Dynamic Problem Solving for Assessment of Strategic Engineering Capabilities

Agostino G. Bruzzone[1,*], Marina Massei[1], Anna Franca Sciomachen[2], Jan Mazal[3], Paolo Scotto di Castelbianco[1], Elvezia Cepolina[2]

[1] STRATEGOS, Simulation Team, via Opera Pia 15, 16145 Genova, Italy
[2] *Strategic Engineering* International PhD Program, Genoa University, via F. Vivaldi, 5, 16126 Genova, Italy
[3] Simulation Team & DISPO, Genoa University, 16124, Genova, Italy

[*]Corresponding author. Email address: agostino.bruzzone@simulationteam.com

Abstract

This paper addresses the opportunities provided by Strategic Engineering as well as an innovative model devoted to support assessment of young scientists applying for this educational path; considering the highly trans-disciplinary nature of this discipline and the big requests from Industries and Institutions, the authors developed a simple set of problems to be evaluate candidates and conduct preliminary assessment as well as screening on them. The paper outlines the structure of this approach and the most critical aspects putting in evidence that this approach could be relocated for other positions and that simulation base assessment of capabilities is a promising sector for future developments in education and training.

Keywords: Education and Training; Modelling and Simulation; Strategic Engineering; Potential Assessment

1. Introduction

Strategic Engineering is an innovative discipline devoted to support Decision Makers dealing with complex systems by integrating advanced techniques such as AI, Simulation and Data Analytics; in this sector there is a major need for young talents skilled in quantitative analysia and modeling of systems as well as in computational intelligence; these new strategic engineer need to be able to interact with decision makers and due to these reasons they need to acquire skills also in open source intelligence, economics, risk analysis and other sectors turning into really transdisciplinary resources. This paper proposes an approach to assess people by using web based simulation in order to propose unique stochastic problems to be solved within stochastic framework and considering the scenario complexity. The authors tested this approach over over 420 candidates and used the results to finalize their assessment in combination with oral interviews through individual Skype/Teams and reviews of each Curriculum Vitae

2. Strategic Engineering

Strategic Engineering is defined as the joint combination of Modeling, Simulation, Data Analytics, Artificial Intelligence and Intelligent Agents in closed loop with reality for supporting Decision Making. It is crucial to outline that in this sense the use of M&S (Modeling and Simulation) is one of the major pillars of Strategic Engineering and that the emerging initiative in this field strongly relies on people from M&S Community

In facts Strategic Engineering could be used as key approach to address major challenges and nowadays it represents a way to find possible solutions to many real problems in various fields, including staff training, STRATCOM, marketing, business development, service reorganization et cetera (Bruzzone et al., 2018).

This article presents an overview on how M&S could support Strategic Engineering as well as what kind of talents are required to students and how it could be possible to develop automated solution for assessment of te potential of the candidates. In addition, it should be stated that in this field the extensive use of Modeling, Interoperable Simulation and Serious Games (MS2G) paradigm during development of the models has a big potential, supporting the engagement of the decision makers.

3. STRATEGOS @ Genoa

Based on the opportunities offered by Strategic Engineering and the interest demonstrated by many companies, the Author decided to activate the first Italian Master of Science in Strategic Engineering at Genoa University, the initiative required two years to obtain all the internal and National approvals for being activate as educational path and turned operative in 2019. Currently STRATEGOS is in operations since 3 years and is supported by a proactive and dynamic Faculty including Academic Members and people from the many Companies and Agencies joining the initiative. Indeed, the initial efforts to activate STRATEGIS on Genoa required several years and were carried out in string synergy with Different Schools in the Genoa University as well as in joint cooperation with over 10 Major Multinational Companies, around 15 Small and Medium Size Enterprises and multiple Agencies and National Institutions. The synergy among schools involved professors from Engineering, Economics as well as International Affairs creating a really multidisciplinary framework, that is one of the corner stones of STRATEGOS, but require our student to have capability to interoperate with other people with different background and using very different approaches. In addition to prepare the students to work on intensive use of innovative technologies and in development of complex models over trans-disciplinary framework we required them a big effort along these two years and we provide even many advanced webinars and workshop to carry out simulations on complex scenarios working side by side with experts and leading companies. The necessity to have qualified students with very strong foundations, capability to move over different application field, flexible and hard workers within an international framework it is a challenge, therefore we decided to develop some solution able to finalize an assessment of potential candidates in innovative way.

Before to proceed, we should consider the current situation of this initiative, being aware that currently the official reports of Genoa University outline that STRATEGOS, the First Degree in Strategic Engineering in Italy (International MSc on Engineering Technology for Strategy and Security @ Genoa University) summarized over 115 pre-registrations, resulting the first Master degree in Polytechnic School from Genoa and the second from the University of Genoa, after that Master in Law.

These results is due to the very strong interests of companies in these profile and the high expectation of young candidates; indeed Strategic Engineering prepares engineers to master the combined use of Modeling, Simulation, Artificial Intelligence, Data Analytics and System Engineering with different data sources, from Business Digitization to Sensor Networks, Autonomous Systems, IoT, IIoT (Internet of Things and Industrial Internet of Things) as well as IoE (Internet of Everything). The main aim is to support Decisions in presence of VUCA (Volatility, Uncertainty, Complexity & Ambiguity) over complex scenarios. Indeed, STRATEGOS prepares young people to interact with those who make those Decisions in order to make them able to create a correct understanding of the Scenario to be faced and by choosing the most appropriate data sources, filtering the Big Data with analytical, numerical methodologies and using AI engines.

Currently STRATEGOS is by Polytechnic School in strong synergy with other Sectors and Departments, by cooperating with Economics (i.e. teaching Economy by Economists and Engineering by Engineers) and with International Affairs (e.g. using Intelligence Experts for teaching Intelligence). As anticipated the fundamental courses, are integrated by remarkable series of Workshops and Webinars ranging from Open Source Intelligence to Predictive Plant Maintenance.

In facts, looking around today, we can see an almost pathological lack of Strategies in the world, but also in many companie; by using a quote from Antoine de Jomini, we could extend the concept by saying that often we observe a pathological lack of the art of "bien diriger"; indeed, the important aspect to transmit is that Strategy should be seen and the art of bien directing resources to achieve results. The current problems are due to many reasons, therefore it is crucial to understand that to carry out strategies is needed is to have access not only to new technologies and algorithms, but also to new minds. Another crucial aspect is to develop a different mindset and culture able to use the strategic engineering approach and get benefits from rethinking processes by new enabling technologies.

In this regard, I must say that the International and National Companies and Institutions, which desperately need to do Strategy, are very interested in this discipline as well as in these students; therefore, it is not surprising the number of Government Bodies, Multinational Companies, Consulting Firms and High Tech Enterprises that have signed agreements with STRATEGOS along the first two years.

Figure 1. STRATEGOS Web Test dynamically updating remaining time

In this sense the STRATEGOS aim is to satisfy the needs of the Company and of prestigious International Institutions dealing extensively with Digital Transformation, Urban Strategic Planning, Strategic Management, Strategic Communications, Hybrid Warfare, Cyber Security & Defense, but also with many issues that have a substantially plant basis such as New Clear (new nuclear), Green Steel (new hydrogen-based steel industry), the Water Strategy (where desalination plants are one of the factors at stake), Power Grid (renewing the plants, in addition to logic and logic, to produce and distribute energy), etc. .

In facts, since May of this year, we have also activated the 1st International PhD Program in Strategic Engineering in Europe, led by Genoa and connected with universities in France, Spain and Hungary, to which other foreign universities will soon be added; already this year we activated 5 new PhD Grants in Genoa, many financed by European and Asian projects and companies (e.g. activities of interest for activities coordinated by Singapore and Malaysia).

In terms of application, STRATEGOS has been active as Master of Science Degree since the summer of 2018, but has activated the Courses just in 2019 with 22 students selected from 80 candidates, in 2020 we have risen to 44 students chosen from 180 candidates and today we count 115 pre-registrations to in front of over 420 candidates evaluated through interviews. The first graduates, in September 2021, are three brilliant students, already hired by prestigious institution since July, while in October STRATEGOS will organize its second session of defenses.

4. Assessing skills in Strategic Engineering

Indeed, it is interesting to note that we have received and evaluated over 420 applications; all those selected have passed an oral interview and we created a virtual test developed ad hoc that combines mathematical skills, computer programming, modeling skills, problem solving and general knowledge, forcing the candidate with time constraints and test settings to operate in conditions of psychological stress and excitement. Obviously the STRATEGOS test, is a first step to assess the potential in strategic engineering and

for sure it can certainly be improved, but it is interesting to note that even now it is designed to show the behavior of a candidate while he is apply and how he work forward trying to improve his own performance.

Currently the test was implemented as an application in JavaScript interacting with another one on the server taking care of recording the experiences carried out by the users.

The test included the following main rules:

- Each candidate could repeat the test a limited number of times and each test is evaluated separately while the whole performance considers the evolution and repetitions.

- At the end of each test the candidate receives a rough estimation about his specific performance and it is up to him to decide to proceed for improving or to hold on in the current result

- Each test has a limit time to be completed and different scores are obtained, one affected by time used, over a maximum threshold the test is void.

- The system recognizes the candidate based on his email and generate a profile blocking or enabling access to the test on the basis of his previous history and current situation.

The test updates dynamically the indication on the time remaining to inject stress on the player and generate the questions based on a stochastic engine that not only select the single question over a wide spectrum of alternative based on different categories to great a critical mix, but it changes the parameters of the problems to build up a different set of problems and related solution at each test.

The categories for the questions are subdivided as follow:

- Strategic Engineering and how and where it applies over different areas

- Impact of new technologies and innovation within different business sectors

- Identification of shortfalls, criticalities and major challenges existing or emerging and effectiveness of alternative actions

- Very Basic Mathematical computations and problems

- Very Basic Problems in Computer Programming over C#, C++, Java and Python

- Discrimination among realistic and unrealistic data related to regions and towns in terms of dimension, population and distances

- Correlation between Strategy and Historical Main Characters dealing with timeframe and critical issues

Figure 2. Basic Profile in correlating background of players.

Random Generated Problems related to physics and operations to be solve numerically respect a simple simulation model embedded on the server

- Physical Problems ad hoc to be solved in comparative way respect different environment based on specific boundary conditions, for instance comparing the case on Earth and Mars, or Moon and Mars or other combinations.

Figure 3. Overview of Strategic Engineering Quiz on multi sectors

In general, these corresponds to logic problems, more sophisticated problems requiring modeling (e.g. dropping humanitarian aids over an area), correlation on spatial and temporal cultural contexts and capability to discriminate between realistic and unrealistic values. Some of cultural questions could be supported by using Web Search Engines, therefore the time constraints and the shape of the question make it not easy and even confusing., Vice versa the cross cultural issues and the programming and computing issues are distributed within the text to force the candidate to switch between different problem solving approach by evaluating dynamically what is best reaction respect remaining time.Indeed, the system is currently able to provide quite challenging problems generated by simulation that could be hard to be solve analytically in correct way while they require to adopt assumptions to solve them with approximated conceptual models; this context is soliciting the candidate capability to identify problems and look for acceptable solution within a time sensitive environment and with several noisy additional issues to be solve concurrently. The evaluation engine is based on a fuzzification of the performance and a simple AI devoted to compare the answers progressively even during the test to measure the progress not only in

terms of time advance, but also considering the way the candidate is adopting in terms playing strategy. These elements are evaluated by tracking each game in terms of adopted sequence for addressing the question, how much time is dedicated to each, how much it changes the playing mode among different games and how much is the improvement or degeneration over the different areas.

The AI provides a synthetic evaluation of each performance using a performance measurement baseline provided by a reference set of previous available games and finalize it both in absolute value and respect corrective factors that modify it in consideration of respect of the time constraints. Each candidate is ranked based on these elements and their evolution over time to identify the playing strategy effectiveness and the learning curve.

In case necessary the candidate could be required to provide additional information for his profiling and providing a personalized assessment respect his expected performance to have a clue about the crucial issues to face during STRATEGOS. In this case another evaluation procedure available as web service to candidates is the Quiz that goes deeper on what kind of effect are possible in many different application areas.

5. Strategic Engineering & Education

Strategic engineering have a big potential to address problems both to address current and future challenges for decision makers. In fact, the main objective of the teaching Strategic Engineering is to create a multidisciplinary framework based on solid scientific foundations, which allows to prepare experts and to create new interoperable and interconnected models; these are the reasons while the candidates are evaluated through these tests and quiz, but even because final evaluation deal with an interactive oral interview carried out over skype/teams or phone. In facts it is crucial to identify people that have a potential in problem solving and good background for being ready to adopt innovative paradigms in Modeling and Simulation as well as in AI and other fields related to Strategic Engineering, In fact, these engineers and scientists should be able to learn and apply new approaches allow to develop strategies in various fields, such as Industry, Business, National and International Activities, Defense and Homeland Security.

Obviously, when used by a strategic engineer, technologies such as M&S, Data Analytics, AI, IoT and cloud based solutions could solve many complex problems, but requires capabilities to adopt a system engineering approach and to get the whole picture of the context despite the multiple perturbation factors and contingencies. For these reasons, to improve the efficiency of problem solving it is necessary to consider not the single technologies and concepts, but even their effective synergy, such as the one that could be estimated among the proposed assessment solution.

It is expected that the candidate passing the test and processed by oral interview could reach an higher capability in terms of decision making level and complex problem solving. Indeed, well-trained staff with the best tools available could be able nowadays to develop new strategies in numerous sectors, especially when multidisciplinary elements are indispensable for success (Elfrey 2006). Therefore, it is necessary to work to further improve these tests by improving the definition and development criteria for skills and competences required for strategic engineering, to create educational programs that would benefit from the collaboration between scientific institutions, industries and public administration in order to train new specialists to develop and use new methodologies and tools. (Bruzzone 2018).

6. Conclusions

This paper is just a first step forward in developing assessment capabilities to be used for strategic engineering, therefore the authors are working on extending it and improving by including more engaging serious games able to improve the quality of the evaluation. It is interesting to state that the need to address strategic engineering due to the pretty high number of applications is just an example, while the proposed concepts could easily extended to other field and could very useful to test people by measuring their capability to solve problems related to the context they should address in case of selection. These models could be very interesting in future to improve the selection criteria with more effective evaluation procedures and more consistent estimation of the candidate capabilities. The authors are working on this subject for STRATEGOS as well as to develop engines for evaluation to be used in a broad sector of assessments

References

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, NYCBruzzone, A.G., Sinelshchikov, K. & Massei, M. (2019). Application of blockchain in interoperable simulation for strategic decision making. International Summer Computer Simulation Conference, Summersim, SCS, Berlin, Germany, July 22-24

Bruzzone, A.G., 2018a. MS2G as pillar for developing strategic engineering as a new discipline for complex problem solving, in: 30th European Modeling and Simulation Symposium, Keynote Paper at EMSS Budapest, . pp. 405–411.

Bruzzone, A. G., & Di Bella, P. (2018b). Tempus Fugit:

Time as the Main Parameter for the Strategic Engineering of MOOTW. Proceedings of WAMS

Bruzzone, A.G., Sinelshchikov, K. & Di Matteo, R. (2018c). Population Behavior, Social Networks, Transportations, infrastructures & Urban Simulation for Decision Makers. 30th European Modeling and Simulation Symposium, EMSS, Held at the International Multidisciplinary Modeling and Simulation Multiconference, I3M

Bruzzone A.G., (2017a) "Smart Simulation: IA, Simulation and SG as enablers for Creating New Solutions in Engineering, Industry and Service of the Society", Keynote Speech at International Top-level Forum on Engineering Science & Technology Development Strategy- AI and Simulation, Hangzhou, China

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

Bruzzone, A.G., Agresta, M. & Sinelshchikov, K. (2017c). Simulation as decision support system for disaster prevention. In proceedings of SESDE 2017, Barcelona, 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 (pp. 389-400). IEEE Press.

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

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

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.

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.

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