Zsolt Pastorek – Matúš Grega[1]

Simulation and Simulation Technologies

From their beginning, when they were implemented in the educational and training environment, simulations reflected the need to increase the effectiveness of personnel preparation (from an individual to a coordinated staff) for events and situations that are very difficult to carry out – to prepare in a real environment. Currently, simulation technologies have fully established themselves in the educational and training environment in the form of:

- instrumented simulation (also referred to as live simulation)
- virtual simulation
- constructive simulation
- distributed simulation (a universal term that also refers to a combined simulation, also called blended simulation)

Instrumented simulation

The instrumented simulation focuses on the possibility of approximating the behaviour of real individuals and groups/teams equipped with fundamental tools and systems that simulate their activity (e.g. handgun – real, but simulating fire using a laser beam). In other words, an instrumented simulation enables an operation to be carried out that is led by real individuals (soldiers, police, paramedics, etc.), crews and operators who use real weapons with practice and imitation ammunition. Instrumented simulation is practical training in real conditions or training areas with real participants equipped according to standards, solving a specific crisis in a real workplace. The technologies of this simulation are oriented towards bringing the training of individuals and teams closer to the conditions occurring in an actual situation using accurate technical means and systems equipped with special sensors. The means of instrumented simulation emphasise the equality of chances of all parties involved, using the advantage of the knowledge of the environment, stimulating creativity and competition in

[1] Armed Forces Academy of General Milan Rastislav Štefánik.

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the search for possible solutions. By using accurate technical means, systems and vehicles, individuals and groups consolidate practical habits in real activities applied directly in an actual deployment. The positives of instrumented simulation are, for example:

- activities in a natural environment with the possibility of evaluating the performance of tasks by individuals as well as groups
- using accurate technology without modifying it, quick and easy installation of simulation tools on the technical equipment
- strengthening the habits of actual use of technical means or systems without additional actions
- the possibility of creating deceptive activities and sources of threat in a real environment

Instrumented simulation is minimally applicable in terms of its purpose and uses for combating hybrid threats; however, for the completeness of the information on simulation technologies and their possible use, it is necessary to pay attention to it.

Virtual simulation

Virtual simulation has seen significant development over the past 20 years. Its justification is growing in connection with the preparation of people in leading positions and crisis managers to solve and prepare for various crises, including hybrid threats. It is a dynamically developing technology in the field of modelling and simulations. It is part of the general tendency to incorporate new means, forms and methods into specific aspects of the information development of society as a whole. Virtual simulation can be defined as a unique method of training that uses computer technology with a graphic engine to faithfully imitate various objects and procedures of the natural environment in a synthetic environment. It is mainly used to train individuals, vehicle crews and small team/unit leaders to conduct operations in an artificial environment identical to the real one. The representation of virtual reality in computer technology primarily focuses on two of the five senses: sight and hearing. It is a technology that enables interaction with the world generated by computer technology. Virtual simulation can be classified as physical, interactive and humanoid simulation. Physical, virtual simulation – its representatives are physical imitations of real systems

or reductions and imitations of systems. Interactive and humanoid simulations are of the same class and represent a system in which entities and users interact with a synthetic environment, such as simulators or trainers (like simulators for drivers).[2] Virtual simulation provides sensations to training entities in virtual reality with technological means and devices whose feelings are mediated by sight, hearing and touch. This technology, creating virtual reality, is built into technical means and systems. For the needs of training and education of crisis managers, they are pioneering assembled in the form of *reconfigurable virtual simulators* at the Armed Forces Academy in Liptovský Mikuláš, Slovakia (hereinafter referred to as "AFA"). For this purpose, the simulator trainer is used to train the crews, considering the expected activities and to train mutual coordination and cooperation within the team and a specific tactical unit. Drawing attention to the leadership, there are also team leader simulators at the AFA. The team leader simulator is technically based on the same principle as the reconfigurable one. While the reconfigurable is focused on equipment and its crew, the team leader simulator is focused on the person and their role inside the (various) teams. Generally, the virtual simulation shows an individual's view of the digital space – the terrain (the digital database) and the created synthetic situation (primary technical means, the surrounding environment, citizens, the wounded, to whom he will provide first aid, etc.). The positives of virtual simulation in general, for example:

- enable intensive repetition in the training of psychomotor reactions when operating equipment, leading to their automation
- allow creating situations that, in an actual case, could lead to damage to the given system
- enable the elimination of threats to health or life
- let the activity of training entities be constantly analysed and evaluated in online mode
- enable the performances of the training entities to be repeated, compared and corrected immediately after the parts of the training
- enable, through a synthetic space that is identical to the real environment, to conduct activities even where it would not be possible in reality
- significantly influence the ecological and economic aspects (energy consumption, fuel, elimination of environmental damage, etc.)

[2] Çayirci–Marinčič 2009.

Despite the mentioned benefits, only a few simulators are introduced in the educational process at educational and training workplaces. The reason is mainly their narrow focus on practical issues. The high purchase price reinforces this reason. However, in case of virtual reality tools, it is advantageous to get simulators that are characterised by a certain modularity. In other words, for the needs of education and training of crisis managers and hybrid warfare, such as rescue and decision-making units in hybrid warfare, developing such a specialised virtual simulator would cost considerable financial, personnel and time resources. Therefore, a specific alternative is the already mentioned reconfigurable virtual simulators, which have a broader (modifiable) application and are more financially profitable.

Constructive simulation

Constructive simulation is the most widely used, in terms of time, the longest applied and most commonly used simulation, which has universal use and a broad spectrum of use. It is often referred to as a universal method. As a rule, it is applied in a distributed form when several computing systems are connected via a computer network or can be used independently on a specialised hardware element. Constructive simulation is fully utilised to train personnel responsible for an operation or situation's planning and decision-making phases. This way, personnel are prepared for individual leadership positions and management functions in command, control and verification of planning and decision-making activities. Constructive simulation can also be specified as an artificial entity (model) representative of a realistically behaving human, real technology or a particular unit. Such a model is defined according to actual data regarding its tactical-technical data, behaviour and representation. In constructive simulation, a real object (human being, vehicle, technical device, system, living creature, etc.) is replaced by a model – an entity. It is, therefore, a simulation where synthetic beings, vehicles, systems or technical means move in a virtual environment and, depending on the simulated activities, also perform appropriately assigned tasks.[3] Artificial entities actively behave according to defined algorithms, which are programmed in separate property classes (level of entity behaviour). The operation of such a simulation is realised through the user interface, and the visualisation of the generated situation and the generated environment is projected onto a digital map, which contains all relevant

[3] Hubáček–Vráb 2012.

topographical data and characteristics of the phenomena and objects that enter the simulation. Constructive simulation is applied in two distinctive levels in favour of other types of simulations.[4] This distinguishing level expresses the level of detail of synthetic entities; that is, the size of the given entity is described. These levels in each environment are divided into:

- Systems with a low and high degree of aggregation. This means that all entities in the system are models of physically existing natural objects (elements) and have predefined semi-automatic behaviour. They are applied to higher-level units. Entities independently or in defined groups based on entered commands simulate activity and status depending on their physical properties, conditions of the digital spatial database, meteorological factors and technological limits of the given real representatives. These behave and tactically manage autonomously from the defined level of entity properties. Such behaviour can be autonomous and automatic, but in case of a dynamic, complicated simulation, an intervention requires a solution on the part of the management officer so that the thought intention of the management officer is realised.
- Systems without aggregation. This means that each entity represents individuality and technical means. Grouping them is possible, but each representative is controlled by a separately defined algorithm characterising its behaviour.

Constructive simulation is based on mathematical methods and has many advantages that stimulate its continuous development and expansion into new application areas in education and training. Like any other simulation method, constructive simulation also has shortcomings and limitations. The main advantages of constructive simulation methods are the following:[5]

- makes it possible to simulate threat sources economically and effectively, destructive processes of destruction during a hybrid war or any other crisis situation
- makes it possible to create an environment that is very close to the actual conditions of an emergency and the stages of the crisis
- allows to simulate a crisis taking place in different geographical regions, in different climatic conditions, with various forces and means

[4] Andrassy 2011.

[5] Grega–Bučka 2013.

- constructive simulation models form essential components in other types of simulations and crisis management activities; they represent a universal unifying basis for all groups of simulations
- they reduce the damage caused by exercise from an ecological point of view, and the environment is not disturbed by such training
- its universality results from the applied mathematical basis
- quantification of phenomena and processes enables their more accurate analysis in the decision-making activities of management bodies
- allows for modelling and simulation at any level, similarity or with any degree of generalisation objects, phenomena and processes at the selected level (tactical, operational, strategic)
- enables an objective expression of the impact of terrain and other environmental factors on crisis processes situations, as well as crisis management activities
- gives the possibility of high-quality registration of the course of exercises and their use for a more objective evaluation of their results and formulation of conclusions and recommendations for theory and practice
- the usefulness of constructive simulation in solving the problem of crisis management and, within it also, hybrid war is evident
- mediates the possibility of connecting constructive simulation systems with simulation systems of other categories
- establishes a measurable factor to determine the results of the operation of individuals and teams
- documents the course of solving the situation in a 2D and 3D display
- offers partial and comprehensive statistical data
- records the planned and actual activity of the units
- enables the search for optimal solutions when using forces and resources
- enables future managers to take risks due to their own decisions

Certain shortcomings of constructive simulation include:[6]

- no simulation can replace actual activity
- models of constructive simulation are based to a decisive extent on a rational basis, which means that emotional, ethical and purposeful aspects are suppressed

[6] Grega–Bučka 2013.

– using simulation systems requires excellent precision from the workers of specialised workplaces, mainly when filling databases about technology, crowd reactions, characteristics of chemical substances, fuel models and others

As mentioned above, constructive simulation is usually implemented in a distributed form. Its basis is the implementation of the so-called Computer-Assisted Exercises (hereinafter referred to as "CAX"). Such a form of preparation can be characterised as a sophisticated method of training commanders, management staff, officials and workers of crisis staffs of state components, with the help of which processes and events arising or being created during the implementation of a specified activity of the decision-making process, planning process or process of command and control are played out. Constructive simulations and their CAX are the ideal forms of training and education in crisis management, mainly due to their universality, broad application support and ease of implementation.

Distributed simulation

In a synthetic environment, where different types of simulations located in other places are interconnected, a complex environment is created to simulate highly interactive activities.[7] The meaning and effect of distributed simulation is the participation of virtual models whose behaviour is controlled autonomously (computer-controlled components), virtual models that are controlled by real exercisers, live subjects with instrumented means and constructive models in a joint exercise, which create the so-called blended simulation referred to as distributed interactive simulation.[8] In the distributed simulation, all entities and models interact with each other except instrumented entities. The result of the activity of these (instrumented) entities is transformed into a synthetic environment, and it is not possible to influence them in any way since it is an actual situation performed by real people. Therefore, simulated entities from the environment of virtual simulators and entities from the domain of constructive simulation are usually involved in the distributed simulation for the needs of crisis management training. This situation (simulation) creates

[7] Bučka et al. 2012.

[8] Andrassy–Grega 2013.

a unique environment where they intervene, for example, simulated transport and evacuation components and other simulated entities controlled by actual crisis staff and operation centres. The crews are forced to react to all the stimuli that come to them from various sources, and this is made possible by distributed simulation with participating entities. A simulated crisis situation is generated through the interaction of virtual entities, which arises during the action of a crisis event. Entities act under time stress and under constant pressure from the constituents who control them. Virtual entities from the constructive simulation environment can represent evacuated components, support units or assets meant to make the training situation more complex and thus put control authorities under pressure and stress. Their main task is the coordination and cooperation of all components involved in eliminating the consequences of the simulated situation, including hybrid threats. Distributed simulation offers an advantage that other simulations do not have. In one preparation cycle, the participating parties (trainees) can take turns in individual positions. This factor allows for understanding the solution of a simulated emergency situation from different perspectives. It creates conditions for the components to clarify the problem both from the point of view of the executive and the management. This fact is positively perceived by students who use simulation technologies and those who create tactical and organisational formations.

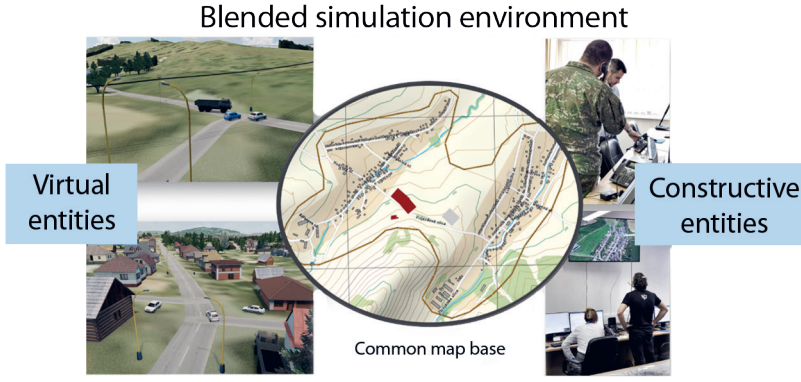

Figure 1: Principles of distributed simulation
Source: Compiled by the authors

Distributed interactive simulation develops operational and tactical thinking of management officials and, subsequently, of the executive departments, respect for the staff's decisions and acceptance of the departments involved in solving the emergency.

Conclusion

Choosing the best technical and methodological solution for simulating hybrid warfare threats is necessary to highlight the most important elements of such simulation. To get as close as possible to the real world, it is required to consider not only the technical method of simulation but also the environment that causes emotional and ethical reactions of users. It is also critical that the chosen simulation system should have as many options as possible for modelling hybrid threats. In this case, the instrumented simulation has minimal possibilities. The same situation is occurring concerning the repetition of conditions. Because of the real-world involvement, repeating the same condition using instrumented simulation is almost impossible. In this case, the other two simulation methods based on an artificial environment are better. The second crucial characteristic of a hybrid warfare simulation is supporting the decision-making process during the hybrid threat elimination. This feature, although present, is least supported in the instrumented simulation.

Table 1 compares all three simulation methods. Each feature is scored from 1 to 5 points: 1 – unsuitable for hybrid warfare simulation; 5 – most suitable for hybrid warfare threat simulation. The two most important features of the hybrid warfare simulation are highlighted in yellow.

Table 1: Evaluation criteria for HW simulation – the higher the coefficient, the more suitable the simulation method

Evaluation Criteria for HW simulation		**Instrumented simulation**	**Virtual simulation**	**Constructive simulation**
The reality of the environment	Technical meaning	5	4	3
	Emotional and ethical meaning	5	5	2
The scope of Hybrid Warfare scenario modelling options		1	3	5
Repetition of the same conditions of the simulation		2	5	5
Simulation difficulty for	Staff	3	3	5
	Users	5	5	3
Suitable for the training of	Psychomotor reactions	5	4	1
	Decision-making process	2	4	5
Evaluation of tasks for	Individuals	5	5	3
	Group(s)	5	4	5
Financial requirements	Initial costs	3	2	5
	Modality	3	5	3
Suitability coefficient		3.67	4.08	3.75
Coefficient of embedded simulation	**3.91**	*Instrumented*	*Virtual*	
	3.71	*Instrumented*		*Constructive*
	3.92		*Virtual*	*Constructive*

Source: Compiled by the authors

The suitability coefficient represents the average value of points in every feature. Using another simulation method to eliminate individual shortcomings in each technique is advisable. This offers a distributed form of simulation (see the relevant section above), where one method compensates for the shortcomings of the other. The comparison of distributed simulations is shown in the table, and the combination is marked orange. The highest coefficient acknowledges that using distributed simulation as a combination of virtual and constructive simulation tools is the best way to simulate hybrid threats. For this reason, the following chapter describes only these components of the simulation system.

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