TECHNOLOGY TREND ROADMAPPING FOR MODELLING & SIMULATION

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ABSTRACT

The NATO Science & Technology Organization (STO) currently monitors more than 15 Disruptive Technology Trends that are expected to have a major influence on defence. Within the NATO Modelling & Simulation Group (NMSG) a team of subject matter experts analysed the impact of these trends on the modelling and simulation (M&S) domain in order to guide future research and development (R&D) activities in the most effective and efficient direction.

This paper describes the methodology developed by the NMSG team for Technology Trend Assessment and provides an overview of M&S relevant trends. Examples illustrate which future trends today's NMSG Program of Work (PoW) already addresses and which topics should be considered for tomorrow's research in M&S technologies.

KEYWORDS

Disruptive Technology Trends, NATO Modelling & Simulation Group, Technology Trend Assessment Methodology

1. INTRODUCTION

The operational environment for future NATO actions will become increasingly complex due to the influence of global trends such as demographic and economic shifts, increasingly rapid technological advances or technology proliferation. It will therefore be of critical importance for the Alliance to maintain the technological edge and to detect, track and react upon potentially disruptive emerging technologies.

Within NATO, the STO and the Chief Scientist coordinate research on emerging technologies. The bi-annually updated Tech Trend Report lists all the technologies considered relevant for the Alliance in the near future and serves as a guideline for further investigation of these trends.

To address this need for research on the impact of a general technology trend as described in the Technology Trend Report on the M&S domain the NMSG has set up a small team to develop a methodology for the assessment of a technology trend. Such an assessment methodology helps to bridge the gap between the general description of a technology trend and its concrete utilization in a particular field and therefore serves as a tool to define a research roadmap and to eventually shape the PoW of the NMSG.

2. METHODOLOGY

From the general understanding and description of a technology trend, it is rather difficult to conclude what the next steps in R&D should be or how an emerging trend can be successfully addressed in research projects. In this case, usually interviews with subject matter experts (SMEs) are employed to better understand the consequences and impact of a trend on a particular domain and to derive further actions. The result of such interviews strongly depends on the skills of the interviewer to find the right balance between asking very general and very specific questions. General questions like e.g. “What is the impact of Cloud Computing on Modelling & Simulation?” may result in very broad general answers which are not specific enough to detect gaps in the research programmes, whereas very specific questions possibly narrow the field of view in SME interviews and may miss important gaps or chances. Our approach therefore in a first step identifies the different types of technology utilization in the M&S domain and in a second step then maps the emerging technologies to the identified M&S technology usage areas. This systematic approach forms the basis for a more structured input from SMEs and a clearer mapping to the PoW.

2.1. THE M&S WORKFLOW

The use of Modelling and Simulation in general follows a three-staged workflow as depicted in Figure 1.

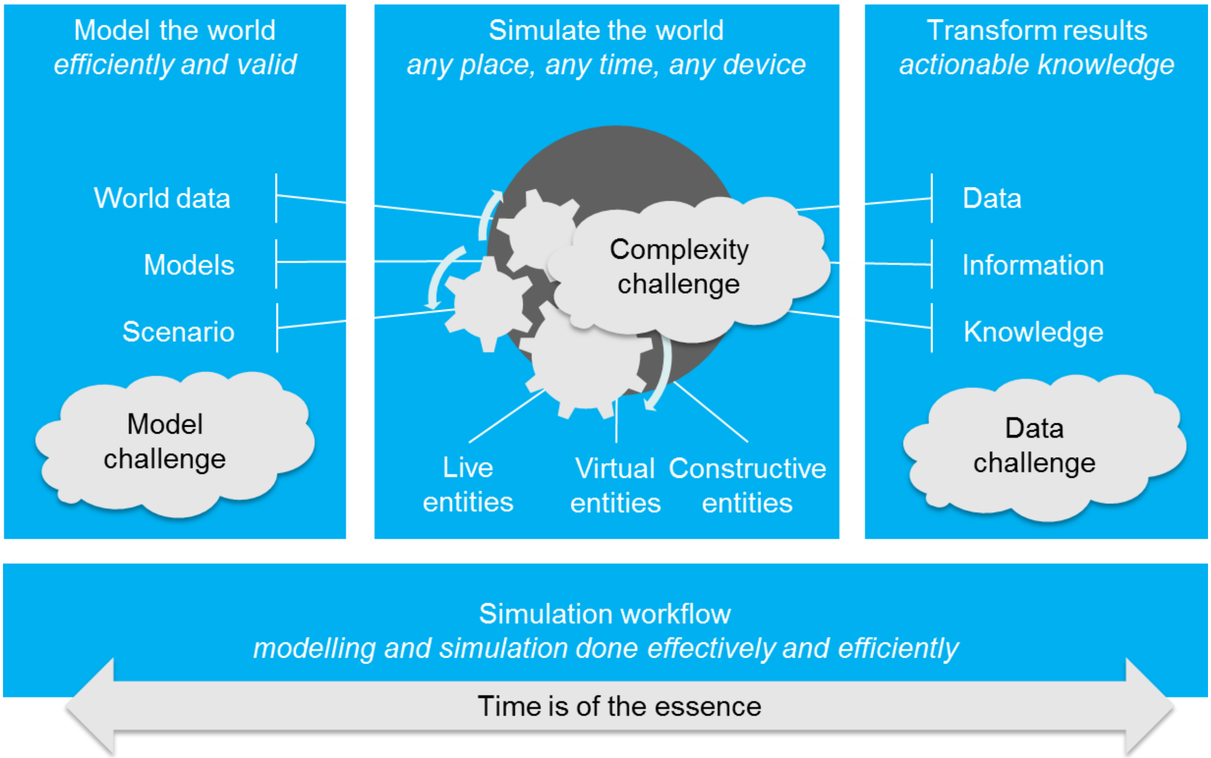

Figure 1 Generalized M&S Workflow

The workflow starts by creating a representation (model) of a section of the real world. This model consists of data describing the real world (e.g. terrain data), the actual model that is representing the dynamics and behaviour, and a scenario describing the interaction of the model with other sections of the world. The challenge for M&S is to create valid (for the intended purpose) models efficiently (time, economical aspects).

In the next step, the model is executed in a simulation run. In many cases during this execution there is a dynamic interaction of the entities represented by the model with entities from other models executed in parallel (constructive entities), with entities operated by humans (virtual entities) or even entities not simulated but being part of the real world (live entities). The M&S challenge here is to handle the complexity of these interactions and the execution environment, which typically is distributed over several nodes. A typical user expects this execution environment to be accessible from anywhere at any time via specialized or non-specialized devices (hardware, software).

In the final step, the results from the simulation run are collected. These data mainly comprise of result data which in subsequent steps then are transformed into usable information (inferred from the data) and finally into knowledge (information being processed and applied, i.e. "put into action"). The challenge for M&S in this step is to handle the data at different levels of processing and to transform the data into actionable knowledge.

2.2. M&S TECHNOLOGY USAGE AREAS

To constitute a technology trend assessment and M&S technology roadmap the three-staged process as described above has to be analysed for the actual usage of technology. We also found that a trend analysis in addition has to include the area of techniques (rather than pure technology). This is required to capture innovation and evolution at the process level that are not necessarily related to the utilisation of a new technology but also may have a significant impact on the M&S domain. Abstracting from the process in Figure 1 we identify the M&S Technology Usage Areas as shown in Figure 2 (orange boxes).

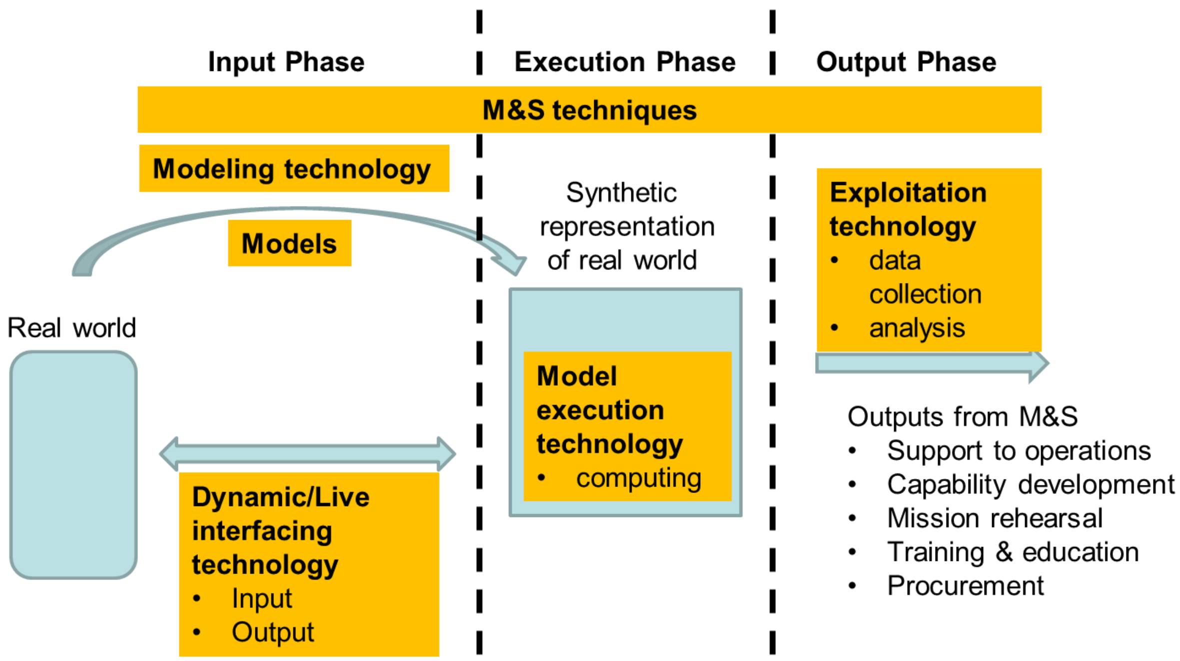

Figure 2 M&S Technology Usage Areas

Modelling technology refers to any kind of technology used to build models. Building models actually is a creative process that requires deep domain knowledge of the "problem domain". Although there are a number of techniques available, not too much technology is typically involved here. Rather building a good model today is still is a matter of experience, the right "feeling" and some black magic. However, the availability of large amounts of data and the capability and computer power to handle these data and to feed it into machine learning algorithms may change the way of model building in the future (e.g. models may be learnt from observations rather than being engineered explicitly).

Models are the result of a modelling activity and are used in the Execution-Phase. In many cases, they are more a description of the essential real world entities, their properties, relationships and behaviors. Executable simulation models typically are comprised of computer code accompanied by supporting documentation. This is well-established technology, however new technologies influencing the military domain may need to be represented in simulations and thus need to be incorporated into existing models. Alternatively, new models are required in order to simulate the (military) effect of new technologies (e.g. models for social networks, for hypersonic vehicles, for autonomous systems, for directed energy weapons, etc.). When broadening the term “model” to physical/tangible models (e.g. in the context of virtual prototyping), new technologies like additive manufacturing may also become relevant.

Dynamic interfacing technology denominates any kind of technology used to put “something” (e.g. weather data, position of live entities) from the real world into its synthetic representation and the other way round during simulation execution. A lot of technology is involved here including any kind of sensor or visualization technology. This includes all new technologies like AR/VR technologies, sensors (and actors) everywhere and the possibility to connect to virtual worlds from any place at any time.

Model execution technology refers to any technology needed to “run” one or more models. This mainly refers to any kind of computing technology including networks. Newer technology trends like Cloud Computing or Everywhere Computing may have a significant impact here.

Exploitation technology denotes any kind of technology used to “get something out of” a simulation, i.e. mainly data collection, processing and analysis technology. Emerging technology trends like predictive analysis, machine learning or new computing technologies (Clouds etc.) here may have a significant influence in the future.

M&S techniques finally covers all improvements or substantial changes to processes and activities in the M&S domain. Although this is not directly related to an emerging technology trend, changes in this field may heavily influence M&S and therefore must be captured in a trend analysis as well. Examples are changes to the M&S workflow or business model that come along with a shift from today's stand-alone or networked execution environments to cloud-hosted environments and widely available service provisioning. Also new modelling techniques not yet widely adopted in the M&S domain may become important, e.g. semantic modelling (i.e. ontologies) as used for example by Google in their "knowledge graph".

2.3. TECHNOLOGY TREND ASSESSMENT TABLE

The technology usage areas identified in the previous section now allow a more precise assessment of the impact of an emerging technology trend on the M&S domain. We gain specificity by narrowing the scope of SMEs input to each of the areas rather than the M&S domain as a whole.

Our first experiments with the proposed methodology furthermore showed that in some cases the impact of a technology trend depends on the M&S application area. For example, the "Social Media" technology may be of significant influence for M&S applications used for mission rehearsal or training & education, whereas it may be of less importance for M&S applications used to support procurement or military operations. To account for these differences we included the M&S application area as an additional category in our technology trend assessment methodology. These categories taken from the NATO Modelling and Simulation Masterplan are support to operations, capability development, mission rehearsal, training & education and procurement.

For a better overview, we subsequently capture the results of a technology trend assessment color-coded in a table. Thereby we are using green colour to indicate that we consider a technology trend as highly important for a particular M&S technology usage area and M&S application area. Green colour also indicates that the M&S community has already acknowledged this trend and we are aware of ongoing research activities in nations or in the NMSGs PoW, or that the technology is state-of-the-art in the M&S domain and is already been utilized in simulation systems.

In contrary, we are using red colour to mark a highly important technology trend that to our knowledge does not currently reflect in any research activities. This means that there is a gap or “blind spot” and taking further actions should be considered.

For cases where we are unsure about the impact of a technology trend, we have chosen yellow colour. The evolution of trends with this marking should be observed and a more detailed analysis of their impact may be needed until finally a decision can be made. Finally, we selected grey colour to indicate that we do not consider a technology trend to be relevant for a particular combination of M&S technology usage area and M&S application area.

3. TECHNOLOGY TREND ASSESSMENT EXAMPLE

To illustrate the proposed assessment methodology we performed the analysis on the “Unmanned Vehicles” and the “Social Media” technology trends listed in the NATO STO Trends Report 2017 and give our results in Table 1. This table is to be read as follows.

		M&S Technology Usage Area					
Technology trend	M&S Application Area (from NATO M&S Masterplan)	Modelling	Models	Dynamic interfacing	Model execution	Exploitation	M&S techniques
Unmanned Vehicles	Support to operations	grey	grey	yellow	grey	grey	grey
	Capability development	grey	green	yellow	grey	grey	grey
	Mission rehearsal	grey	grey	yellow	grey	grey	grey
	Training & Education	grey	green	yellow	grey	grey	grey
	Procurement	grey	green	yellow	grey	grey	grey
Social Media	Support to operations	yellow	red	grey	yellow	yellow	yellow
	Capability development	yellow	red	yellow	yellow	yellow	yellow
	Mission rehearsal	yellow	red	yellow	yellow	yellow	yellow
	Training & Education	yellow	red	yellow	yellow	yellow	yellow
	Procurement	grey	grey	grey	grey	yellow	yellow

Table 1 Trend Assessment Example for the "Unmanned Vehicles" and "Social Media" trends

Unmanned vehicles in general surely are an important trend. However, their technology cannot directly support modelling (grey colour). As they play an important role in military operations, they must also be represented as models in simulation systems. This is already the case in many of today’s simulation systems. This mainly applies to simulation systems supporting capability development, training and procurement in which cases current and future unmanned systems need to be simulated (green colour). To a lesser extent, this applies to simulation systems used in support of operations or mission rehearsal where the real unmanned vehicles normally would be used instead of simulated ones (grey colour). We expect however a significant impact of unmanned vehicles dynamically interfacing with simulation systems and observe already some activities in this field (yellow colour). Prominent examples are the use of UAVs to sample terrain data for the use in simulation systems (i.e. rapid terrain generation). We expect a larger impact of unmanned vehicle technology on the M&S domain here and conclude that more work is needed to fully assess and raise their potential for the M&S domain. As unmanned systems represent a piece of real world technology their use for actual model execution, exploitation of simulation results or invention of new M&S techniques probably is very limited (grey colour).

Similarly, for the social media we expect some impact on modelling as they provide means to better share knowledge or bring SMEs together. More analysis is needed to find way how this can be integrated into today's modelling activity workflows (yellow colour). This probably applies to all M&S application areas except for procurement where modelling typically happens along strict specifications and development cycles (grey colour). In contrast to their huge impact on civil information and communication flow, valid models of social media are not present in today's simulation systems. However, it is well known that they play an important role as a publicly available command & control system that is freely accessible everywhere by anyone on any device. It is therefore questionable whether simulation based analysis of military operational scenarios give valid results if the influence of social media is neglected. This currently is a gap in simulation systems and more research is needed (red colour). The role of social media as a dynamic interfacing technology, for the exploitation of simulation results and the M&S techniques is rather unclear. Whereas they integrate smoothly into normal civil life, dynamically interfacing them with simulation systems seems of little value. Regarding model execution, one may think of distributing models across social networks and use them as network backbone. In addition, more information might be gained from simulation results if the "crowd intelligence" of social networks could be used. Social media also have proven successful in organizing activities, be it large open source software projects or real world meetings. There are more potential applications, however none of them has been under closer consideration in the M&S community until now and there also seems to be no urgent action required (yellow colour).

4. SUMMARY AND DISCUSSION

In this paper, we have presented a methodology for assessing the impact of a technology trend on the M&S domain. For a structured analysis, we examined the three phases of a generalized modelling & simulation workflow for their dependence on technology. We found that technology in the M&S domain is used to build models, is represented in models, and is used to execute models, to dynamically interact with simulations and to collect and exploit simulation results. We also found it helpful to include techniques (in addition to technologies) into our assessment scheme to be able to capture the evolution of methods and procedures. Using this scheme and the M&S application areas listed in the NATO M&S masterplan we were able to perform a systematic assessment of technology trends listed in the NATO Science & Technology Organization Tech Trends Report. A simple colouring scheme visually indicates where the NATO Modelling & Simulation Groups Program of Work is well aligned with the technology trend assessment, where urgent action is required to fill a gap addressing a potentially disruptive technology trend and which trend should be monitored and examined in the near future.

The technology trend analysis presented here in a next step can expand into a technology trend roadmap for the M&S domain. This will require the involvement of more subject matter experts to obtain a more extensive trend assessment (i.e. colour coding). For this, also a catalogue of assessment criteria will be helpful to better scale an assessment (i.e. which colour to assign). A roadmap then can easily be derived by identifying and prioritizing topics for future research (e.g. models for social media). Detected gaps (red colour) obviously should receive a high priority whereas for the rest of the identified topics the timeline from the NATO STO Tech Trends Report could be used (i.e. short, medium, long term).

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