumer demand on the organic food market in Europe. NJAS-Wageningen Journal of Life Sciences, 58(3), 79-84.

Kahneman, D., & Knetsch, J. L. (1992). Valuing public goods: The purchase of moral satisfaction. Journal of Environmental Economics and Management, 22(1), 57-70

Mahajan, V., Muller, E., & Bass, F. M. (1991). New product diffusion models in marketing: A review and directions for research. In Diffusion of technologies and social behavior (pp. 125-177). Springer, Berlin, Heidelberg

Massei, M., Tremori, A., Novak, V., Poggi, S., Bartolucci, C., Ferrando, A., & Chiurco, A. (2013). Obesity Epidemic Simulation Based on Behavioral Models and Intelligent Agents. International Journal of Privacy and Health Information Management (IJPHIM), 1(2), 96-114.

Matejka, F., & McKay, A. (2014). Rational inattention to discrete choices: A new foundation for the multinomial logit model. The American Economic Review, 105(1), 272-298.

Peloza, J., White, K., & Shang, J. (2013). Good and guilt-free: The role of self-accountability in influencing preferences for products with ethical attributes. Journal of Marketing, 77(1), 104-119.

Schröder, M. J., & McEachern, M. G. (2004). Consumer value conflicts surrounding ethical food purchase decisions: a focus on animal welfare. International Journal of Consumer Studies, 28(2), 168-177.

Sharma, N., Pabreja, R., Yaqub, U., Atluri, V., Chun, S., & Vaidya, J. (2018, May). Web-based application for sentiment analysis of live tweets. In Proceedings of the 19th Annual International Conferenc+e on Digital Government Research: Governance in the Data Age (p. 120). ACM..

Siro, I., Kápolna, E., Kápolna, B., & Lugasi, A. (2008). Functional food. Product development, marketing and consumer acceptance—A review. Appetite, 51(3), 456-467.

Strong, C. (1996). Features contributing to the growth of ethical consumerism-a preliminary investigation. Marketing Intelligence & Planning, 14(5), 5-13.

Swait, J., & Adamowicz, W. (2001). Choice environment, market complexity, and consumer behavior: a theoretical and empirical approach for incorporating decision complexity into models of consumer choice. Organizational Behavior and Human Decision Processes, 86(2), 141-167.

Vermeir, I., & Verbeke, W. (2006). Sustainable food consumption: Exploring the consumer "attitude–behavioral intention" gap. Journal of Agricultural and Environmental ethics, 19(2), 169-194.

White, K., & Simpson, B. (2013). When Do (and Don't) Normative Appeals Influence Sustainable Consumer Behaviors? Journal of Marketing, 77(2), 78-95. doi:10.1509/jm.11.0278

Zahavi, A. (1975). Mate selection—A selection for a handicap. Journal of Theoretical Biology, 53(1), 205-214

A SIMULATION STUDY TO SUPPORT STRATEGIC CHOICES TO IMPROVE AIRPORT EFFICIENCY AND SECURITY

Agostino Bruzzone [(a)], Anna Sciomachen [(b)]

(a) Department of Mechanical, Energy, Management and Transportation Engineering, University of Genoa
(b) Department of Economics and Business Studies, University of Genova

[(a)]agostino@itim.unige.it
[(b)]sciomach@economia.unige.it

ABSTRACT
In this work we deal with the critical issues that have emerged at the main terminal of a crowded international airport due to the considerable congestion at the arrival gates for the security check-point and the luggage control before the exit. We face this problem by evaluating the efficiency of the passenger flow management within the terminal through the development and analysis of a discrete event simulation model. More precisely, starting from the present scenario, we propose an alternative layout and passenger path able to overcome the actual inefficiencies of the control process and minimize the gate exiting time. A cost-benefit analysis is also given aimed at showing that strategic decisions relevant for the efficiency and security of the airport can be usefully supported by simulation techniques such as those proposed here.

Keywords: *Discrete Event Simulation, Performance Evaluation, Passenger Flow Management, Airport Security Gates*

1. INTRODUCTION

Nowadays, airports play a strategic role in the passenger mobility sector, being relevant origin, destination and connecting nodes in the overall air transport network. For this reason, airports emphasize the improving in the quality of services and the safety of the structure, trying to get success by both respecting declared security standards and satisfying passengers. Note that, due to the recent terrorist attacks, security screenings at airports have been significantly improved; on the other hand, usually passengers are still complaining about the resulting long waiting time (Podemska-Mikluch and Wagner, 2017). Therefore, it is easy to understand that meeting passenger needs is increasingly becoming a competitive factor for airports.
Following this trend, in the last years, information communication technologies and self-service technologies have considerably increased on the air transport market. In fact, to reserve and pay for tickets, check-in over the Internet or mobile phones, pick up boarding passes at airport desks and receive flight updates on mobile devices is a quite common practice of air passengers (Castillo-Manzano, 2010). Further, airport operators, together with the airline companies, are now investing in new technologies to improve the operational efficiency of the terminals according to the high passenger flow, adapting as much as possible their infrastructure, equipment and technologies to facilitate and fasten the check-point process.
However, among the services provided within an airport, one of the most critical, even if more and more technologically advanced, is generally the security check of passengers and their baggage; this check is carried out both before the boarding procedure and at the arrival gates before leaving the terminal in case of international flights.
The criticality related to this process is mainly due to the total time that passengers spend inside a terminal before/ after their flight, which is considered too high.
Just to cope with this problem, a great attention has been devoted in the recent research to the areas of an airport terminal devoted to the security control process; the main goal is evaluate the service level, the efficiency of the security procedures and the waiting time (Baltazar, Rosa and Silva, 2018; Correia, Wirasinghe and de Barros, 2008; de Lange, Samoilovich and van der Rhee, 2013; Skorupski and Uchroński, 2018).
In particular, among the proposed methods, simulation has been largely used in the recent literature concerning services at airport passenger terminals, mainly for the performance evaluation of the security screening systems and their associated waiting times (Kierzkowski and Kisiel, 2017; Li, Gao, Xu and Zhou, 2018; Perboli, Musso, Perfetti and Trapani, 2014). In particular, in the last cited work authors show how a discrete event simulator can be used to analyse and improve the performance of the security system involved in the operations of the low-cost companies.
It is worth noting that among the management sciences tools, simulation techniques have been widely recognized to be a valid and necessary support in the strategic planning process of complex systems (Law, 2077).

Many are the simulation studies concerning logistics and transport systems, as well as infrastructures (see, e.g., Bruzzone, Massei, Maglione, Di Matteo and Franzinetti, 2016; Cartení and De Luca, 2012; Parola and Sciomachen, 2005; Dulebenets, Golias, Mishra and Heaslet, 2015).

Convinced of the powerful of simulation techniques as decision support tool, in this work we present the result of a simulation study aimed at evaluating the efficiency of the passenger flow management within the arrival gates of the main terminal of an international airport in order to minimise the waiting time due to the income security procedures. Further, an analysis of the trade-off between additional cost required to speed up the security and safety process and benefits obtained is provided. The study has been performed by using the simulation software environment Witness (Lanner Group, 2017; Waller, 2012).

The work is organized as follows. Section 2 briefly describes the airport terminal under analysis and introduces its main components together with the passenger routing rules within the terminal to be implemented in the simulation model. Section 3 presents results of the simulation experiments in terms of performance indices of interest of the suggested configuration of the terminal. Some conclusions and suggestions for future works are also given.

2. THE AIRPORT TERMINAL AND ITS SIMULATION MODEL

The terminal involved in the present study is reserved to the international flights of a very crowded intercontinental airport. The focus of the analysis is on the management of the passenger arrival flow; passengers arrive at the terminal through three gates which are dedicated, respectively, to the continental arrivals and to the intercontinental ones of the main two airlines companies having flights assigned to this terminal.

In our simulation experiments we refer to data provided by the Customs and Border Protection Service of the airport under study and the Airport Annual Reports and Operational Statistics dated 2016. Unfortunately, for privacy reasons, many data cannot be disclosed.

Approximately, 1,325,000 passengers pass through these gates every year. Without any loss of generality, in our analysis it is assumed that the totality of the passengers passing through the gates comes from flights of the three main airlines that stop over at the airport. More precisely, the following percentage of passenger flow arrivals are assumed:

- Continental flight: 60% (these passengers will be denoted "*CPax1*" in all simulation models of our experimentation);
- Main intercontinental airline company: 25% (these passengers will be denoted "*IPax2*" in all simulation models of our experimentation);
- Other intercontinental airline company: 15% (these passengers will be denoted "*IPax3*" in all simulation models of our experimentation).

After their arrival, passengers get in line for the metal detector, then go to the security check and, if it is the case, go to the baggage inspection and/or to the police document control and immigration officers before leaving the airport. The initial layout of the terminal is reported in Figure 1, where the passenger flow is also shown. Note that in this actual organization of the terminal, at the Metal Detector Stations 1 and 2 are located two and three machines, respectively. Moreover, two airport employees are dedicated at the security check desk. We implemented the model of the terminal by defining and detailing in advance the main elements that constitute a simulation model in Witness; these are grouped into three types, namely parts, buffers and machines. The dynamic parts modelled in the system, which are the elements flowing throughout the terminal, are the passengers arriving at the terminal after the landing of their plane. According to the above description of the arrival process, we have three dynamic part types flowing through the model, namely, *CPax1*, *IPax2* and *IPax3*.

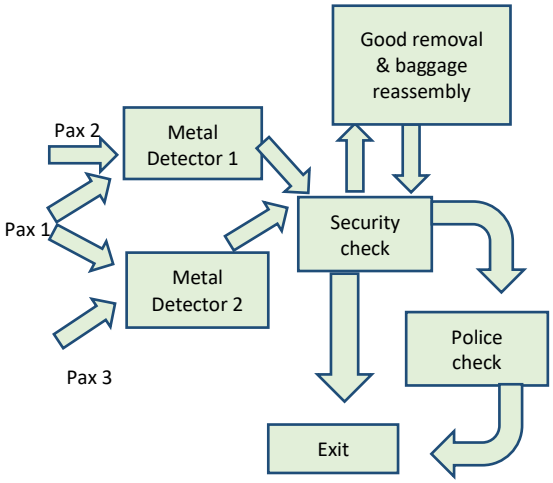

Figure 1: Initial terminal layout & passenger flow.

In order to properly represent the passenger flow in the model, for each part type the distribution of the arrival times and the routing that passengers follow within the terminal from the gate to the exit must be defined.

The average number of passengers per hour of type *IPax2* and *IPax3* has been calculated taking into account the flight schedules within the time interval between two consecutive arrivals. From these values, the arrival profile reporting the frequency distribution for both passenger types has been derived. An example of the input file window related to *IPax2* is reported in Figure 2, where 912 arrival per day are scheduled. As for the inter-arrival times of passenger type *CPax1*, it is expressed by an exponential negative distribution function, having rate $\lambda = 0.011$, corresponding to about 90 passenger arrivals from a continental flight per hour on average.

Buffers are all the areas of the terminal where parts, i.e., passengers, wait for some service. In our model buffers are the queues, explicitly represented, before metal detectors, security check points, baggage inspection and police control stations; their capacity is enough to adequately represent the length of the corresponding queue. Referring to Figure 1, in the simulation model there is a buffer associated with each control activity (depicted with a rectangle). For instance, passengers stand waiting for their turn to go into the Security Checkpoint System.

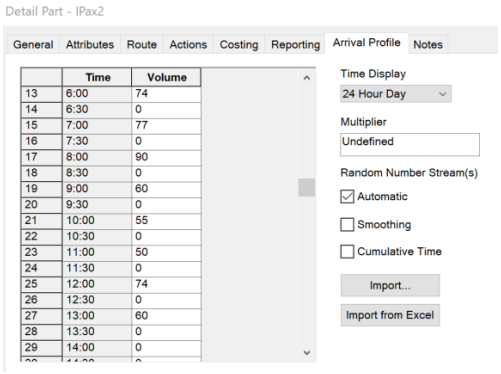

Figure 2: Daily arrival profile of passengers IPax2.

Finally, machines represent all equipment and manpower at the terminal performing a control activity; these are listed in the already mentioned rectangles represented in Figure 1.

Once the distribution of the arrivals of the parts in the system to be simulated is given, it is necessary to define the activity time of the machines of the model. To be congruent with the data related to the arrivals of the passengers, the processing times of all machines are expressed in hours. First, after having carried out an accurate estimate of the available observed times, we hypothesized that the service time of the machines of type "*Metal Detector*" is distributed according to a gamma function GAMMA(1.1;0.025). The metals detectors are the first type of security control. All passengers come to them and from them go to the baggage inspection. A gamma function GAMMA(1.1;0,016) is also used as the distribution of the duration of the security inspections. On the other hand, the time needed to check baggage is represented by a normal distribution NORMAL(0.016;0.002).

Note that the flow of the parts within the terminal changes according to the results of the security check at the control stations. Therefore, the input/output rules of the parts to/from each machine are implemented in the model taking into account the type of the part (i.e. continental or intercontinental passengers) and the data provided by the operational statistics report concerning the percentage of passengers/baggage which fail the control, based on the list of not allowed goods. In particular, an attribute "*Control*" has been created in such a way that, according to a randomly generated uniform distribution, 5% of passengers are sent to the next "*Good removal & baggage reassembly station*", 5% of passengers are sent to the "*Police document control*" and 90% of passengers leave the terminal (see Figure 1).

As an example, the following dispatching rule from the security desk is implemented:

IF BabbageFail = 1
PUSH to QueueBC
ELSE
IF BaggageOutlaw = 1
PUSH to PoliceDept
ELSE
PUSH to SHIP
ENDIF
ENDIF.

The above described main elements of the model, together with the routing rules, have been first considered for validation purposes and tuning the parameters for the successive simulation experiments aimed at suggesting the best compromise between adequate investments and passenger satisfaction.

3. THE SIMULATION EXPERIMENTS

Starting from the existing layout of the terminal shown in Figure 1, numerous alternative scenarios were analyzed. In particular, we evaluated different layout configurations and routes of the passenger flow from their landing from the plane to their exit from the airport in order to propose a solution able to minimize the actual exiting time that is considered very unsatisfactory both from the airport management and the passengers themselves.

Figure 3 shows the model representing the layout of the terminal that, as it will described below, is our best solution in terms of efficiency. It was implemented by using the discrete event simulation software environment Witness (Lanner Group, 2017), which has been also used for the computation and analysis of the performance indices of interest.

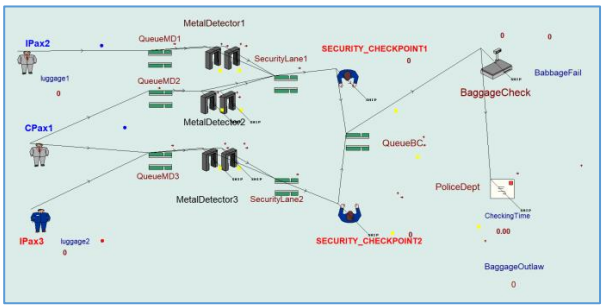

Figure 3: Simulation model of the layout of the terminal.

Referring to the original layout of the terminal reported in Figure 1 and looking at Figure 3, readers can easily note that in the new proposed terminal configuration, intercontinental passengers *IPax2* are addressed directly to a reserved line before passing the metal detector

control; two machine for these service are foreseen. Continental passengers (*CPax1*) are addressed directly to two additional lines before the metal detectors, where fast dedicated security checkpoints have been hypothesized. However, the same reserved metal detectors are supposed to be used also by the intercontinental passengers *IPax3* whenever their dedicate queue is longer than the contiguous one reserved to continental passengers. In particular, after a number of trials, the routing rule to be associated with continental passengers that provided best results in terms of waiting time minimization for *Cpax1* and *IPax3* is:

MOST FREE QueueMD2, QueueMD3.

Note that since passengers *CPax1* come from continental flights, they do not have to go to the baggage check; therefore, the output rule implemented from the metal detector for managing their routing is:

IF TYPE = Pax1
PUSH to SHIP
ELSE
PUSH to "SecurityLane1,2"
ENDIF.

Instead, passengers *CPax2* and *CPax3* are addressed to an own metal detector point, having a dedicated security check point System.
In all simulation runs we eliminated sampling of the results of the model by considering a warm-up period of one week; then, one month statistics were collected. Ten independent replications for each scenario were executed to estimate the average values of the various performance measures. In fact, by using the T-Student confidence interval test, the number of replications was found to be sufficient, as the average standard deviation was less than the corresponding coded value (Law, 2007). The first interesting result to be highlighted is that the number of entered passengers equals the shipped ones in the reports statistics; this means that there is no bottleneck in the model.
Table 1 reports the average sojourn time, corresponding to the average exiting time, of all types of passengers resulting from the model depicted in Figure 3. The same values relative to the original configuration are also given.

Table 1: results concerning the passengers.

	Original scenario			Proposed scenario		
	CPax1	IPax2	IPax3	CPax1	IPax2	IPax3
N. entered	80867	33744	20424	80867	33744	20424
Ave W.I.P.	28.46	41.36	9.25	6.45	37.22	12.01
Ave time	0.29	1.09	0.40	0.07	0.98	0.52

From Table 1, we can observe a reduction in the time spent in the terminal by passengers *Cpax1* and *IPax2*, which represent about 85% of the total number of passengers, from the original system to the one here proposed. On the other hand, note that the sojourn time of passengers *IPax3* increases of about 7 minutes, moving from 24 to 31 minutes, in our proposed scenario. However, we can observe that the average exiting time of all passengers decreases of about 5 minutes, that is from 36 to 31.
Further, looking at Table 1 it is worth noting that the average number of passengers in the terminal reduces from 79 to 55 units.
The sampled statistics concerning the buffers, corresponding to the queueing states and the related waiting times of the passengers, can be found in Figures 4 and 5 representing, respectively, the output reports of the buffer information provided by Witness of the starting model and the proposed one.

WITNESS
Buffer Statistics Report by On Shift Time

Name	QueueMD1	QueueMD2	SecurityLan	QueueBC
Total In	58101	76934	54168	9102
Total Out	58101	76934	54168	9102
Now In	0	0	0	0
Max	171	103	95	9
Min	0	0	0	0
Avg Size	54.27	10.40	7.41	0.13
Avg Time	0.83	0.12	0.12	0.01

Figure 4: buffer statistics of the original configuration.

WITNESS
Buffer Statistics Report by On Shift Time

Name	QueueMD1	QueueMD2	QueueMD3	SecurityLan	QueueBC	SecurityLan
Total In	33744	62119	39172	33744	9259	20424
Total Out	33744	62119	39172	33744	9259	20424
Now In	0	0	0	0	0	0
Max	54	43	67	144	8	69
Min	0	0	0	0	0	0
Avg Size	6.90	3.34	6.44	28.51	0.13	5.16
Avg Time	0.18	0.05	0.15	0.75	0.01	0.22

Figure 5: buffer statistics of the proposed model.

From the above figures, readers can easily note that in the proposed model passengers are well distributed inside the terminal. In particular, queue lengths are shorter than those reported in Figure 4; the average waiting time in the queues is lower too. Therefore, these data seem to prove that passengers definitively like more to see different queues in which there are not many people, while perceiving a waiting time not too high.
The final question concerns the cost / flow ratio; in particular, airport operators, together with the airline companies, need a support in order to establish the best trade-off between the necessary improvement of the passenger flow efficiency, and consequently increase their satisfaction rating, and a reasonable growth of the total management costs, due to the required increase of the airport equipment and staff.
In order to perform this last analysis, Table 2 reports the hourly operative costs (expressed in $) of the terminal, split into fixed and variable ones.

Table 2: Hourly equipment and staff costs of the terminal

	Metal Detector	Security check	Baggage control	Police control
Fixed cost	8,05	40,34	16,23	48,29
Working cost	8	8	8	8

Additionally, in order to take into a proper account the satisfaction of the passengers, in the calculation of the overall costs, the cost associated with the time spent in a line waiting for carrying out the required controls is also considered by the airport management.
Just to give an idea of what is the impact of such cost in the overall evaluation of the best configuration of the terminal, in our experimentation we fix to one $ the hourly dwelling time spent by passengers in each queue from their arrival to their leaving from the terminal.
Figures 6 and 7 show the resulting cost reports provided by Witness related to the actual configuration of the terminal and the proposed one.
In these reports all costs associated with all machines, namely metal detector, security check, baggage control and police control, whose hourly costs are given in Table 2, are grouped together; the fixed and in use costs are shown in the corresponding columns.
The costs associated with the buffers represent the dwelling time spent by passengers.

Costs	Element	Fixed	By Use	By Quantity	Total
	Machines	$164,679.60	$36,031.72	$0.00	$200,711.32
	Buffers	$0.00	$64,115.24	$0.00	$64,115.24
Total Cost		$164,679.60	$100,146.96	$0.00	$264,826.56

Figure 6: cost reporting of the original configuration

Costs	Element	Fixed	By Use	By Quantity	Total
	Machines	$171,828.00	$36,890.49	$0.00	$208,718.49
	Buffers	$0.00	$44,715.58	$0.00	$44,715.58
Total Cost		$171,828.00	$81,606.07	$0.00	$253,434.07

Figure 7: Cost reporting of the proposed model

Looking at the machine's fixed costs in both figures, it can be easily observed that the increase of 7,000 $ in the proposed model (see Figure 7) is due to the presence of an additional metal detector, that is from 5 to 6, which is considered necessary to reduce the waiting time of the passengers for the first control from their arrival. Instead, the values reported in the "*By use*" column clearly show a dwelling time cost reduction of about 30% in the proposed model.
By considering the total cost in both cases, it is possible to observe an overall saving of about 4.5% in the proposed model. To this last result we must add the greatest appreciation from the passengers of the proposed model (see the above comparison between Figures 4 and 5).

CONCLUSION

The paper represents an interesting case where Strategic Decisions devoted to improve Airport Efficiency have been obtained by simulation; obviously the specific results are related to the analysed case, but the simulation approach demonstrated its full potential.
As a final consideration, it is evident that the results obtained by performing this study are very satisfactory and proved the strong capabilities of simulation techniques as a decision support framework.
In particular, in this work we proposed a simulation study aimed at developing a quite efficient model of the arrival process at a terminal of an international airport that are usefully used as starting point by the airport management for further decisions concerning:

- how to improve the passenger flow management in order to minimize their exiting time;
- what is the right investment in equipment and staff to be made in order to reach the desired level of passenger satisfaction.

Taking into account the given hourly operative costs and the data related to the flight schedules, we believe that the results presented here have to be considered a very valuable support to the managing society of the airport and a reference approach for other entities operating in this kind of applications.

REFERENCES

Baltazar M.E., Rosa T., Silva J. (2018). Global decision support for airport performance and efficiency assessment. *Journal of Air Transport Management*, V 71, 220-242.

Bruzzone A.G, Massei M., Maglione G.L., Di Matteo R., Franzinetti G. (2016). Simulation of manned & autonomous systems for critical infrastructure protection. 6th International Defense and Homeland Security Simulation Workshop, DHSS 2016, 82-88.

Cartení A. and De Luca S. (2012). Tactical and strategic planning for a container terminal: Modelling issues within discrete event simulation approach. *Simulation Modelling Practice and Theory* 21 (2012), 123-145.

Castillo-Manzano J.I. (2010). Determinants of commercial revenues at airports: Lessons learned from Spanish regional airports. *Tourism Management*, 31, 788-796.

Correia A.R., Wirasinghe S.C., de Barros A.G. (2008). Overall level of service measures for airport passenger terminals. *Transportation Res. Part A: Policy Practice*, 42 (2), 330-346.

de Lange R., Samoilovich I., van der Rhee B. (2013). Virtual queuing at airport security lanes. *European Journal of Operational Research* 225 (2013) 153–165

Dulebenets M.A., Golias M.M., Mishra S., Heaslet W.C. (2015). Evaluation of the floaterm concept at marine container terminals via simulation. *Simulation Modelling Practice and Theory* 54, 19-35.

Kierzkowski A., Kisiel T. (2017). Simulation model of security control system functioning: A case study of the Wroclaw Airport terminal. Journal of Air Transport Management, 64, 173-185.

Lanner Group Ltd. (2017) Witness. Discrete Event Simulation with VR available on desktop and cloud.

Law A.M. Simulation modelling and analysis. McGraw-Hill, New York, (2007).

Li Y., Gao X., Xu Z., Zhou Z. (2018). Network-based queuing model for simulating passenger throughput at an airport security checkpoint. Journal of Air Transport Management, 66, 13-24.

Parola, F. and Sciomachen, A. (2005) Intermodal container flows in a port system network: Analysis of possible growths via simulation models. *International Journal of Production Economics* 97(1): 75–88.

Perboli G., Musso S., Perfetti F., Trapani P. (2014). Simulation of new policies for the baggage check in the security gates of the airports: the Logiscan case study. *Procedia - Social and Behavioral Sciences* 111, 58 – 67.

Podemska-Mikluch M., Wagner R.E. (2017). Economic coordination across divergent institutional frameworks: dissolving a theoretical antinomy. *Rev. Political Econ.*, 1 – 18.

Skorupski J., Uchroński P. (2018). Evaluation of the effectiveness of an airport passenger and baggage security screening system. *Journal of Air Transport Management* 66, 53-64.

Waller A. (2012) Witness Simulation Software. *Proceedings of the 2012 Winter Simulation Conference* C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

AUTHORS BIOGRAPHY

Agostino Bruzzone is full Professor at DIME University of Genoa and he is President of MIPET (Master in Industrial Plant Engineering and Technologies), the 1st International Master of Genoa University. He is President of Simulation Team and Liophant Simulation; he has served as Vice President in the SCS and MIMOS and has developed, as Project Leader, the new research track on *Marine Simulation* in the Science and Technology Organization of NATO.

He works since long time in innovative technologies such as M&S, IA, AI, VR, AR, directly applied in Industries, International Organizations, Agencies, Services, Defense and Homeland Security.

Anna Sciomachen is full Professor of Operations Research at the Department of Economics and Business Studies, University of Genoa. She is past President of the Italian Society of Operations Research. She is Coordinator of the Master of Science in Management of Maritime and Port Enterprises, University of Genoa. She teaches Simulation techniques and operations Research.

Her main actual research fields are: Simulation techniques; Performance analysis of transportation and logistics systems; Optimization models and methods in distributive logistics.

ISBN 9788885741225 WAMS 2018 PDF

ISBN 9788885741232 WAMS 2018 Paperback