THE 4TH INTERNATIONAL DEFENSE AND HOMELAND SECURITY SIMULATION WORKSHOP

SEPTEMBER 10-12 2014
BORDEAUX, FRANCE

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Co-Chairs' Message

Defense and Homeland Security are very popular areas for applying Modeling and Simulation since its origins; today this aspect is further reinforced thanks to the technological and operational opportunity to create dual use synergies combining industrial and civil applications.

Indeed, the current advances in sectors such as Autonomous and Robot Systems, Internet of Things, Nanotechnologies, Additive Manufacturing, Space, Cyber Warfare are expected to change drastically our world with huge impact in the homeland security and defense arena; in many case Modeling and Simulation represents the only effective investigation approach able to study these future scenarios; indeed simulation allows today to obtain a strategic advantage by investigating new solutions devoted to properly address tomorrow challenges through capability assessments, test and experimentation. From this point of view simulation is a strategic asset for driving the “transformation” of complex systems by estimating the effective benefits provided by the new enabling technologies and by defining the operational and technological requirements of future systems. Today this point is even more critical, considering the very quick evolution of geo political scenarios, and it requires access to M&S solutions to anticipate problems and to design appropriate plans. The economic crisis and the international competition are stressing, currently, the necessity to improve efficiency and effectiveness with limited resources: these conditions represent exactly the optimal conditions for promoting simulation as convenient solution able to operate within an accessible, safe and realistic virtual world. Last but not least, especially today for Defense and Homeland Security sector, the need to improve training and education is becoming even more critical than in the past, this aspect is pushing forward the development of innovative simulation paradigms (e.g. Serious Games, SaaS, Mobile Training, MS2G). So it is not surprising that this year, in Bordeaux, we are celebrating a successful 4th edition of the International Workshop on Defense and Homeland Security Simulation (DHSS); this conference was established originally in occasion of the joint event I3M 2011 and NATO CAX Forum in Rome, where over 500 attendees coming from 58 different countries met together. Today, I3M is still evolving and involving top M&S scientists from around the world, being recognized along last 11 years as one of the most successful simulation scientific events worldwide; in this framework DHSS is an important subject able to attract very qualified attendees and experts interested in defense and homeland security sectors; therefore DHSS interactions with other I3M simulation conferences promote synergies and development of new Research Projects addressing "dual use" as concurrent applications of simulation in civil and military domains. In this period the opportunities to develop joint R&D Projects is very popular, so it is evident the importance to organize DHSS meetings and discussion points about innovative and promising simulation advances. From this point of view DHSS acts as a real workshop supporting networking and consortium establishment for developing new proposals.

However it is important to stress the scientific value of the workshop: DHSS is indexed by scientific reference systems (e.g. SCOPUS) and DHSS submissions are subjected to a rigorous review process based on multiple reviews; the selected contributions are included in the DHSS proceedings while the authors of best manuscripts are invited to extend their works in order to be evaluated by the International Journals supporting I3M: for instance this year 7 International Journals are offering this opportunity to authors; in addition, the best DHSS paper, together with other I3M2014 Conference winners, will be officially awarded during the Gala Dinner organized in the unique framework of Château Smith Haut Lafitte in Bordeaux.

So…Welcome to DHSS2014! Please enjoy our Workshop, the I3M Multi Conference, the Scientific & Social Networking as well as Bordeaux… in broad sense!

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The DHSS 2014 International Program Committee (IPC) has selected the papers for the Conference among many submissions; therefore, based on this effort, a very successful event is expected. The DHSS 2014 IPC would like to thank all the authors as well as the reviewers for their invaluable work.
A special thank goes to all the organizations, institutions and societies that have supported and technically sponsored the event.

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GENERIC MOTOR FOR SIMULATION ANALYSIS

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ABSTRACT

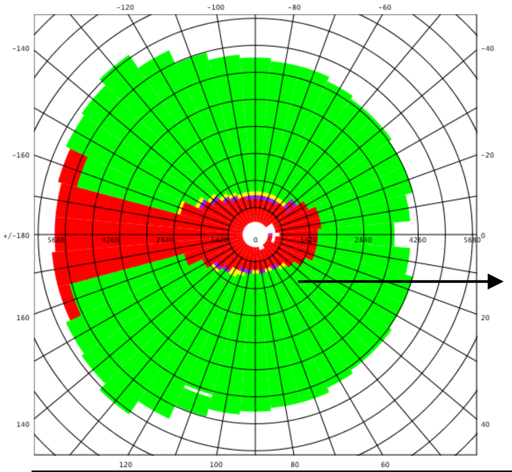
In the area of aircraft/missile simulation, the result "target/missile final distance" or "decoy/not decoy", needs to be explained. One solution to get those informations is to ask an expert to analyze the simulation signals. At about ten minutes by simulation for a thousand simulations, it takes roughly a month of work. Another way of getting those informations is to use a "generic motor for simulation analysis" which allows defining automatically a diagnostic for each simulation. This kind of diagnostic takes only a little more simulation time for the computer, fifteen minutes for a six hours simulation as example and no time of an expert. The purpose of the document is to present how to build this kind of "generic motor for simulation analysis". This motor is not limited to this kind of simulation and can also be used for other simulations where complex diagnostic is requested.

Keywords: aircraft/missile simulation, automatic diagnostic, infrared seeker, flares

1. INTRODUCTION

DGA Information Superiority, part of FRANCE Department of National Defence builds tomorrow's defence. DGA Information Superiority uses aircraft/missile simulations. The simulation tools used for this work employ many models: threats, targets, infra-red scene generator… each one at the appropriate level of modeling. The result of simulation is the "target/missile final distance", "decoy/not decoy" information. This information is very useful but not sufficient enough to understand what happens during the simulation and to deliver validated advices to the forces.

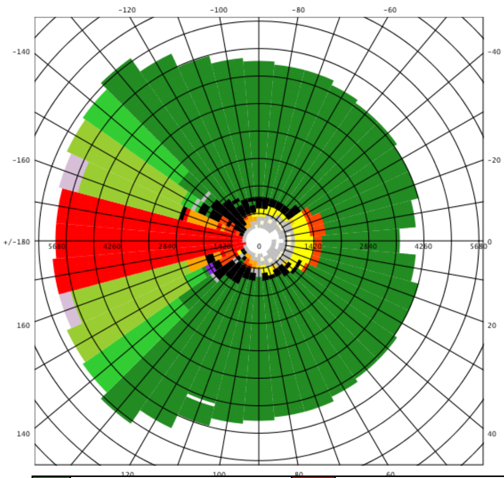
In Figure 1, for an aircraft flying from the left to the right, threats are placed around the aircraft (Polar coordinates: Rho, Theta). The "target/missile final distance" is indicated with a color code: green for a target not hit and red for a hit target for example. To understand the result, improve the materials tied to the simulation and also to increase the confidence in the result, more detailed information is needed. As a study to protect an aircraft can involve easily to more than one hundred thousand simulations, the method to ask at one expert should be extremely limited.



(red)	(green)
Target hit	Target not hit

Figure 1: Missile/target Final Distance

Figure 2 is a diagnostic of simulation create with a "generic motor for simulation analysis» displaying in several color codes the reasons of each result.



Decoy, good KC	Not decoy, KC to low
Decoy, KC middle	Not decoy, CCM
Decoy, KC low	Decoy, no separation

Figure 2: Diagnostic of simulation

This diagnostic is more accurate that the diagnostic of an expert because the motor performs the analyses for each simulation and at each step of the simulation.

To build this kind of motor, a prerequisite is needed: an expert should be able to analyze the simulation with the signals of simulation. In fact, as this motor looks differently at the simulation, it can be interesting to look at the first steps of motor construction, which can give ideas to analyze the simulation. Building this kind of motor is like a project of "valued engineering" or a project of "experimental planning" because there is a big amount of analysis required at first. This work of analysis is followed by a process of motor construction and a process of configuration and testing. Each simulation should have a specific motor even if the big steps of building are the same.

2. PRINCIPLE OF CONSTRUCTION

Figure 3 shows the principle of construction. A final result is associated to an instantaneous result. The reasons of a final result are linked to reasons of instantaneous result. The time evolution analysis of the reasons of instantaneous reasons allows to define reasons of the final result.

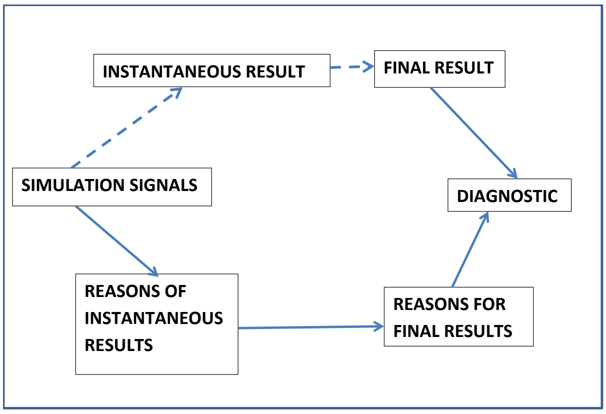


Figure 3: Motor action (high level)

In the area of aircraft/missile simulation, the instantaneous result is the direction followed by the missile and reasons of instantaneous result depend on each threat, defined differently depending on the threat and the kind of modeling.

A behavioral model of the seeker gives at each moment the point followed by the seeker (instantaneous result) and the reasons of the choice of this point can be understood through the behavioral equations (instantaneous reasons).

A detailed model of the seeker gives at each moment, an order to the flight control surfaces of the missile. This order can be of two kinds: on-off order or a proportionnal order. For an on-off order, the on-off equation will be used by the motor to determine the instantaneous reasons and the result. For a proportionnal order, it is necessary to think differently about electronics. Electronics should no more be seen only as "Automatic Gain Control", "Limiters", Filters"… The question to answer is "How this function will act on the order to the flight control surfaces of the missile for this object. For example, a limiter prevents to take too much in account a new object with high energy level, like a flare.

Two create a motor, there are five steps:

- Static analysis
- Dynamic analysis
- Specification definition
- Motor construction
- Motor configuration and tests

The two firsts steps of analyses are mandatory to validate the feasibility of the motor construction.

2.1. Static analysis

The goals of the static analysis are:

- To define the four items (instantaneous result, final result, reasons of instantaneous result and reasons for final results)
- To check the coherence between these four items
- To check the coherence with the simulation signals

The coherence checking will be made following rules of §3. The most difficult job in static analysis is to define the reasons of instantaneous results which are the base of the motor construction. The other items are only present to check the coherence of the analyses and don't need to be so accurate. The reasons of instantaneous result should be defined carefully by:

- Definition of the objects of the simulation
- Definition of the aspects angle of the simulation objects
- Definition of simulation signals useful to analyze the aspects angle of each object
- Creation of new signals if necessary to analyze the aspects angle of each object
- Creation of logical signals from previous signals
- In case of periodic scan, creation of logical signals by scan period to synthetize periodic information
- Creation of logical states by logic combination of logical signals for each aspect angle of each object
- Simulation to test relevance of logical states if necessary
- The reasons of instantaneous result might not be defined at each step of the simulation, non-determined cases may occur for some steps, if signals are too difficult to analyses.

The decomposition of instantaneous result in aspects angle by object is a key point of motor construction. An aspect angle view is the list of exhaustive cases where one object can be seen following an aspect angle at one moment.

The simulation models have limited inputs signals to be representative of reality, but the motor has no limitation of input signals to respect. The motor knows who is each object, target or flare, the positions of the objects, when an object is on the detector of the seeker and which energy it has … The motor knows the total time of the simulation

The fact than a motor, can get extra signals to allow the automatic diagnostic is also a key point of the building. For behavioral models, reasons of instantaneous result could be defined easily by an expert without simulation. For complex models, this process can be re-made several times before getting logical states sufficient for motor construction. The explanation of the simulation is a complex problem which is divided in several simple problems to perform the automatic analysis.

2.2. Static analysis for aircraft/missile simulation

The result of the simulation exists and is already given by the simulation and the instantaneous result is the point followed by the seeker. A preliminary list of reasons for final results has to be built by the expert, but the reasons for final results will be defined by concatenation of the time analysis result of instantaneous reasons in the dynamic analysis. The reasons for instantaneous result are explained in figure 4 which shows three aspect angle views for each flare (seeker view, scene generator view and ignition rising edge view) and one for the target (seeker view).

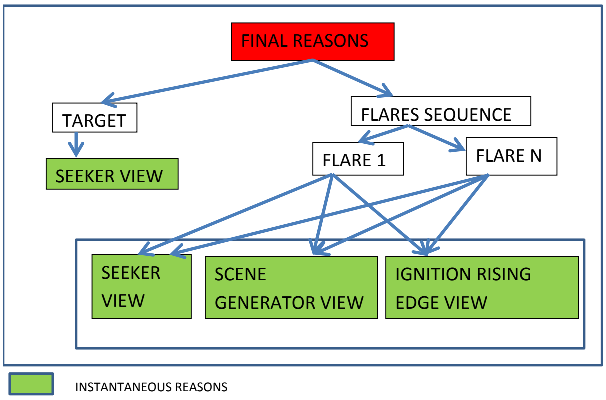


Figure 4: Instantaneous reasons decomposition

For example, a seeker can follow an object for reasons A, B, C or not follow an object for reasons D, E, F tied to the counter-counter-measure of the seeker. The SEEKER's VIEW will be made by the cases: A, B, C, D, E, F. As the seeker's view is defined, it is easy to apply it at the different objects of the simulation, target and flares

An expert knows well that it is necessary to have another look of the object to understand what happens sometimes. This other look is the "**scene generator view**", which can give information about the objects.

It's up to the expert to define other information useful for the diagnostic as for example the "**ignition rising edge view**" of the flares.

The details of signals construction depending on each model cannot be explained here and needs a very high level of expertise.

2.3. Dynamic analysis

The dynamic analysis will define how to move from instantaneous reasons to reasons of final result with a finite state machine, how to define the diagnostic as shown in figure 5.

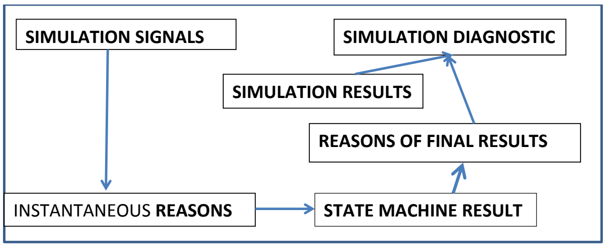


Figure 5: Dynamic analysis

The most difficult job is to build the finite state machine because diagnostic concatenation is only logical combination.

To build the finite state machine, it is necessary:

- To define the states of the machine
- To fulfill the finite state machine transition

The states of the machines consist of:

- Stabilizes instantaneous reasons (alone or grouped) tied with the reasons of final result
- Interesting succession of instantaneous reasons tied with the reasons of final reasons
- Other cases valuables for the expert

In the case of many instantaneous reasons, it can be interesting to build a two level finite state machine. Instantaneous reasons are grouped to main instantaneous reasons which are used to build the first level of the finite state machine. The second level of the finite state machine identifies the difference in a main reason. All the main states have the same second state even if some are never used. A finite state machine can be represented as shown in figure 6.

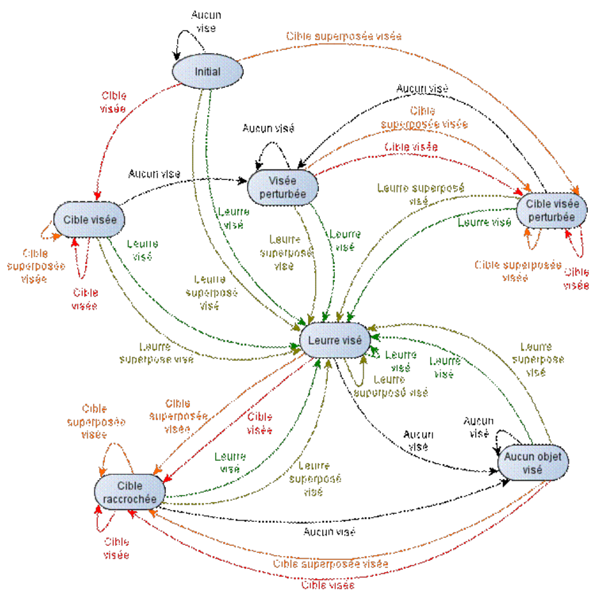


Figure 6: Finite state machine

The reasons of final result are made by logic combination of the finite state machine results. To simplify this work, the use of several steps as shown in figure 7 is recommended.

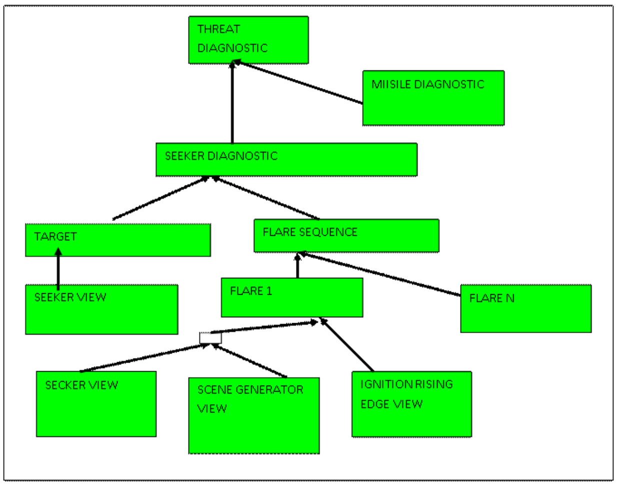


Figure 7: Diagnostic combination steps

A practical way to perform diagnostic combination at one step is to use a matrix.

Table 1: Diagnostic combination

	VIEW B				
VIEW A	FRB1	FRB2	FRB3	FRB4	FRB5
FRA1	FR1	FR2	FR1	FR1	FR1
FRA2	FR1	FR2	FR7	FR4	FR2
FRA3	FR3	FR6	FR3	FR3	FR8
FRA4	FR4	FR4	FR3	FR4	FR4

FR FINAL REASON

The diagnostic can sometimes be completed by extra information like missile diagnostic due to the fact that kinematics limits can sometimes modify the result. The dynamic analysis should be checked following rules of §3.

2.3.1. Specification definition

The static analysis and the dynamic analysis, if successful, have allowed to determine the feasibility of the motor and defining how the motor will work. In this case, the specification of the motor can be done.

The specification definition consists to define the informatics specification of the motor from the static and dynamic analysis. These specifications include the synoptic of the motor as shown in the example of figure 8 which resumes the static and dynamic analysis. The specification definition becomes standard informatics specification as soon as static and dynamic analyses are well made and will not be described here.

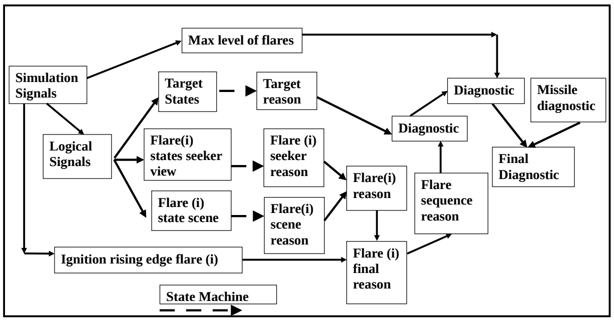


Figure 8: Synoptic motor example

2.4. Motor construction

Motor construction is informatics work, which will not be developed here. It is possible to make a prototype or directly upgrade the simulation. A thousand lines code are sufficient on MATLAB to define this kind of motor.

2.5. Motor configuration and tests

The configuration and tests of the motor are important tasks to be performed.

2.5.1. Motor Configuration

The motor configuration consists of :

- Adjust thresholds
- Optimize signals for analyses
- Adjust inputs of finite state machine
- Adjust outputs of finite states machine
- Finalize combination matrix
- Adjust last moment of motor analyses

The thresholds used to get logical signals could be simple threshold (one value), variable threshold (table) or adaptive thresholds. They should be adjusted by looking at logical signals, logical states, and outputs of states machines.

The analyses view by object is sometimes not compatible with global signals including effect of all objects. It can be necessary to optimize signals for analyses by:

- Use additional signals to limit the list of object impacting the global signals to influent objects
- Use parallel treatment to allow view by objects…

The inputs of the finite state machine should be sometimes adjusted to manage:

- Transition incoherent information not adapted to motor operation
- Switching errors in transition, limit cases
- Need of stabilized inputs for motor operation

The outputs of the finite state machine should be sometimes secured or weighted by statistics on instantaneous reasons.

The combination matrix should be finalized to manage undetermined cases.

The last moment of motor operation should be adjusted because too late or too early, diagnostic could be not optimal.

Motor configuration is not a simple task because of it's adaptation of the theories analysis to the reality of simulation which depends of each simulation.

2.5.2. Motor Configuration Validation

The validation of the motor configuration has to be made at two levels, global and detailed.

For global validation, look at the coherence of the results for a set of simulations (like in figure 1)for:

- The final diagnostic
- The different steps of combination
- The statistics on instantaneous reasons

For detailed validation, check motor operation on some specific simulations

2.5.3. Motor tests

As this work is VV&A (Verification, Validation and Accreditation), it will not be detailed here.

3. RULES OF CONSTRUCTION

To build a generic motor for simulation analysis, the different steps of construction should fulfil rules detailed here after.

3.1.1. Static analysis rules

The static analysis rules between elements of the motor shown on the next figure are described below.

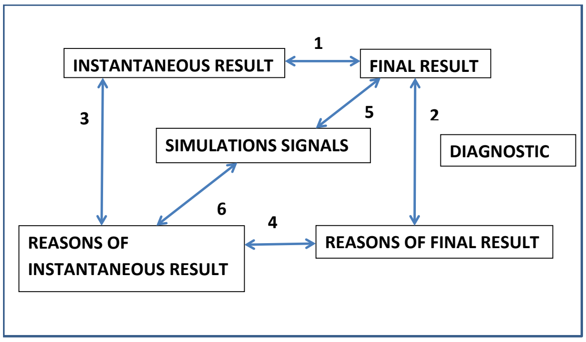


Figure 9: Static analysis rules

1. Each final result of the simulation must be associated with one instantaneous result, the opposite is not true. Each instantaneous result could be associated with no or one final result (an instantaneous result can be transitional…)
2. Each final result of the simulation could be associated with one or more reasons for the final result, the opposite is not true. At each reason of the final result could be associated only one final result. (a reason used to differentiate the final result can not apply to several possible results)
3. To each instantaneous result could be associated one or more reasons of instantaneous result for each aspect of view of each object, the opposite is not true. Each reason of the instantaneous result for each aspect of view of each object could be associated with only one instantaneous result. (a reason used to differentiate the instantaneous result can not apply to several possible results)
4. To each reason of the final result could be associated one or more reason of the instantaneous result for each aspect of each object, the opposite is true.
5. Each final result should be defined by simulations signals clearly to prevent indeterminate cases.
6. Each reason of instantaneous result for each aspect of each object should be defined by simulations signals clearly to prevent indeterminate cases.

In addition to these rules between elements of the motor, the following rule applies too.

7. All the relations between elements of the motor should be justified in the description of the static analysis of the motor to prevent possible misunderstandings in case of evolution of the motor.

3.1.2. Dynamic analysis rules

The dynamic analysis rules between elements of the motor shown on the next figure are described below.

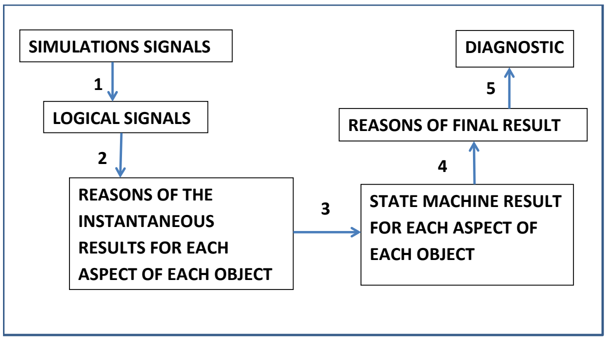


Figure 10: Dynamic analysis rules

8. Each logical signal should be defined by one or more simulation signals clearly to prevent indeterminate cases.
9. The reasons of the instantaneous results for each aspect of each object should be defined by total logic combination of one or more logical signals to prevent indeterminate cases.
10. The finite state machine should be checked carefully to prevent indeterminate cases.
11. The reasons of a final result should be determinate by total logic combination of the finite state machine results to prevent indeterminate cases.
12. The diagnostic should be determinated by total logic combination of the reasons of the final results with the final result and extra information if needed.

In addition to these rules between elements of the motor, the following rules apply too.

13. With all the choices of logic combinations, the finite finite state machine should be justified in the description of the dynamic analysis of the motor to prevent possible misunderstandings in case of the evolution of the motor.
14. The number of reasons of the instantaneous results for each aspect of each object should be limited to prevent an excessive size of finite state machine. The major reasons are not all interesting. A maximum of 10 reasons is preconized.
15. Use if necessary an indeterminate case. Signals simulations are not clear at each moment especially for detailed models, also it is preconized to not take in account these cases. Clear states are sufficient to define a diagnostic.
16. The number of outputs of logical combination should be limited to prevent excessive size of the following matrix. The main logic combinations are not all interesting. An increase of 1.5 of the biggest vector is preconized. This rule applies too to the finite state machine.
17. The reasons of final result should be obtained by several steps of logic combination to prevent an excessive number of combination.
18. In the definition of the finite state machine, each stable reason of the instantaneous result should be associated a state of the finite state machine.
19. In the definition of the finite state machine, each interesting succession of reason of the instantaneous result should be associated with a state of the finite state machine.
20. To prevent to have a final diagnostic with too much case not really interesting, rationalize the possible cases by groups of similar cases.

3.1.3. Motor configuration rules

21. Introduce systematically in the code management devices for unforeseen cases
22. Use a good test coverage basis (tests for each possible diagnostic, tests for typical use of the simulation…)
23. Redo the basis of test in case of modification of configuration
24. Perform tests on parameter sensibility to adjust them at best
25. In case of undetermined diagnostic, perform a detailed analysis of motor operation to correct the right item.

4. RESULTS

As motors have been built for classified simulations, an example of diagnostic (out of context) has only been shown in the introduction and it's not possible to show all the information given by the motor.

This diagnostic modify methodology of aircraft self-protection studies because it's now possible to quantify reasons of result, the action of each flare instead of general consideration of the expert.

On the results, the following message can be given: As the motor used logic combination, the only cases of dysfunctions are logic combination not taken in account. If the analyzis and the configuration are well done, diagnostic can be made at nearly 100%.

5. APPLICATION CASES

The generic motor for simulation analysis have been built and defined for aircraft/missile simulations.

This motor can be used for other simulations for which a diagnostic is requested. The diagnostic can be a final diagnostic or a temporary diagnostic for a monitoring system for example. The only conditions to build a motor is that Static and Dynamic Analyses are successful.

If an expert knows how to analyze the simulation, it is helpful, but not necessary to build a motor. The different way of thinking to build this motor has shown that making static and dynamic analysis can help in simulation analysis.

6. CONCLUSION

The present work on a generic motor for simulation analysis allows to notably increase the coverage ratio of analysis of simulations well as the reliability of the results and show a new image of the results with the statistics on the behavior of the simulation.

The construction of a motor is not a quick and easy task, but the added value and the time spare by an expert for manual analysis can make it interesting. The time to build a motor depends on how well the procedure is defined, so the present document has tried to described it with details.

The present method to build a generic motor for simulation analysis has been described based on the feedback of motor realized in a specific aera. This method will evolve with the construction of new motors and every one can adapt it for his purpose.

The "Simulation diagnostic expert" will be perhaps a new job as "value engineering expert", "experiment plan expert".

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SMALL ARMS TRAINING SIMULATORS IN THE NEW ZEALAND DEFENCE FORCE

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ABSTRACT
Contemporary operations require soldiers to be well-trained in all aspects of the employment of small arms, including the ability to make rapid decisions and have experience operating in a wide range of employment contexts. At present, no single small arms training simulator used by the New Zealand Defence Force can deliver all small arms training requirements however the use of multiple systems has proven to offer a flexible and low-cost solution for planning and executing mission-specific training.

Keywords: Small Arms, Training, Simulation, Defence

1. INTRODUCTION
The New Zealand Defence Force (NZDF) operates a number of different simulation systems to support individual training (a process that aims to improve knowledge, skills, attitudes, and/or behaviours in a person to accomplish a specific job task or goal), collective training (a process for a group of people that aims to mould their individual capabilities into an effective team) and mission training (a process that aims to prepare individuals for upcoming deployments).

Small arms simulators in the NZDF typically fall into two categories (Kerry 2010):

- **Live simulation:** Real people operating actual operational weapons and equipment in a typical combat or training environment.

- **Physical simulation:** A simulation in which physical objects are substituted for the real thing. These physical objects are often chosen because they are smaller, safer or cheaper that the actual object or system.

This paper provides a brief summary of the small arms simulators that are used by the NZDF to support small arms training and discusses some of their key benefits and limitations.

2. INDOOR WEAPON SIMULATORS
The NZDF operate two types of indoor small arms simulation training systems. These are the Weapons Training System (WTS) and the Combined Arms Collective Trainer (CACT).

2.1. NZDF Weapons Training System
The Weapons Training System (WTS) produced by Meggitt Training Systems is a multi-lane virtual weapons range that is used for range practices and shooting coaching for all three services.

The NZDF currently operates a 24 lane WTS system at Waiouru Military Camp and 12 lane systems at its Linton and Burnham Camps. There are also mobile variants that can be deployed outdoors.

WTS works by using a computer to generate virtual firing scenarios, which are projected on to fixed screens. Soldiers then sit in a pit in which they operate tethered modified weapons (including assault rifles, light machine guns and anti-tank weapons). Inside these weapons are various electronic sensors that provide information regarding weapon status, such as trigger pressure and orientation. The weapons also employ speakers to emulate firing sound effects and weapon recoil is simulated using pneumatic actuators (compressed carbon dioxide).

Figure 1: The NZDF Weapon Training System

A primary simulation computer is used to analyse and display the fall of shot on the screens, while an instructor control station assists the conduct of training serials.

The original WTS system installed in 2001 had a number of criticisms, these were as follows:

- **Fall of shot.** This was calculated by using accelerometers inside the weapon to estimate where the weapon was being pointed at the time of the trigger being squeezed. Latency issues meant the system did not always result in the fall of shot occurring at the operator's intended aim point.

- **Screen resolution**. The projected image was fairly low resolution (800×600 pixels), making the imagery appear grainy when attempting to represent targets at extended ranges (e.g. greater than 800 m).

- **Tethered weapons.** The weapons were tethered, preventing them from being used in many of the manoeuvres and/or firing positions employed by soldiers in real combat situations.

- **Scenarios.** The system only had one training scenario which consisted of open terrain with pop-up static targets.

In 2009, WTS was upgraded to address some of these issues. Key changes included:

- **Fall of shot detection upgrade.** This was achieved by the addition of an infrared camera and laser pointers on the weapons. The infrared camera monitors the screen and records where the laser beam hits the screen when the trigger is squeezed. This produces a more accurate estimate of where an actual projectile fired from the weapon would impact.

- **Display and scenarios upgrade.** Upgrade of the projection system and simulation software. The projected image resolution was increased by using multiple screens, each with their own high definition projector (1920×1080 pixels). The system also now uses a commercial gaming engine (Steel Beasts Professional), to enable more realistic objects and scenarios to be represented. This helps train soldiers in more realistic environments. For example, scenarios that contains complex terrain and multiple types of battlefield entities.

One of the key benefits of the WTS is that the computer can capture data that can provide immediate feedback to individuals on their marksmanship skills. For example, the system can indicate if the weapon is being held correctly, if the operator is snatching their trigger or flinching on firing (Kilpatrick 2009).

The ability to generate custom scenarios also enables a much wider range of situations for soldiers to practice against. For example, having to make rapid decisions as scenarios evolve/change. This makes WTS well-suited to meeting the training requirements of contemporary operations.

2.2. Combined Arms Collective Trainer

The Combined Arms Collective Trainer (CACT), developed by Laser Shot Inc, is similar to the upgraded WTS, in that it employs a commercial gaming engine (Virtual Battlefield 2, developed by Bohemia Interactive) for scenarios and a thermal imager to record fall of shot. The NZDF is looking to install this system in the near future.

The key difference with CACT compared with WTS is that un-tethered weapons can be used. This enables soldiers to conduct manoeuvres and drills while wearing full combat gear. In addition to lasers, the infrared camera can also be used to detect the impact of non-lethal training munitions, such as Simunition® or AirSoft® rounds. This is achieved by the use of rubber coated walls, which when hit by projectiles, leave a minor thermal signature. This is sufficient enough for a thermal imager to detect the point of impact and relay its position back to the computer running the simulation engine. The use of real projectiles also provides the weapon with more realistic firing characteristics compared to using a laser.

Much like WTS, the system allows for users to create custom scenarios. Examples from the manufacturer include:

Close-Quarter Combat. A virtual shoot house can be constructed using multiple projectors and thermal imagers. This enables soldiers to practice missions that demand rapid assault and the precise application of lethal force (e.g. building clearance, hostage rescue).

Figure 2: Virtual Shoot House example

Reaction Speed Trainer. Pop-up targets appear that are either friendly or hostile. These are then used to assess and improve engagement reaction speeds.

Branching Video. Video is presented which changes along different possible outcomes depending on the actions taken by soldiers. This is used to train soldiers on having to make rapid decisions under pressure.

Lead Time Trainer. This software presents different sized targets that move at different speeds across a presented scene. This allows operators to practice estimating lead time adjustments when engaging moving targets.

Figure 3: Lead Time Trainer

Virtual Firing Range. Emulates a standard firing range, where virtual paper targets are either static or can move towards the weapon operator.

Figure 4: Virtual Firing Range

Another feature that adds more realism compared with WTS, is that the Virtual Battlefield (VBS2) entities and terrain features are responsive. For example, missing a target will result in damage to terrain features behind them (e.g. walls) and the targets react to being fired at (e.g. diving behind a table for cover). Entities will also react differently depending where they are hit, such as dropping to the ground if a leg is hit, or switching their weapon to the other hand if hit in the arm. The system can also be programmed to allow entities to react to virtual less-than-lethal weapons (e.g. Tasers and flash bangs), allowing tactics and procedures for these systems to be developed and rehearsed.

Laser Shot Inc are also currently working on new features to make their system even more realistic. Examples include:

- **Blue tracking.** Small tracking devices will be attached to soldiers providing the computer with information that will allow the digital enemies to react to their presence.

- **Physiological effects.** Soldiers will be able to wear clothing that will deliver a sharp thud when a virtual bullet hits them, allowing the virtual enemies to fight back.

- **Three-dimensional display.** The use of polarised projectors and glasses will allow enemy units to appear as if they are a few meters away from the wall (i.e. in the room).

2.3. Indoor Summary

Indoor systems have a number of training advantages over traditional weapon ranges.

- They enable training to occur at reduced cost by reducing ammunition overheads, wear on weapons and transportation costs.
- There is less risk to personnel and equipment than live-fire activities.
- Training can still occur during adverse weather conditions (e.g. heavy rain, snow, fog).
- They provide the ability to rehearse techniques and procedures that cannot be achieved with static paper targets.
- Terrain and entities can be customised to reflect a wide range of operational scenarios.

The drawbacks of such systems are:

- They are not compatible with magnified optics. This is due to parallax errors associated with the weapons proximity to the screens (typically less than 10 m) and the resolution limit of the displays. Injection sights have been offered as a possible solution. This is where a display screen is positioned inside the sighting system of the weapon itself.
- Additional personnel are required to maintain the system and customise scenarios.
- There is limited ability to train with night vision equipment (due to the use of projectors).

3. OUTDOOR WEAPON SIMULATORS

The NZDF operate several types of outdoor small arms simulation training systems. These include the Man Marking System (MMS), the Improved Tactical Engagement Simulation System (I-TESS) and the Small Arms Retaliatory Target (SART).

3.1. Man Marking System (MMS)

The Man Marking System (MMS) works by incorporating a modified barrel (including paint ball rounds) onto the current- in-service NZDF assault rifle (Steyr AUG). Players then compete, in teams or individually, to eliminate opponents by tagging them.

Figure 5: NZDF Man Marking System

Game fields are often scattered with natural or artificial terrain, which players use for tactical cover. Game types vary, but can include capture the flag, elimination, ammunition limits, defending or attacking a particular point or area, or capturing objects of interest hidden in the playing area. Depending on the variant played, games can last from minutes to days.

Advantages:

- Soldier can use their own personal weapon.
- The system provides instantaneous kinetic and visual feedback to players (i.e. a visible and uncomfortable mark is left when hit).
- It puts soldiers in real environments with their actual standard issue weapons, clothing and equipment.
- Training can occur at lower cost than using real ammunition.

Disadvantages:

- Personnel can still be wounded (e.g. the use of masks and minimum engagement ranges need to be enforced).
- Weapon firing characteristics (e.g. recoil) are different to the real weapon

3.2. Instrumented Tactical Engagement Simulation System (I-TESS)

The Instrumented Tactical Engagement Simulation System (I-TESS) is an eye-safe laser-based tactical training system produced by Cubic Defense Systems.

I-TESS laser projectors attach to the small arms systems that NZ soldiers utilise, while hits are recorded by I-TESS laser detectors attached to the soldier's webbing. The system is powered by lithium ion batteries, which can last up to 10 days without recharging. Similar systems can also be fitted to NZDF vehicles, enabling large-scale training exercises involving multiple force elements to be conducted.

There are also a wide range of different replica weapon options, including claymore mines.

Figure 6: The NZDF Instrumented Tactical Engagement Simulation System

Advantages:

- Provides real-time feedback on 'hits' to game control
- It puts soldiers in real environments with their actual standard issue weapons, clothing, vehicles and equipment
- Soldiers can transition from one weapon type to another seamlessly
- Training can occur at less cost due to not using physical rounds.

Disadvantages:

- Limited amount of equipment available to allow larger formation activities (e.g. pre-deployment training).
- The hardware itself is wearing out quite rapidly
- Weapon firing characteristics are different to the real weapon.

3.3. Small Arms Retaliatory Target (SART)

The Small Arms Retaliatory Target (SART) was developed by SAAB Training Systems and has been in service in the NZ Army since about 2009. The system can be on either a Gazetted Range (normal rifle range) or in a live field firing situation. It can be used for both live firing and blank firing.

When live firing, a human torso-sized rigid plastic target is placed in the target holder. There is a 'hit sensor' (vibration sensor) that is situated at the bottom of the target holder to sense the shock of the round as it passes through the target. The sensor will only sense a vibration from a round going through the target so things like stones being flicked up will not set it off. Once a hit is registered, the target drops (folds down). The target will then lift up after a predetermined time or when instructed to via a wireless signal.

Figure 7: NZDF Small Arms Retaliatory Target

When using the SART for blank firing the plastic target is replaced with an aluminium one with a laser sensor on it. It is then used in conjunction with I-TESS. This is good for urban environment training when live rounds cannot be used.

The system uses batteries for power, allowing them operate autonomously, and it can operate in hot and cold environments. There is also a speaker system to produce sound effects, such as emulating enemy gun fire.

Figure 8: NZ Army soldiers practising section tactics using SARTs.

Advantages:

- Provides real-time feedback to operators and game control, including operator reaction times and hit statistics.
- It provides a realistic target for live firing, with targets being able to be controlled to follow group instructions.
- Soldiers can use their actual standard issue weapons (and ammunition), clothing and equipment
- Operators have flexible control over how and when the targets appear. This has pros pertaining to variety in training and also practising rules of engagement.
- It is fairly reliable. There are few reports of any issues with either the software or hardware.
- It has the flexibility for the user to be able to programme complex scenarios or control the targets manually.

Disadvantages:

- It is often difficult to tell who in the group got the hit. It is also difficult to isolate where rounds hit on the target because if a shot lands anywhere on the target it will react.
- Targets require replacement (or repair) over time.
- The system is unable to emulate common human behaviours e.g. suppression, movement.
- It can take a long time to set-up a live field firing situation, especially if you have to dig pits to put the targets in.
- The sound simulator is separate to the targets themselves however it would be more beneficial if each target had its own speaker.

3.4. Outdoor Summary

Outdoor small arms training simulation systems have a number of advantages over traditional weapon ranges.

- They enable training to occur at reduced cost (mainly by reducing ammunition overheads).
- They provide the ability to rehearse techniques and procedures that cannot be achieved with static paper targets.
- Units can train in real environments, such as in urban or jungle terrain, and in a variety of conditions (e.g. poor weather, low light).
- Most systems allow the use of standard issue combat gear and equipment.

The drawbacks of such systems are:

- Most of the outdoor systems require batteries to operate.
- A trade-off usually exists between either using real weapons or real enemy units to train against, with most of the systems being based around emulating one or the other.
- Severe weather may prevent outdoor training activities.
- The size of the training area and number of targets is limited. This limits the size of the training exercise to section level.

4. DISCUSSION

In 2010, a review was conducted by the New Zealand Ministry of Defence on the NZDF's use of simulation as a training tool. One of the key findings from this report is that simulation has been used as an integral part of training across the NZDF for many years and is a well-established and essential element for the delivery of its outputs (Ministry of Defence 2011). The Army Land Training and Doctrine Group is preparing a simulation Action Plan which will outline its future requirements for weapons and combat simulation and the simulation capabilities required to achieve this.

5. CONCLUSION

The NZDF employs a number of different small arms training simulation systems, with each offering different benefits and disadvantages. None of the systems on their own offers a full training solution but collectively they enhance the small arms skill that operators should possess in order to deal with the complex spectrum of challenges they are likely to face on the modern battlefield. Examples include rapid decision making, the use of multiple weapons, cooperative tactics and conducting operations around non-combatants. Many of these skills are difficult to acquire when using traditional small arms training techniques i.e. static paper targets on a weapons range.

Although the NZDF claims that small arms training simulators have improved marksmanship skills, very little analysis appears to have been done to support this claim. It is therefore likely that more quantitative assessments will be done in the future.

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COLLABORATIVE MODELING, SIMULATION, AND VISUALIZATION FRAMEWORK FOR AIRPORT EMERGENCY

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ABSTRACT
Airport is a highly dynamic environment, turning emergencies into extensively costly and disruptive events with cascaded effects that will adversely affect the entire aviation system. Airports' management and safety divisions exercise precise and case-based procedures to accommodate any possible emergency scenarios. With this regards, airport emergencies have a number of challenges that require better and more adaptive way of addressing. Challenges such as lack of adaptive and customizable simulation-based decision support tools, infeasibility of conducting frequent physical emergency exercises, and the time-critical nature of emergencies in general raise an immediate need for a technology that collaboratively performs modeling, simulation, and visualization to guide first responders throughout the decision-making process. Here we propose a collaborative emergency modeling, simulation and analysis software system that provides an all-in-one simulation technology for enhancing emergency response at airports.

Keywords: emergency simulation, airport security, risk analysis, disaster analysis, what-if scenarios

1. INTRODUCTION
Aviation safety and security has always been recognized as one of the top challenges of the Department of Homeland Security. Previous CREATE project (SAAS) has attempted simulating "in-the-air" emergency events and their risk/cost analysis focusing only on aircrafts behavior under attack situations. Since many of aviation related emergencies are affected by attacks originating from the airport ground, it is crucial to be able to simulate emergencies at the airport itself. The recent shooting in LAX is one catastrophic event that disrupted not only the normal operation of the airport itself, but also the entire aviation system (1,550 flights, 167,050 passengers, air cargo system, car rentals and hotel reservations, sales at airport restaurant sand store, and all related services supporting the aviation domain were affected). Efficient crowd guidance methods are one of key concerns of airports' personnel under emergency evacuations. Handling such events is only possible through precise estimation and training. To mitigate the enormous financial and human loss caused by airport emergencies, here we propose a full-scale modeling, simulation, and visualization framework that provides an all-in-one solution to airport security and emergency response planning. The tool addresses multiple interdependent aspects of airports' emergency scenario by integrating different aspects of an emergency situation, providing situational awareness in the form of the entire picture to planners, trainers, and first responders. The proposed framework provides real-time modeling and analysis capabilities for the airport risk analyst. The tool allows the user to quickly define a microscopic model of the airport emergency scene by selecting the airport area (e.g. gate, terminal, or security checkpoint), disaster type, crowd reaction behavior, and crowd guidance strategy. It will then takes in virtual- and real-time data feed, performs rapid emergency response analysis by incorporating live and historic information. Simultaneously, the tool will generate real-time 3-D visualization of the entire disaster scenario (airport environment, progress of the disaster event, and crowd behavior), allowing airport security officers to obtain live feedback and analysis of the emergency situation. As an emergency simulating and analysis tool, the framework will significantly improve the DHS's capability in the emergency response and risk management field. Specifically, the FLETC (Federal Law Enforcement Training Center) and TSA (Transportation Security Administration) could benefit from this tool to optimize their emergency guidance strategies. Requirements elicitation for the project will be conducted from the personnel (a current Director of Public Safety and a former Airport Manager) in Daytona Beach International Airport in Florida. The first prototype of the framework will be tested by security personnel and risk analyst from this airport.

2. BACKGROUND AND MOTIVATION
The existing airport simulation technologies (RescueSim, paxport, and CAST) are mostly used for training purposes, providing augmented virtual environments for practicing response to emergency situations. These technologies mainly focus on a single aspect of the emergency scenario (e.g. modeling only one type of disaster event or simulating only the disaster and not the environment) and usually lack real-time data processing and analysis capabilities, thus, fail to provide a holistic and effective representation of the emergency situation. This research attempts to provide a full-scale simulation-based decision support technology that provides a real-time modeling, simulation, and analysis benchmark to aid emergency analysts and personnel in identifying optimal tactical strategies for handling

disaster scenarios at airports. With integrated risk/cost assessment capabilities, the tool helps emergency responders make optimized decisions under multi-aspects and dynamically changing situations. The tool supports both real-time and virtual-time simulations and is operated under two modes: learning/training (processing historic data in advance of actual crisis), and live response (processing live data as the emergency is happening). Providing a holistic emergency response framework, it attempts to address the following goals:

- Providing full-scale, adaptive, and configurable models of natural (earthquake, flood, fire, etc.) and manmade disasters (terrorist attacks, explosives, chemical spill, etc.);
- Modeling disaster impact to study and estimate the impact of a disaster event (e.g. analyzing crowd guidance strategies, as well as evacuation time and speed);
- Analyzing the emergency response activities (e.g. crowd guidance) by monitoring the disaster event in real-time using the live 3-D visualization feedback of the scene;
- Estimating disaster progress based on historic and real-time data feed, allowing significant disaster cost reduction or even prevention;
- Logging large-scale data of disaster management and emergency response for use as database for estimating and analyzing current and future scenarios;
- Offering emergency assistant to responders by quickly providing optimal evacuation strategies for efficient evacuation of the crowd from the emergency scene;
- Allowing for collaborative interfacing and interoperability with existing and future disaster simulation technologies for extending the tool to simulate first responders' activities.

Aiming for the goals stated above, the proposed tool will be implemented to provide the user a framework to define disaster events over an airport area, thus, dynamically analyzing the crowd evacuation behavior, the progress of the disaster event, and make on-demand and real-time tactical adjustments to the emergency response activities.

3. ARCHITECTURE OVERVIEW

The proposed airport emergency simulation and analysis system is based on discrete-event modeling and simulation theory. The airport area, crowd behavior, and the disaster models are constructed using the Discrete-Event System Specification (DEVS) formalism (Zeigler, Praehofer, and Kim 2000) and its cellular extension (Cell-DEVS) (Wainer 2009). The tool will be implemented on top of an existing open-source discrete-event modeling, simulation, and visualization framework called CD++ (Wainer 2002). The CD++ toolkit implements DEVS theory and supports model creation and real-time/virtual-time execution, as well as dynamic generation of 3-D scenery. The proposed system is composed of three main subsystems as shown in Figure1:

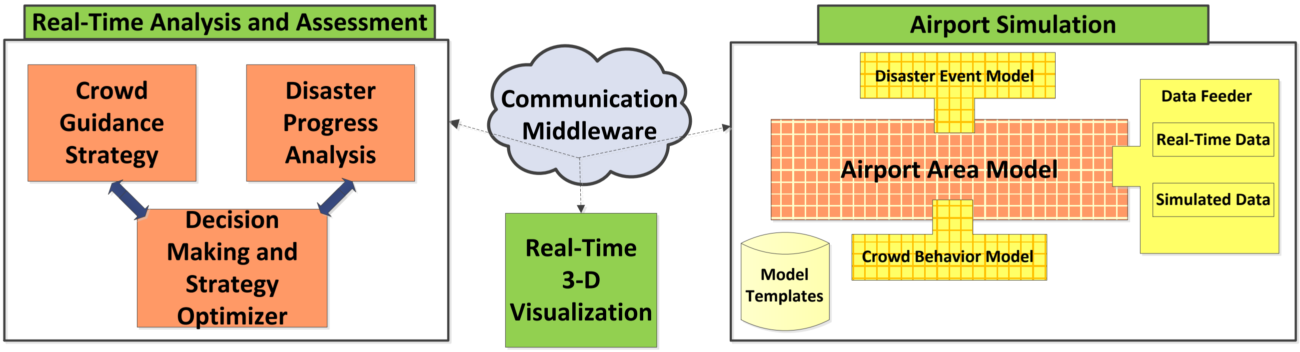


Figure 1: System Architecture

Airport Simulation: to model and simulate the complete disaster event and the surrounding environment. This subsystem is further divided into six components:

- *Airport Area Model*: a grid of discrete-event cellular entities that represent the environment model, depicting an actual airport area (gate, terminal, TSA checkpoint, etc.).
- *Disaster Event Model*: a cellular discrete-event model representing the disaster event (for instance, spread of fire at the gate due to an explosion).
- *Crowd Behavior Model*: a cellular discrete-event model representing the flow of the crowd at the disaster scene (people are modeled as independent agent entities).
- *Data Feeder*: a data source unit providing simulated (based on historic information) or real-time data such as spread of fire, crowd flow direction, or building collapse.
- *Model Templates*: the user has the option of selecting various models from the templates repository. These templates provide various already-built models than can be used "as-is", extended, or even modified. The templates

repository includes various models for: airport area layout (area layout for gates, terminals, checkpoints, etc.), natural and manmade disaster types (earthquake, fire, explosion, terrorist attack, shooting, etc.), and crowd emergency behavior (herding behavior, multi-directional flow, uneven density distribution, etc.). Given the duration of this project, only a number of sample models will be implemented for each category. Some crowd evacuation and behavioral models already exist from model repository available from CD++ users community (http://cell-devs.sce.carleton.ca/). Additionally, the user will be given instructions on how to define their specific model and save it in the repository for future reuse. The CD++ toolkit already supports this and provides an easy and user-friendly model development environment.

Real-Time Analysis and Assessment: to provide real-time and on-demand feedback to airport risk analyst and security personnel. Statistical cost/risk analyses are provided which evaluate alternative evacuation strategies in the form of text and graph.

- *Crowd Evacuation Guidance*: suggests crowd evacuation guidance strategies (egress models (Tsai and et. al. 2011)) that get integrated dynamically with the Crowd Behavior Model. The suggested guidance method will affect crowd behavior. The resulting behavior is instantly observed through the visualizations generated from the Crowd Behavior Model.
- *Disaster Progress Analysis*: provides current and estimated progress of the disaster event (e.g. percentage of terminal area affected by the emergency event, fire spread rate, etc.). This entity is fed dynamically by the Crowd Behavior and Disaster Event Model.
- *Decision Support and Strategy Optimizer*: evaluates current evacuation process, provides assessment on alternative evacuation strategies, and searches for optimal strategy. This entity provides decision making support based on historical and live data to guide emergency responders in identifying optimal tactical strategies. The framework uses two metrics to evaluate the response strategies: 1) evacuation speed, 2) number of people evacuated. The tool also includes a logging facility that records all events that occur during a simulation. These logs can be used to search or replay a simulation, allowing researchers to conduct post emergency analyses.

Real-Time 3-D Visualization: to render 3D visualization images of the disaster event and the airport environment sceneries in real-time. This component provides an interactive environment to visually track the disaster propagation and crowd evacuation behavior. The 3-D scenes are generated at run-time as the models execute. This entity is already implemented and provided by the CD++ toolkit. The required interfacing mechanism to the visualization engine is also already available.

This proposed research is conducted with the collaboration of Daytona Beach International Airport and the existing facilities at Embry-Riddle Aeronautical University (ERAU). Personnel (Director of Public Safety, Airport Manager, and Security Officers) form the Daytona Beach Airport will provide data resources and consultation for defining airport environment, disaster models, and testing scenarios. Since the framework will be built on top of the existing CD++ modeling and simulation tool, a large portion of the underlying infrastructure is already available. The CD++ tool also allows web service-based parallel and distributed execution. This feature can be combined with the computing cluster available at the researchers' institution (ERAU's Zeus computing cluster - 256 Xeon nodes @ 3.2 GHz processor with Myrinet Interconnect) to allow for very large-scale emergency simulations.

4. UNDERLYING TECHNOLOGY: EXISTING AND NEW MODULES

Aiming for technology reuse and benefiting from open-source resources, the framework will integrate existing and new modeling/simulating modules. As discussed in the previous section, the core computing power of the framework is provided by the open-source CD++ M&S engine (Wainer 2002). Figure 2 provides an overview of how various modules will be incorporated into the proposed collaborative technology. As illustrated on Figure 2, there are two different building blocks of the framework: ***existing components***, and ***proposed components***.

The *existing components* are a set of publicly available and open-source technologies that are ready to be used. These include:

Model Templates: various cellular models implemented in CD++, based on Cellular DEVS formalism, are freely available from a model repository available on http://cell-devs.sce.carleton.ca. Among them, there are various Evacuation and Natural Disaster sample models that can be used for creating an emergency scenario by slightly modifying them and customizing them to reflect the user's needs. The proposed emergency framework will package such models along with newly created models matching airport emergency scenarios (such as airport specific areas and sceneries) and provide a well-established model repository to the user. The airport models generated for this research will also be made available to other researchers as open-source and free products;

Visualization Capabilities: Beside models, a DEVS-based modeling and simulation toolkit (created as an eclipse plug-in) is also available for reuse. The tool allows 3D rendering of the simulation results by sending the output to open-source visualization engines (such as Blender or VegaPrime) through an interface.

The *proposed components* will provide the unique features of the framework, which include:

Real-time Analysis and Assessment: this component provides “what-if” analysis to guide decision makers to take optimal paths in evacuating the crowd under emergencies. Given an emergency scenario, the component will run several simulations of the same scenario but with varied metrics (e.g. dictating difference evacuation methods such as adding more patrolling agents, evacuating through different routes, blocking a specific area or exit door, etc.). These various simulation instances will be executed simultaneously to provide an optimal solution. While such simulations are in execution, real-time data can be fed into them to reflect updated emergency data. Given the nature of emergencies, time is a critical factor and the framework thrives to make these simulations as efficient and precise as possible by incorporating fast simulation techniques. This is made possible through using cellular discrete-event simulation mechanism which allows to simulation thousands of independent agents in a matter of seconds. Cell-DEVS not only will allow to simulate each individual person on the scenery, but also allows simulating the environment of the airport and integrating the two concepts seamlessly into one single simulation scenario. At the same time, the mathematical backbone of Cell-DEVS provides a powerful calculation mechanism for analyzing risk and other sensitive statistics.

Data Feeder: As emergency is evolving, metrics change and new data arrive continuously (status of the building, number of people injured or blocked, new fire locations, arrival of first responders and patrolling staff, etc.). These data must be captured in real-time and fed into the “already-running” simulations to reflect realistic scenarios. The Data Feeder component is in charge of capturing and streaming these information to the simulation entity to update the scenarios as information becomes available. Not only real-time data can alter emergency responses, but historic data can also be used to predict situations. Thus, the data feeder, provides a storage mechanism as well for extracting of data from old emergencies.

New Models: Generic airport layouts will be generated and stored in the framework Model Template repository to speed up the scene generation process. Building areas such gats, terminals, baggage claim, parking, etc. will be created in Cell-DEVS allowing the user to reuse or customize them accordingly.

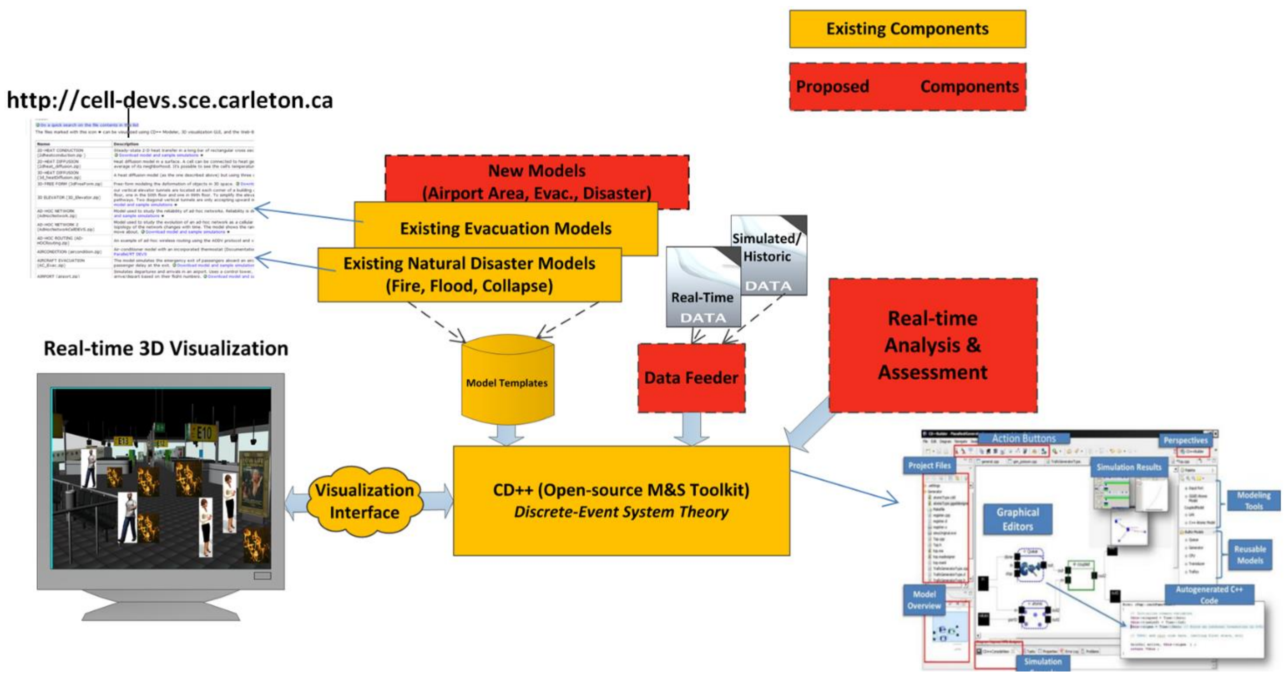


Figure 2. Framework Existing and New Modules

5. TECHNOLOGY OUTCOMES

The tool aims at providing a “plug-and-play” framework where various components can be easily integrated into the system. From the user’s stand point, the framework is executed in the following steps:

1. Define Airport Area Model: User can select a pre-existing model from the templates repository or define a new one using the tool’s development environment (the new model can be added to the templates repository for future use).
2. Define Disaster Event Type: User can select one or more disaster types from a Graphical User Interface (GUI) listing various disaster types.

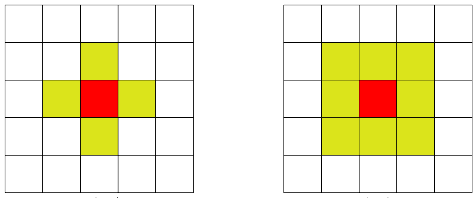
The user will need to specify the location of the disaster and pin it on the Airport Area Model.

3. Define Crowd Behavior Model: User selects among various crowd emergency behavior. Similar to the above models, the template repository contains various options that can be selected by the user from a GUI window.
4. Select Data Source: User defines the data source (real-time data that will be injected into the simulation at run-time, historical data from data repository, or a mixture of these two).
5. Visualization Generation: Given the above required inputs, the simulation launches and real-time data are fed into the visualization engine. 3-D scenery of the airport emergency area, disaster progress, and crowd flow behavior are rendered and presented to the user in real-time.
6. Analysis and Assessment Evaluation: Statistical data (text and graphs) are presented to the user providing cost analysis of current scenario and alternative strategies. These data are dynamically logged for later investigation and analysis of emergency situations.
7. Run-time Strategy Switching: Based on the feedback obtained from the analysis, the user can dynamically switch to other alternatives at run-time. For instance, the user can select a different crowd evacuation strategy and observe the resulting behavior (the tool will provide a number of most efficient egress strategies that can be selected by the user and implemented on top of the Crowd Behavior Model as the simulation is in progress or prior to its start).

Advancing the tool by incorporating other subcomponents (e.g. Simulation of First Responders Activities) and intelligence is in the future milestone for the framework. Also, the tool can be potentially expanded to allow for modeling larger airport areas (i.e. ultimately the entire airport facility including all buildings and lots).

6. CELLULAR DISCRETE EVENT APPROACH

The selected modeling and simulation methodology for this work is the Cellular Discrete-Event System Specification (Cell-DEVS) formalism (Wainer 2009). A model defined by Cell-DEVS is a cellular grid where each cell represents an independent agent. Agents communicate and interact with each other throughout the simulation by sending/receiving messages. The behavior of each agent is expressed using a state-machine. Agents can be stationary or mobile meaning they can change their position within the grid. Each cell defines a surrounding neighborhood that affects its state value. Whenever a computation is performed and the cell's value is modified, all its neighboring cells get an update to re-evaluate their states accordingly. A cell's value changes as a result of a simple local computation based on the current state of the cell and its immediate neighbors as dictated by the Cell-DEVS specification. Figure 3 illustrates a typical Cell-DEVS grid and the neighboring definition. Each cell can choose to have as many direct or indirect neighbors.



(A) (B)

Figure 3: Cell Neighborhoods: (A) Von Neumann, (B) Moore.

A Cell-DEVS model is defined by:

$$TDC = < X, Y, I, S, \theta, N, d, \delta_{int}, \delta_{ext}, \tau, \lambda, D >,$$

where X is a set of external input events; Y is a set of external output events; I represents the model's modular interface; S is the set of sequential states for the cell; θ is the cell state definition; N is the set of states for the input events; d is the delay for the cell; δ_{int} is the internal transition function; δ_{ext} is the external transition function; τ is the local computation function; λ is the output function; and D is the state's duration function. The modular interface (I) represents the input/output ports of the cell and their connection to the neighbor cell. Communications among cells are performed through these ports. The values inserted through input ports are used to compute the future state of the cell by evaluating the local computation function τ. Once τ is computed, if the result is different from the current cell's state, this new state value must be sent out to all neighboring cells informing the state change. Otherwise, the cell remains in its current state and therefore no output will be propagated to other cells. This will happen when the time given by the delay function expires. Finally, the internal, external transition functions and output functions (λ) define this behavior. Cell-DEVS improves execution performance of cellular models by using a discrete-event approach. It also enhances the cell's timing definition by making it more expressive.

CD++ (Wainer 2002) is an open-source object-oriented modeling and simulation environment that implements Cell-DEVS theories in C++. The tool provides a specification language that defines the model's coupling, the initial values, the external events, and the local transition rules for Cell-DEVS models. CD++ also includes an interpreter for Cell-DEVS models. The language is based on the formal specifications of Cell-DEVS. The model specification includes the definition of the size and dimension of the cell space, the shape of the neighborhood and the border. The cell's local computing function is defined using a set of rules with the form *postcondition delay {precondition}*. These indicate that when the *precondition* is met, the state of the cell changes to the designated *postcondition* after the duration specified by *delay*. If the precondition is not met, then the next rule is evaluated until a rule is satisfied or there are no more rules. CD++ also provides a visualization tool, called *CD++ Modeler*, which takes the result of the Cell-DEVS simulation as input and generates a 2-D representation of the cell space evolution over the simulation time. This feature of the tool provides an interactive environment allowing for visual tracking of the mode's evolution.

7. CELL-DEVS MODEL OF AIRPORT

To demonstrate a cellular representation of an airport area, here we present a Cell-DEVS model depicting check-in, lobby, and baggage claim area of the Daytona Beach International Airport (on Figure 4 and 5).

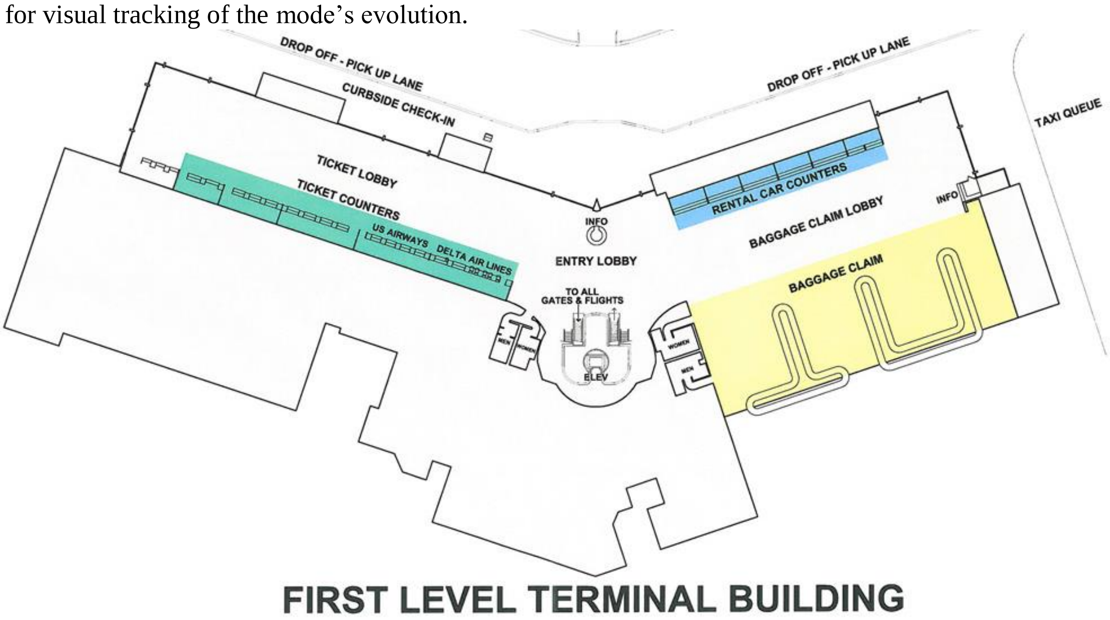


Figure 4: Daytona Beach Airport, First level terminal

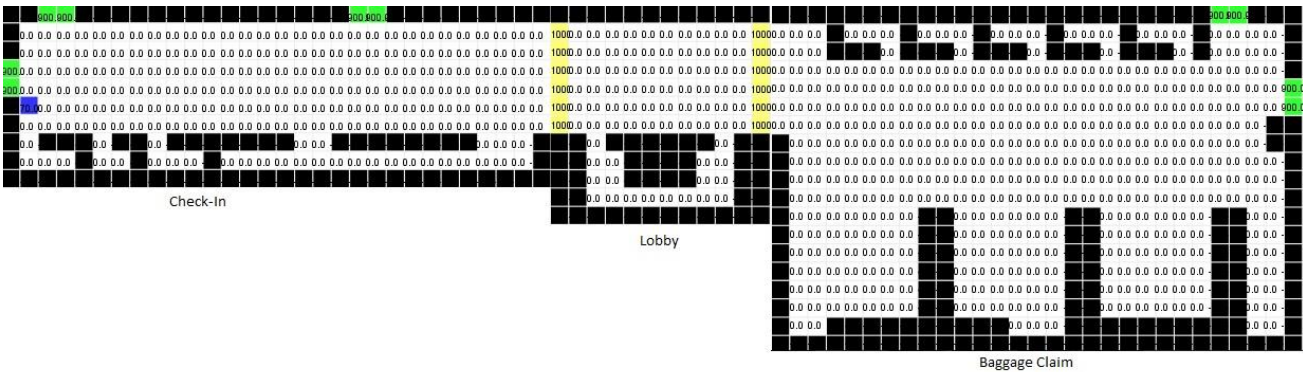


Figure 5: Cellular Representation of First Level Terminal Layout

When comparing Figure 4 and Figure 5 it can be seen that there are a number of differences between the two images as a result of design decisions. The first design decision was to remove the angular aspect of the terminal design by stitching together three separate cellular designs of the terminal. The Check-In, Lobby and Baggage Claim each represent separate components within the top-level Cell-DEVS model, which have been coupled together at the seams represented by yellow colored cells. The second design decision was to remove the areas that are not accessible by the general public. The third design decision was to get the cellular representation as close to scale as possible, and only modify the design when reaching the limits of the Cell-DEVS visualizer. Note that green cells represent exits, black cells are walls/obstacles, blue cells are crowd, while white cells represent vacant space.

Using the airport layout model, various egress strategies can be applied to study and analyze two important emergency metrics: speed of evacuation, number of evacuated persons. Using the same cellular structure, multiple airport egress models (e.g. random movement, directional movement, guided evacuation, follow the herd, etc.) illustrating crowd evacuation behavior are studied. Given the scope of this article, here we will only present one evacuation strategy and demonstrate the preliminary results.

The simulation was conducted by placing crowd on various locations on the cellular grid. Cell's rules was written in such a way that crowd would move in a random behavior not knowing the exists (simulating panic scenario where crowd is panicked and can not determine where the nearest exit door is located). Each cell representing crowd was modeled to have access to twelve surrounding neighbors (to determine direction and avoid collapsing with walls/ moving people, etc.). The model executed based on discrete-event steps (arrival of events determined the simulation time advancement). The airport model of Figure 5 included total of 995 cells (Check-in: 10x30 cells, Lobby: 12x12 cells, Baggage: 19x29) was modeled where 80 people were placed at different locations on the three areas of Lobby, Check-in, and Baggage. The simulation was executed till the entire crowd was evacuated, which took almost 2600 seconds (201 minutes). Given the nature of random movement, it was expected to take the longest time compared to guided/directional crowd evacuation. The detailed simulation scenarios and other statistical metrics will be published in near future. Figure 6 presents three screenshots of the airport random evacuation simulation at *initial*, *half-way*, and *near final* stages of the execution.

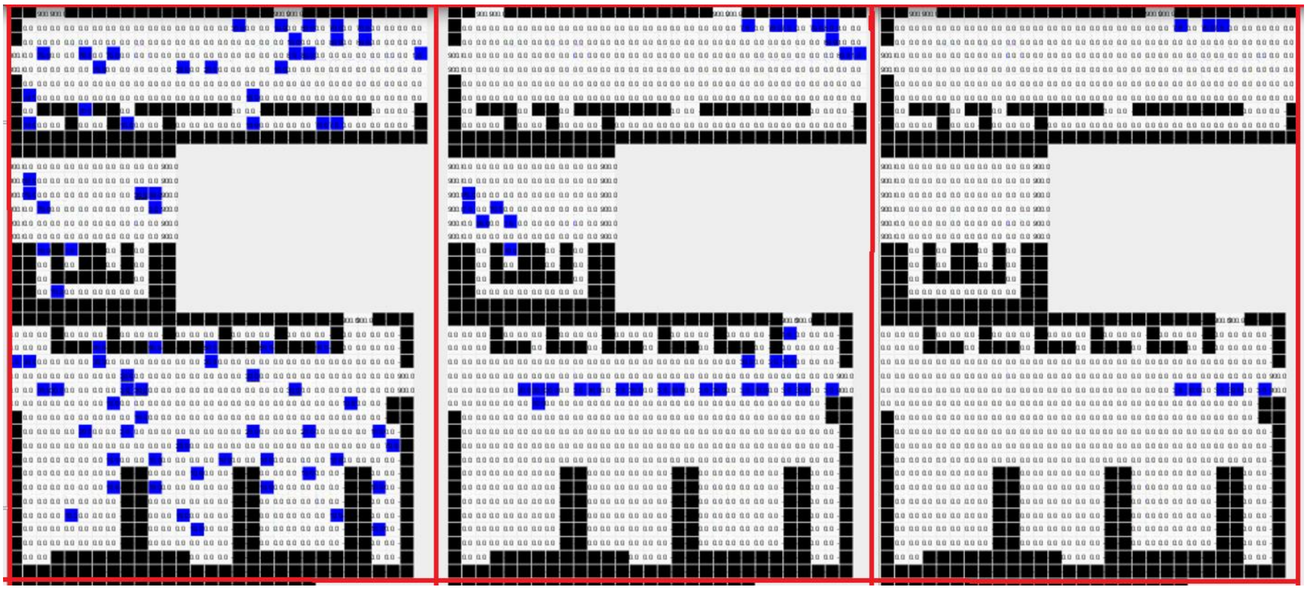


Figure 6: Airport Random Evacuation at Initial, Half-Way, and Near Final Stages.

8. SAMPLE APPLICATION OF CELL-DEVS TO EMERGENCY MANAGEMETN – A SUCCESS STORY

DEVS and Cell-DEVS has been successfully used in the past for emergency management (Moallemi and et. al. 2011). The initial idea of the proposed framework was actually driven by that work. For demonstration purposes, a simple emergency scenario depicted from (Moallemi and et. al. 2011) will be presented here to show the use of Cell-DEVS and 3D visualization in managing fire emergency.

The work illustrates a real-time robotic firefighter that is place on the field and is updated about fire locations. The first responder officer sitting in his fire department office is getting real-time and simulated (expected) fire locations and reports them to the robotic firefighter. The fire simulation (Cell-DEVS model) running on the first responder's computer is warning about the speed and direction of the fire and predicts the fire progress using lively-fed data (from the firefighter acting on the scene) and historic/simulated fire data. The first responder officer is also viewing 3-D live scenery of the fire location and the activities of his firefighters. The robotic firefighter periodically reports back his fire extinguishing results, updating the officer's visualization scenery. This collaborative work provides highly precise and dynamic information of the fire progress, allowing for much faster emergency management and an optimal supervisory control experience to first responders. Figure 7 is a snapshot of the 3-D real-time scenery, illustrating a robotic firefighter approaching fire location, while the first response officer is watching his activities and the simulated fire progress.

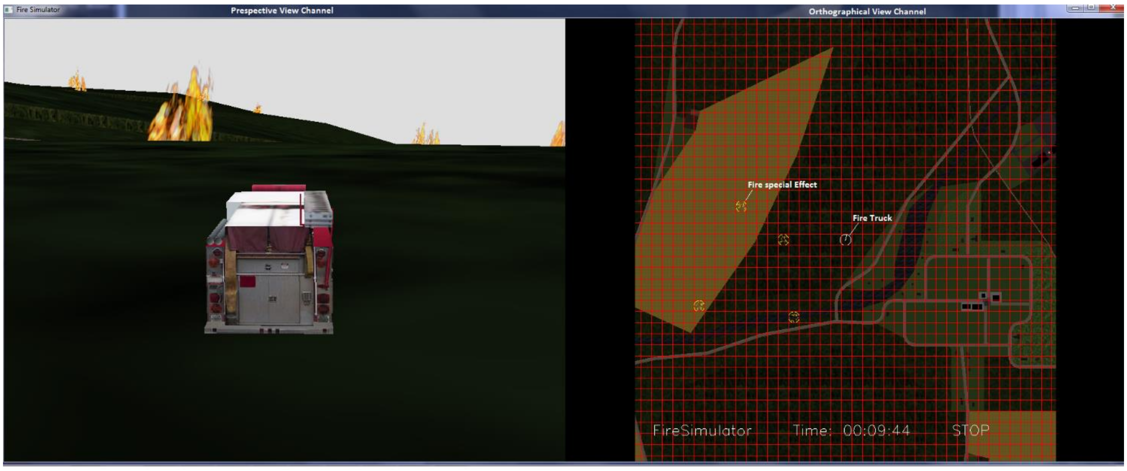


Figure 7: Cell-DEVS 3-D Modeling of Fire Emergency Management (Moallemi and et. al. 2011)

9. CONCLUSION

This work attempts to propose a collaborative modeling, simulation, and visualization architecture to enhance airport emergency preparation and management. A plug-and-play framework was presented that integrates various airport emergency components. Such adaptive and scalable system not only could be used for training and supervisory control, but it could also play a great deal at real-time disaster management. Although the work is still under development, but successful projects have been implemented in the literature that use modeling, simulation, and visualization for disaster engineering. The framework discussed in this work allows first responders to define the airport area model (user fine-tuned), the disaster type (natural and manmade), and crowd behavior (various egress strategies) and simulate the entire disaster scenario in virtual or real-time. Constructed on top of an open-source M&S environment (CD++), the proposed framework supports live 3D visualization, what-if analysis, as well as run-time strategy switching. The work presented here outline the research goals and the software architecture, while the core implementation activities are still under development. The outcome of this research will be a tool that can be easily used by non-experts (airport security officers and first responders) to enhance emergency exercises and complement table-top and field-based trainings.

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DESIGN OF A COLLABORATIVE PLATFORM FOR SUPPORTING CRISIS MANAGEMENT

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ABSTRACT
In many organizations today, efficiency strongly relies on critical decisions involving heterogeneous expertise and requiring collaboration to deal with complex data. Designing collaborative platform for crisis management in civil security involves dealing with numerous issues related to various parameters (e.g. users, data, tasks and context), which are extremely difficult to specify and assess in a general manner. The requirements in terms of reliability, intuitiveness, flexibility and robustness associated with such an application introduce the strongest possible set of constraints. Likewise, the highly hierarchical structure combined with the high stakes related to such a context demands a clean and optimal environment within which to evaluate the system. This article describes the civil security crisis context and requirements, the collaborative multi-touch solution we developed, which eases heterogeneous document sharing on a single multitouch-enabled meeting table, and the feedback we gathered from end-users.

Keywords: crisis management, collaboration, innovative technologies, decision support system

1. INTRODUCTION

After the enhancement of individual coordination solutions, easing the collaboration among actors involved in a crisis scenario is a significant challenge, as introducing new digital information can invade a crisis manager's usual approach. While discussing our product with end-users (such as actual crisis managers), we observed that all shared information currently converges fairly easily towards several digital devices that combine various data. The multiplication of information and communications technologies allows users to select the best available solutions for their individual challenges. However, this heterogeneity creates a steep hurdle for collaboration. Indeed there is still much more work to be done in order to arrive at the theoretical workspace where each actor can share information with collaborators regardless of compatibility issues. This paper introduces an overall solution to dealing with widespread issues of flexibility, whilst building on the analysis of crisis management requirements.

As described in Manuel Zacklad (2010), cooperative work is essentially defined as the output produced in common by several actors engaged in individual activities. Thus, the final challenge is definitely to raise a genuine interest from heterogeneous experts in terms of user experience, but also in terms of effectiveness with regard to their professional objectives. Several attempts have been made to achieve this objective, such as the framework for disaster response process management (Franke and Charoy, 2010). This framework provides support for modeling, execution, monitoring and cross-organizational aspects of disaster response processes. Another example, this time in the field of medical research, is the Multi-Knowledge project. This project validated a collaborative IT platform for knowledge management, allowing a geographically dispersed group of researchers, dealing with different data sources as well as dissimilar technological and organizational contexts, to seamlessly create, exchange and manipulate new information (Amoretti, Zanichelli and Conte, 2008).

In the crisis management process we are dealing with, the platform does not attempt to directly address the monitoring or the management of crises, but is instead designed to support communication during a crisis. Unique to this project is that it is not limited to previously defined, specific types of data or applications, but also includes a strategy for unexpected content. The design of this platform has been entirely conducted with the supervision of end-users, i.e. crisis managers, firemen, policemen, and civil security employees. This flexibility, also called malleability (Thomas Herrmann, 2008), is critical in ensuring the long-term use of a new solution in the ever-changing field of crisis response.
After introducing the crisis management process within which we devised a new collaborative solution, this paper presents the actual solution both in terms of hardware and software, as well as a final overview of the feedbacks we gathered from several workshops with civil security experts.

2. CRISIS MANAGEMENT AS A COOPERATIVE PROCESS

2.1. Challenges to contemporary crisis management

These days, crisis managers are faced with increasingly complex crisis management tasks. Beyond the notion that the frequency, nature and consequences of crises and disasters have changed, the increased interconnectedness of our modern day world inherently causes crises and disasters to – directly or indirectly – play out differently (Boin, 2009). That is, today's crises, more than before, are spanning multiple jurisdictions, undermining the functioning of multiple sectors and infrastructures at once, while escalating and evolving rapidly along the way (Ansell, Boin and Keller, 2010). In dealing with a transboundary threat and the urgency and uncertainty it brings, the need for a "response system that can reach across boundaries and bring together available capacities in an effective and timely manner" (Ansell, Boin and Keller, 2010) is thus ever more pressing.

2.1.1. Crisis management as a cooperative process

Crisis management is indeed a collaborative process among available capacities. The stakeholders in a joint crisis response generally concern parties from the operational disciplines (e.g. on-scene police officers, firefighters and medical teams) up to the tactical (lower-level, on-scene command) and strategic levels (higher level, remote decision-making).

2.1.2. Arriving at a Common Operational Picture

Ensuring an effective multilateral crisis response, a "uniform picture of the events" (Boin, Hart, Stern and Sundelius, 2005), among all levels involved is indispensable. However, this shared understanding, generally referred to as the Common Operational Picture, is hardly self-evident. To make sense of a situation and decide on actions accordingly, crisis managers often bring together information on flip-overs, whiteboards, and other helpful but somewhat outdated tools that prevent real-time integration and consolidation of all the available information. Moreover, the process of arriving at a Common Operational Picture is often inhibited by challenges pertaining to, for example, the limited interoperability of systems and organizations, and the multitude and diversity of information streams.

2.2. An integrated multidisciplinary operational picture

Given the slow speed and limited adequacy of information processing, cogent signals risk being overlooked. Therefore, a system that helps crisis managers overcome these challenges and facilitates the emergence of an integrated and multidisciplinary operational picture truly adds value. Yet, to facilitate such a process towards a Common Operational Picture, a few essential requirements must be fulfilled

2.2.1. Requirements

In a state-of-the-art study of existing crisis management systems, the E-SPONDER project team researched these essential requirements. Results showed that for a tool to facilitate improved sense- and decision-making in times of crisis it should, for instance, at least comply with demands of user friendliness and interoperability of components, while having the ability to gather data from different information sources and to access data and systems through a single application. In other words, intuitiveness, practicality and the capacity to share among and connect with multiple disciplines are essential in a multidisciplinary operational picture. The Collaborative Solution, developed as part of the E-SPONDER project, aspires to meet these challenges. The following section outlines how this will be achieved, and with what applications and functionalities.

3. COLLABORATIVE SOLUTION

Building on these requirements and observations, our goal was also to cope with the daily constraints imposed by the Emergency Operational Centers' (EOC) physical environments, into which we wanted to bring the Collaborative Solution. Our priority was indeed to focus on the development of a fully operational system rather than experimenting with elaborate functionalities

3.1. Functional specifications and environmental constraints

One feature the users indicated as very important is the flexibility of the system and its capability to flawlessly integrate with the current habits of each user. While the strategy of innovation is often to suggest a revolution of tools, the source of this platform is to suggest a transparent evolution of the existing processes that make digital information available without requiring the learning of new, complex tools. In line with this idea, the challenge was to design a collaborative workspace where people could use their own device (e.g. computer, laptop, tablet) and share their own content while still using the multi-touch screen of the platform to visualize, consolidate and annotate any kind of information (e.g. 2-D, 3-D, text, image, multimedia, web). This meant providing users with the capability to:

- Share and combine various content by sending thumbnails of files from their own device to the shared space;
- Manipulate, organize, aggregate and duplicate the data that has been sent on the shared space with simple and efficient gestures;
- Add graphical and textual information on the collaborative surface;
- Allow for group discussions with the support of shared content, while having the capability to enrich this information with further annotations.

In addition to these features focusing on the users' inputs, the platform should also allow them to exploit the outputs from the collaborative exchanges. This therefore means the capability to:

- Export decisions to one's personal computer;
- Activate automatic local or distant archiving;
- Save important steps or conclusions;
- Drag and drop content in a report, e-mail or database.

Our research showed that no available solution existed that covered each of these requirements. Among existing software, none of them ensures the flexibility with regard to profiles and the number of users, the compatibility with many file formats, the naturalness and efficiency required to exchange and manipulate digital content in real-time, and the environmental considerations such as light and congestion

3.2. Hardware constraints and features

Figure 1: Modular multi-touch device

The platform's core is a 55'' multi-touch screen displaying the Common Operational Picture (Figure 1). Relying on the latest projected capacitive technology, the system allows several users to use the system in any environment, thus meeting the expectations about the low light sensitivity that was defined as critical. Furthermore, our studies showed that a screen size of between 46'' and 55'' seems to be the best choice for small group interactive sessions. A larger size would strongly decrease the spatial resolution, view angles and reachability when used in a horizontal orientation, while choosing a smaller size would reduce both the screen and the space around the table.

Touch input has been selected as the technology of choice for interaction. It is now well known that a well-supported touch input can greatly increase user confidence and interaction speed with the system (Mauney, Howarth, Wirtanen, and Capra, 2010; Sears and Shneiderman, 1991). This is especially true when the system is used to mimic the way actual users would interact with the real counterparts of digital objects, which is exactly the case with crisis management. That is, in managing the crisis response the actors involved are constantly manipulating paper maps, writing notes, and sticking paper notes or pictures onto whiteboards in order to create a shared understanding of the events. Nevertheless, multi-touch input is increasingly more common to crisis managers, as they are used to and attracted by such technology, provided the system works in the exact same way they expect it to work. Finally, multi-touch technologies enable several users to interact with the system simultaneously. Touch input is critical in such a collaborative situation not only to interact with the system, but also for other users to see, follow and understand what their colleagues are doing.

The projected capacitive technology is especially reliable as it ensures sub-millimeter touch precision at 1920 x 1080 HD resolution with near-zero parallax. Having their fingers directly touching the digital content, with close to zero space between the real and physical object, allows inexperienced users to focus on the management tasks without the disturbance of awkward technology. Finally, the ultra-low latency touch response also ensures a user-friendly experience (i.e. a 120 Hz frame rate for display and touch sensor). While this feature is not mandatory for the system to fulfill the users' requirements, it definitely adds to the system's performance and experience.

Outside lighting is not a constraint, as the platform is designed as a mobile and modular system in order to be easily moved and re-positioned. Users identified this solution as useful for briefing or debriefing with a small group or in front of a large team. For these reasons, the screen is mounted on a modular stand allowing users to switch between horizontal or vertical positions with an electronic command: table mode, tilt mode and wall mode (Figure 2). More generally, the design of the platform is aligned with ergonomic studies to ensure an efficient integration of this solution in a daily working environment.

Figure 2: Pictures of Collaborative Workspace prototype during E-SPONDER review or during LAVAL VIRTUAL 2014

3.3. Collaborative platform features

Figure 3: Pictures of Graphical User Interface supporting the Collaborative Solution

The Collaborative Solution is an integrated interactive platform designed to address processes and decisions requiring interaction among actors of all levels during a crisis. Crisis management, as a typical collaborative process, is used as a guideline to specify the components of this platform. The Common Operational Picture is the focus of the platform since it represents the pool of information that must be displayed, compared, enriched and discussed during the crisis response. The challenge of research related to this platform was that it simultaneously addressed common features such as reliability, intuitiveness, and user-friendliness, and ensuring the flexibility needed by the uniqueness of every crisis event. Indeed, Emergency Operational Centers (EOCs) can be installed in small rooms, in a large location or open landscape, outside or inside. An EOC is commonly used during crises. For example, the majority of airports have their own center.
Moreover, resolving a crisis can require sensitive data. For security reasons, one specification of this platform is to provide a session system and an automatic back up directory ensuring the protection of the content involved in each crisis. Once users have logged in, they can easily integrate their files into the Common Operational Picture from an external mass storage device if users have no personal devices. The compatibility is in line with all needs emerging from field requirements: images, pdf, video, office, 3D, and web content. Users can also upload and download all content on the interactive table with a memory stick or any mass storage device. Thus, they can intuitively organize documents on the common picture, and add comments using annotation tools and a post-it tool.

As illustrated in Figure 4, the design of the platform has moreover been studied to best forge a common view between several users with several data files and several kinds of personal devices.

Finally, to take advantage of the hardware capabilities, especially in terms of high precision and frequent multi-touch input, special care was taken when designing the interaction techniques. Indeed, while some people will use one or two fingers to gently interact with the application, others will use both their hands and perform gross gestures while expecting the same result. We therefore developed generic interpretation techniques of the multi-touch input that do not strongly rely on the number of fingers on the content, and took into account the frequent lifting of some fingers that would otherwise affect the device's use.

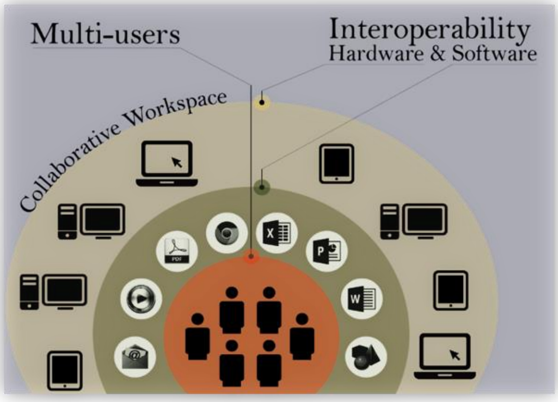

Figure 4: Schematic representation of the flexibility of the Collaborative workspace

From a personal device, a user can connect to the platform via WIFI network and share files instantly with a 'drag and drop'. In order to guarantee confidential requirements and hence avoid inadvertently sending critical files, users can just send a screenshot from their personal screen. In other cases, users can directly share their screen with other off-site collaborators. These features ensure a flexible experiment during briefing sessions regardless of technical specificities. Regarding debriefing, the requirement was to be able to grab the result of common reflections and decisions. The collaborative platform therefore allows user to grab the content from the Common Operational Picture and transfer it to his or her personal device, thereby producing reports in real time

4. FEEDBACK AND FUTURE WORK

At the end of September, a demonstration session was organized in Athens with end-users from France and the Netherlands. During this milestone event, end-users tested the solution and provided their feedback on the Collaborative Solution. Firefighters and crisis experts were enthusiastic about the multi-touch table and its quality of interaction. The initial desire to create this solution as a transparent layer easily supporting all interactions in an emergency center is a success. This transparency allows for movement, flexibility, and adaptation among different modes of interaction, which is necessary for modern systems design. The first contact with the solution was completely natural, as a « physical paper on a traditional table ». As it turned out, training professionals in using the platform would be relatively straightforward. Users have proven to be quickly capable of working with multiple screens, synchronizing content, and exchanging information within a small group or with all collaborators around the table. The interoperability was a crucial requirement especially concerning the Common Operational Picture from the field. Actually this picture is traditionally a map including the geographic information required to get an overview of the situation. An interesting asset of the Collaborative Solution is its ability to extend the Common Operational Picture with other types of information, including non-geographic details.

Globally, end-users have seen the added value of the Collaborative Solution for crisis management. At this point the platform meets all critical requirements. Nonetheless, in addition to all positive points, end-users provided feedback for final improvements. They stressed the importance of the data backup process in crisis context where electrical issues could emerge. They also stressed the protection of user's data as these could be top-secret documents. And finally, they noticed that improvements could be made concerning the ergonomic features of the interactive table (e.g. a space for storing users' personal belongings).

In addition to those in crisis management, professionals in other fields have used the system. According to interviewed architects, the system allows users to have a more concrete vision of their project, and thus be in a position to validate hypotheses, and prevent and avoid mistakes. Working around technical plans and all data describing the project also proved to be critical for the strategy board, design review, brainstorming, and commercial presentation. Finally, the system has also been approved for formation by allowing trainers to involve learners, facilitate their learning and boost training efficiency (Figure 4). This early feedback highlights critical challenges of this kind of platform that goes beyond the framework of this paper. Yet crisis management seems to be a pertinent case to build an interesting list of requirements for collaborative processes.

Figure 5: Pictures from users' sessions: architectural firm (Bastia), Microsoft Technology Center (Paris), aeronautics formation center (Bordeaux)

5. CONCLUSION

This paper briefly introduced the Collaborative Solution, developed partially in the E-SPONDER project as a solution for crisis managers and the challenges they face. This solution aims to address issues of collaboration in a work session with a group of experts coming from different professional fields. During these sessions, all of them have to share digital information with all compatibility issues. This solution is the result of theoretical and technological studies in order to produce a professional solution that could be installed tomorrow in an Emergency Operational Center. Given the fact that the platform may be used in sensitive (information) environments, special precautions have been taken with regard to the setup of the system and its flawless integration in preexisting workflows. As such, the flexibility of this system in terms of inputs/outputs ensures its use without any major upheaval or break in current processes, while specific enhancements have been highlighted to further enhance the solution integration within daily processes.

Finally, the system will be even more strongly tested during field tests with real scenarios and a large audience of professionals. One exercise, for example, is planned at Amsterdam Schiphol Airport in the Netherlands. The main outcomes of the E-SPONDER project will be presented in 2014. More information regarding the activities organized as part of the E-SPONDER project can be found on the project's website: www.esponder.eu.

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UNDERSTANDING SECURITY POLICIES IN THE CYBER WARFARE DOMAIN THROUGH SYSTEM DYNAMICS

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ABSTRACT

In this paper we deal with the analysis of the Italian Presidential Decree on CyberSecurity (January 2013). Reading it, we had the impression that, again, policy makers lack systemic skills and the ability to evaluate the impacts of their choices and assumptions before implementing their decisions. The Italian Cyber Security Act (DL.2013) establishes, in case of cyberthreat to national security, to activate the Inter-Ministerial Committee for the Security of the Republic (CISR), which should take decisions in a timely and effective manner. In this paper, we won't argue about the effectiveness of such board, which would have to be discussed by analysing both the specific competences brought to the Board by the various official stakeholders and by the processes put in place in order to favour the work carried out by such Board, rather we will discuss the inherent delays in the system ultimately made even worse by the need to activate such Board for certain critical decisions.

Keywords: Cyber Security, Cyber Warfare, Homeland Security, System Dynamics

1. INTRODUCTION

Every economy of an advanced nation relies on information systems and interconnected networks, thus in order to ensure the prosperity of a nation, making cyberspace a secure place becomes as crucial as securing society from the presence of criminal bands. Cyber security means ensuring the safety of this cyberspace from threats, which can take different forms. Stealing secret information from national companies and government institutions, attacking infrastructure vital for the functioning of the nation or attacking the privacy of the single citizen can all be seen as extreme examples of a large spectrum of threats. Additionally, perpetrators of attacks on cyberspace are now professionals working for governments, hacktivist organizations or criminal bands rather than teenagers looking for some short-term celebrity as it was in the old days. Intelligence operations are conducted through cyberspace in order to study the weaknesses of a nation and, to complete the picture, in the military domain cyberspace is now seen as one of the dimensions of the battlefield just like space, sea, ground and air. Understanding the complexity of the picture of making cyberspace a safe place turns out to be a problem, which is not only technical but rather a social, legal and economic one. Improving cyber security knowledge, skills and capability of a nation will be essential for supporting an open society and for protecting its vital infrastructures such as telecommunication networks, power grid networks, industries, financial infrastructures etc. (CIS Sapienza, 2013).

Each countries' critical infrastructures (from oil pipelines to the electricity grids, from gas to water, from transportation, to financial/banking systems, to public services) is becoming managed at an IT level in an increasing way. The massive and progressive introduction of network, monitoring and control systems has improved the performance level of such infrastructures, but has also introduced new ways (cyber) for criminals to carry out their misfits. Today, an effective infrastructures protection includes threat identification, vulnerability reduction and attack source identification, thus aiming at service downtime minimization and damage limitation.

The expression "cyber threat" denotes the set of behaviors that can be carried out in and through cyberspace. It mainly consists in cyber attacks, that are actions of individuals, states or organizations, aimed at destroying, damaging or interfering with the proper functioning of systems, networks and related processes, or at violating integrity and confidentiality of data/information (CIS Sapienza, 2013).

Depending on the actors and purposes, we can distinguish the following types:

- Cybercrime: all the activities with criminal purposes (such as, for example, fraud or wire fraud, identity theft, the misappropriation of information or of creative and intellectual property);
- Cyberespionage: unlawful acquisition of sensitive property or classified data or information;

• Cyberterrorism: the set of ideologically motivated actions, aimed at influencing a country or an international organization.

Typically, a cyber attack is launched:

1. to paralyze one or more critical infrastructures' activities;
2. to steal infrastructures information assets.
3. To cause a cyber war, a real conflict between nations that aims at paralyzing their respective vital sectors (when targets are critical infrastructures and warning systems, it is clear that the consequences for the entire society could be disastrous).

It is important to identify in advance which are likely to be possible targets of an attack so to assess the related risks and consequences, also in terms of time required to restore normal behaviour (resilience). Cyber threats are important challenges for the country, because they involve both the digital domain and because of their transnational nature. Cyber threats are not easy to counter: the actors, means, objectives and attack techniques vary continuously.

In light of the above and of the awareness that this is a continuously changing environment, it is urgent to intervene, at the national level and beyond, against all cyber crime forms, which represent a growing threat to critical infrastructure, society, business and citizens (CIS Sapienza, 2013).

2. LEGISLATIVE CONTEXT AND RESEARCH QUESTIION

In this paragraph we will briefly introduce the legislative context that ultimately brought us to consider posing our research questions.

Two main regulatory measures, adopted in Italy between 2012 and 2013, contribute to defining the organization and strategy for Italy's national cyber security. Law n.133/2012 and the DPCM (Decree from the President of the Ministries Council) dated 24 March 2013.

Law 133/2012 attributes new and more detailed responsibility in the field of national cyber defence and security to the Italian intelligence system. For instance this law gives the prime minister the power to issue directives to the Intelligence and Security Department (Dipartimento Informazioni per la Sicurezza - DIS), after prior consultations with the Inter Ministerial Committee for the Security of the Republic (CISR), and to the security intelligence services, in order to strengthen security intelligence activities for the protection of critical infrastructures, with particular reference to national cyber defence and security.

The DPCM 24 January 2013 defines the institutional architecture tasked with safeguarding national security in relation to critical infrastructures and intangible assets, with particular attention to the protection of cyber security and national security. It indicates the tasks assigned to each component and the mechanisms and procedures to follow in order to reduce vulnerability, to improve risk prevention, to provide timely response to attacks and to permit immediate restoration of the functionality of systems in the event of crisis.

It is worth mentioning the setting up of a so-called Nucleus for Cyber Security (Nucleo per la Sicurezza Cibernetica) within the Military Adviser's Office. It is a permanent body responsible for maintaining links and coordination between the different components of the institutional architecture involved in various capacities in the field of cyber security, in accordance with the powers conferred by law to each of them. Members of National Intelligence, Ministry of Internal Affairs and Foreign Affairs, Ministry of Defense, Ministry of Economic Development, Ministry of Economy and Finance, Civil Protection and the Digital Agency are part of the Nucleus for Cyber Security. The nucleus was established to support the prime minister in all activities concerning the prevention and/or preparation for a possible crisis and the activation of warning procedures. The nucleus, among other activities, will:

1. Promote the planning of the response to crisis situations by both government and private stakeholders and the development of all necessary procedures for inter-ministerial coordination, fitting in with the schedules of Civil Defense and Civil Protection;
2. assess and promote procedures for information sharing, including with private stakeholders, for the dissemination of alerts relating to cyber events and crisis handling;
3. promote and coordinate cybersecurity exercises, both Inter-Ministerial and at international level, involving the simulation of events.

In order to handle a crisis event in a coordinated manner, the decree assigns to the NISP the role of Inter Ministerial Cybernetics Crises Table. The inter-ministerial body is chaired by the prime minister's military advisor and will include representatives of all the institutions involved. It will ensure that the response and the appointment of the various departments' and agencies' responsibilities, in relation to cybernetic crisis, are performed in a coordinated manner. The decree, furthermore, establishes a strict collaboration between the Inter Ministerial Cybernetics Crisis Table and the national CERT (see next section) in order to deal with all technical aspects in elaborating emergency responses. (CIS Sapienza, 2013)

Thus, the rationale of this paper finds its roots in the analysis of the Italian Public Presidential Decree of Law on Cyber Security, dated January 2013 namely "Direttiva recante indirizzi per la protezione cibernetica e la sicurezza informatica nazionale" (Dec. PCM, 2013).

By reading such D.L., we got the impression that, again, policy makers lack both systemic skills and nonetheless the ability of being able to evaluate the impacts of their choices and assumptions (ultimately turning into the application of a law and thus into money spent, choices done, people moved around, etc.) before implementing their decisions. The Italian D.L.

Sec. 2013 (DL.2013) basically focuses the attention on the possibility, in case of national security put under threat by a cyber menace, to recur to an inter-ministerial working group (Inter-Ministerial Committee for the Security of the Republic - CISR) which, in case of deep crises, should be able to take decisions in a timely and effective manner. In this paper, we won't argue about the effectiveness of such Board, which would have to be discussed by analysing on one hand the specific competences (if any) brought to the Board by the various official stakeholders and on the other by the processes put in place in order to favour the work to be carried out by such Board, rather we will argue about the inherent delays in the system ultimately even made worse by the need to activate such Board for certain critical decisions.

3. GENERAL A SYSTEM DYNAMICS MODEL TO GET INSIGHTS ON THE CYBER SECURITYAND CYBER WARFARE DOMAIN

A computer emergency response team (CERT) can be defined as an organization responsible for setting up a framework for responding to cyber security incidents. It provides the necessary services for handling incidents and supports its constituents in their recovery from breaches of computer security. In order to mitigate risks and to minimize the number of required responses, many CERTs also provide preventative and educational services for their constituents. More recently the term CSIRT, which stands for Computer Security Incident Response Team, is starting to replace CERT. It invokes a more holistic approach to security rather than relying only on reactive forces. CERTs worldwide are generally founded and financed by governments or academic institutions. The reason for this is that government agencies are interested in protecting national security and universities by their very nature try to find solutions to new problems. Historically, the name Computer Emergency Response Team is the designation for the first team at Carnegie Mellon University (CMU). CERTs existence is linked to malware, especially computer worms and viruses. After the Morris Worm paralyzed a good portion of the Internet in 1988, CERT/CC at Carnegie Mellon University was started under a US government contract.

To respect the indications of EU Directive 140/2009 and to achieve the target fixed by the European agenda, in several EU member states, governments have set up the so-called National CERTs. The main goal of a national CERT, from a cyber security perspective, is to protect national and economic security, the on-going operations of a government, and the ability of critical infrastructure to continue to function. Therefore a national CERT typically monitors incidents at a national level, identifies incidents that could affect critical infrastructure, warns critical stakeholders about computer security threats, and helps to build organizational CERTs in the public and private sectors (CIS Sapienza, 2013).

We will start our analysis by setting up a possible preliminary scenario (to be validated by eventually specializing the model to a real-case scenario in this area) where there are several generic attacks that are being carried out against a certain nation and where the national CERT acts in defence by monitoring incidents and trying to contrast them in order to mitigate the extent of the overall damages.

The purpose of the model is thus to analyze the impact of some cyber attacks on national defense system and the way the latter responds to such attacks.

The main process that will be modelled includes the arrival of some cyber attacks (Incoming Attacks) , according to a stochastic Poissonian distribution. All the attacks will be considered of equal weight in terms of damage caused. Once started (Started Attacks), they are discovered in time thanks to the allocation of specific resources for this task of detection (detection Rate), which is a function of the "Capability to Detect attacks". It is, in turn, the mathematical product between the number of "resources for detection" and the "detection Productivity". Attacks that are not detected (Undetected Attacks), a simplified function of an "average percentage of non detected", are still effective at the level of damage caused and may be rediscovered in time (re-discovery rate) or ending their life cycle (Max Attack Duration) having never been detected (Undetected non-mitigated), since, for example, the attack has completed his mission.

The rate "Undetected Attacks going unmitigated", as seen in Figure 1, depends on an average of time duration of the attack (Max attack duration AVG). In this sense, the greater the duration of the attack in time, the lower the number of attacks that pass in the state "non-mitigated".

The "detected attacks", in turn, will be contrasted (mitigation rate), by using some resources (Capability to Mitigate Attacks, in turn a function of the mathematical product between the resources dedicated to the mitigation and the resources productivity). In this way, Mitigation resources try to mitigate attacks and therefore to limit the attacks damage.

However, we have assumed that some of the detected attacks, cannot be mitigated (see Figure 1), so at the end of their life cycle (Max Duration of Attack) they finish their share of damage and disturbance (not mitigated).

Each "active" attack, in any state of the system (Started, Detected, Undetected, etc..), produces a certain amount of 'effective' damage (Max Damage for Attack) during its life cycle (Max Duration of Attack) (again, Figure 1).

Among the initial hypotheses of the model, we will assume as directly estimated the damages that the observer would expect as a cause of the detected attacks in progress (Expected Damages).

However, the discrepancy between the "Effective damages" to infrastructures (i.e., the amount of damage that can be observed) and the damage that the observer would expect is an information quite relevant to the job of threat contrast: in this way, if the damages that the structures received, are bigger (over a certain threshold) compared to those that would be expected from the detected attacks, then there must necessarily be some attacks that were not detected and that are producing damages unnoticed. The estimation of threat severity (threat of Effective severity ratio) calculated as the ratio of actual damages (Effective Damages), and estimated damage from attacks detected (Expected Damages) is a determining factor of acceleration in the process of acquisition of resources which can be allocated either to the detection or the contrast of the attacks. (see Figure 1).

Among the initial assumptions, we expected in normal circumstances that there is a certain amount of resources dedicated to the one side on detection process (Active resource for detection) and to the other side on mitigation process (Active resource for mitigation) of cyber attacks. As described above, the model provides a self-regulating mechanism whereby if detection or mitigation resources are not able to handle an unexpected peak in attacks, resources are acquired from outside (Resource Acquisition).

But the process of acquiring resources from the outside, obviously requires time (Acquisition process delay time) (Figure 1)

4. RESULTS, DISCUSSION& FUTURE WORK

We have simulated our model with the following assumptions and initialization values (unit: 1 hour):

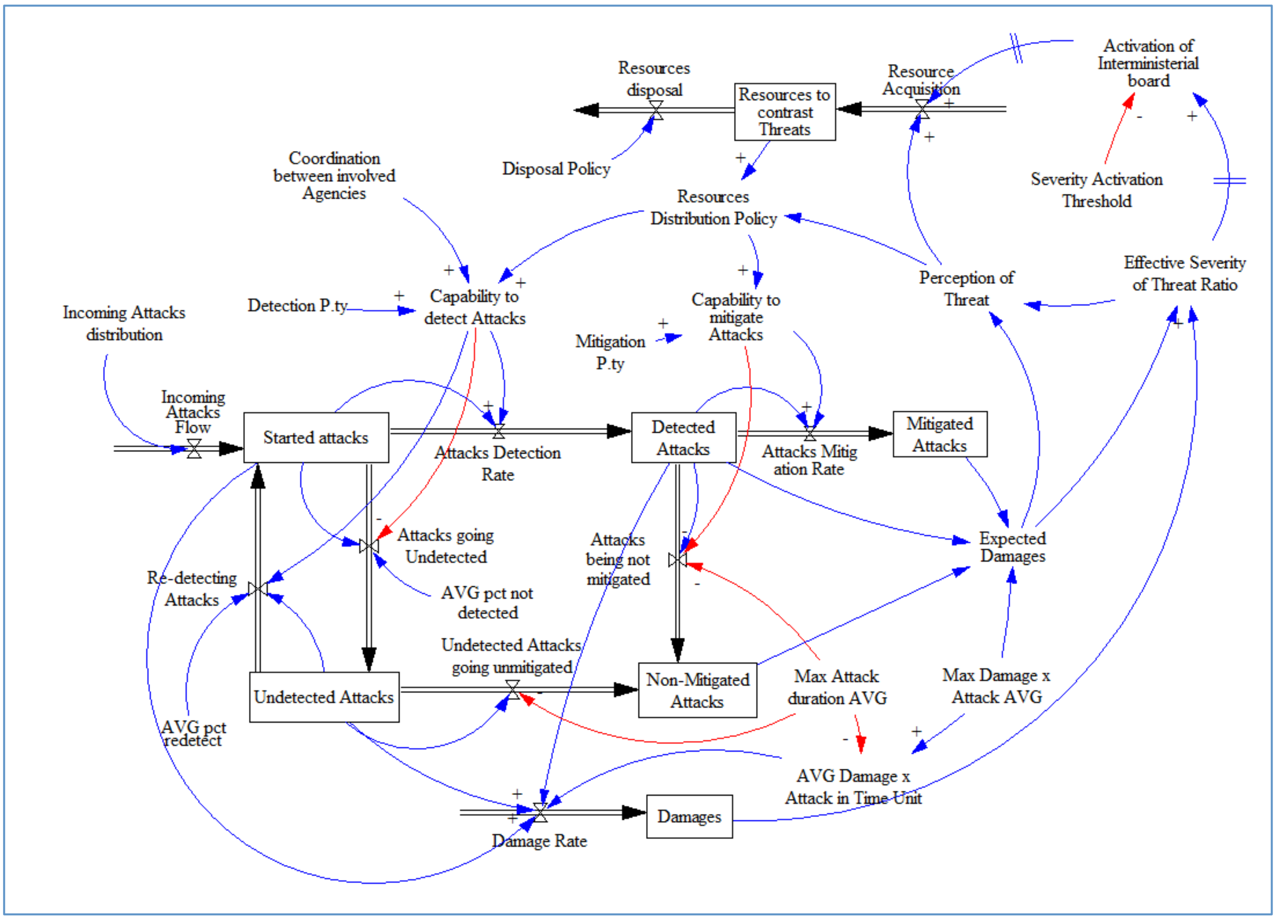

Figure 1: Resource Distribution Policy

- Attacks_Increase = STEP(Offensive,168) - STEP(Offensive,336)
- Acquisition_process_delay_time = 72+(Activation_of_Interministerial_board*96)
- AVG_pct_not__detected = 0.1
- Delay_in_Activating_the_board = 24
- Incoming__attacks_distribution = poisson (Mean_of_attacks+Attacks_Increase)
- Max_Attack_duration__AVG = 96
- Max_Damage_x__Attack_AVG = 10

- Mean_of_attacks = 20
- Offensive = RANDOM (100,150)
- Severity__Activation__Threshold = 2
- Std_Detection_Pty = 6
- Std_Mitigation_Pty = 3

From Figure 2, we notice that we have the desired increase in the number of average attacks after the first week of simulation, which structurally brings, due to the new desired values for resources in detection and mitigation, to a growth in the related rates.

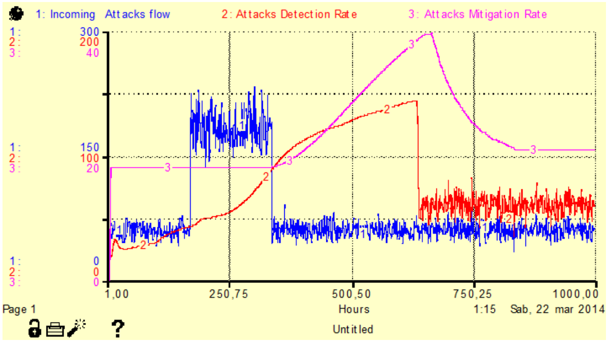

Figure 2: Attacks flow rates

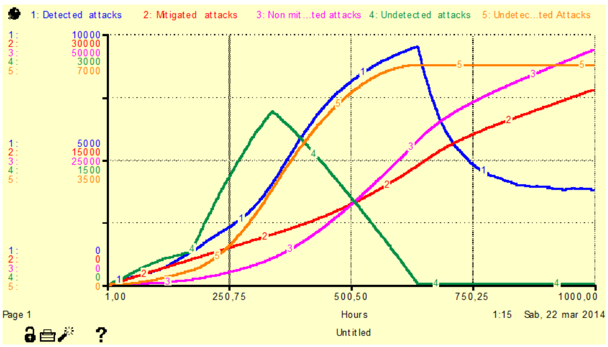

Figure 3: behaviors of "attacks" stocks over time

From Figure 3, we can notice that the backlogs are somehow managed over time thanks to the growth in resources contrasting (detecting and mitigating) the attacks.

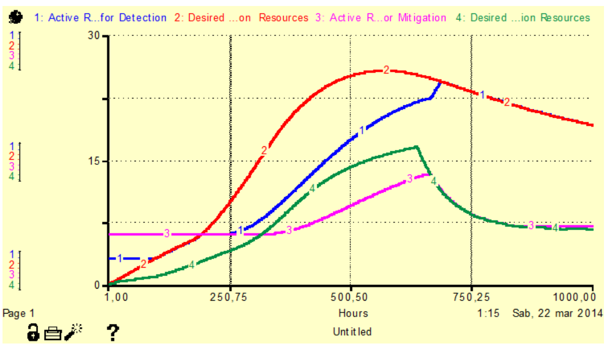

Figure 4: behaviors of resources dedicated to detection and mitigation

From Figure 4, we see that the model gives priority to detecting attacks as at a certain moment, there is a clear perception that the Nation is under attack but the CERT cannot correlate the damages they experience to a real threat that they recognize (so priority is given to detection so to be able to "empty" earlier the Started and Undetected Stocks, which contribute heavily to procure damages "unseen" in the first moments of the simulation.

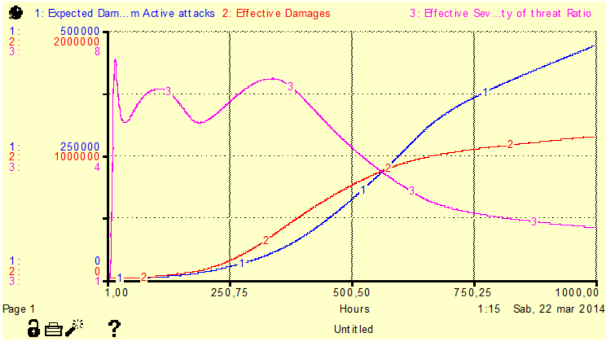

Figure 5: Effective damages vs. Expected Damages

We can see that the Effective Severity of Threat is quite high at the beginning but then decreases as the "unseen" stocks get emptied out over time (Figure 5)

As a final remark, we are obviously still in the tuning phase of our model but we can see the promised potential for understanding the structure of attacks and response to a cyber menace.

From the above results, we can only have a partial conclusion which tells us that the model seem to behave correctly but a more accurate tuning phase, a sensitivity analysis and more structured approach to experiments will be able to tell us more in the near future (possibly by the upcoming conference in summer).

In future developments, in order to provide a way to measure the effectiveness of the response of an organization (i.e.: a CERT) to a cyber threat, we will introduce in the some KPI's that are interesting to consider (5), and namely what is called the cyber security readiness index, which is a composite measure of the capacity and willingness of an organization to face cyber threats.

It consists of the composition of the following KPIs:

- Awareness index: Assesses the situational awareness related to cyber risks of the organization;
- Defense index: Assesses the capacity of an organization to protect itself from a cyber attack. Notice that the defense index is somehow correlated with the awareness index, since the implementation of strong defence mechanisms shows cyber security awareness;
- Policy index: Assesses the implementation of security related policies. A high score in this index shows compliance to several security policies and their constant update. There is a strong correlation of the policy index with the awareness index since the adoption of updated security policies show an increased awareness;

- External independency index: Assesses the correlation between internal systems and external providers. A low score on this index shows the correlation of the organization mechanism to external providers since the fault of an external cloud provider could impact on its possibility to deliver the core product of its business. A high score on this index shows an organization that relies minimally on external services that could impact on its security. Note that such high scores imply larger operational costs as the organization has to insource software services without the involvement of third parties.

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MODELLING INTERDEPENDENT URBAN NETWORKS IN PLANNING AND OPERATION SCENARIOS

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ABSTRACT

We propose a cross-domain methodology to model and evaluate efficiency indicators of a Medium Voltage/Low Voltage (MV/LV) smart grid and its SCADA, interdependent, at physical layer and ICT layer, with water and gas urban networks. Models account the interdependency among the networks, a) adding, when possible, to the main sources of each network, sources belonging to the other networks; b) looking at the active components of water and gas networks energized by the electrical grid and c) considering ICT, which represents a common means, supporting and interconnecting SCADA devices of all the networks. Models use domain simulators to faithfully represent each physical network, and transversal simulators, to represent together the three interdependent physical networks and their SCADA systems. Models built by domain simulators are used to validate models built by transversal simulators. Efficiency indicators, and particularly, the Quality of Service of each network, are predicted along planning and operation scenarios.

Keywords: smart city, smart grid, gas network, water network, energy efficiency, interdependency models, SCADA

1. INTRODUCTION

Modernized urban networks will constitute the backbone of Smart Cities. They will ideally enable the integration of small distributed generation sources and will increase the customers awareness, providing real time optimization of network flows at the urban level, enabling interdependence and facilitating a multi services approach. They will strengthen the links among the electricity carrier and gas, water and ICT infrastructures. Increased use of SCADA (Supervisory Control And Data Acquisition) ideally improves reliability, security, and efficiency of modernized urban networks through a dynamic optimization of urban network operations and resources. Modernization of urban networks is a big long term challenge, for social, economical and technical reasons and it is far away to be realised. An extensive use of models at adequate level of granularity are needed to support such a modernization process (Johansson, 2010). Models have the aim to investigate the Quality of Services (QoS) delivered by each network to customers and citizens.

This paper proposes an cross-domain methodology to represent and evaluate the QoS of interdependent urban smart grid, gas and water networks and their SCADA (Supervisory Control And Data Acquisition), along the phases of planning and deployment of each modernization solution and along the phase of network operation. Planning and operational models, other than physical networks, have to include SCADA that constitute the nervous system of each network, network interdependencies (at physical, geographical, cyber and ideally at organisational levels) and have the aim of predicting QoS and efficiency degradation due to natural, technological and malicious adverse events (Ciancamerla, 2011).

The methodology, the first models and their results will then extended and instantiated on the modernization of the urban networks of the city of Catania, within the MIUR funded research project SINERGREEN, as a mean to evaluate the efficiency of a Medium Voltage/Low Voltage (MV/LV) smart grid interconnected with to water and gas networks. Such models will ideally provide knowledge and algorithms to feed a near real time decision support system for urban network utilities, l utilities of local generation sources, customers, local authorities and regional Civil Protection.

2. MODELLING APPROACH

To build consistent models, we assume a scenario, which includes the three urban networks, with the following minimum requirements: a) a minimal topology of each physical network, that allow to investigate solutions of local generation, load shedding, detection of natural, technological and malicious contingencies and their mitigation, by means of network reconfiguration performed by its SCADA. The topology consists of two (electricity, water or gas) feeders, each one feeding its subnet. In normal operative conditions the two subnets are separated one each other by two two Normally Open Tie switches. Each subnet delivers the physical flow to different (public, commercial, industrial) types of loads/passive customers network by means of physical trunks, connected one each other by Normally Close flow breakers. Local generation sources (such as photovoltaic, gas co-generator, mini- hydro and bio-methane sources) and storage devices (i.e. electrical batteries, water and gas tanks) are also connected to the network, Tie switches, flow breakers and protection breakers at feeder, are remotely controlled by SCADA. SCADA, by means of its Remote Terminal Units (RTU) which monitor the status of the physical network, implements load shedding, network reconfiguration upon contingencies (Bobbio, 2010); b) a minimal SCADA, which includes RTUs to monitor and operate the network ; c) indicators of network efficiency and QoS.

Starting from the above requirements, the first models of smart grid, water and gas urban networks and their interdependencies are implemented, at the adequate level of granularity and abstraction, also in presence of contingences by means of an advanced simulation environment, as shown in figure 1. The environment is constituted by: i) specific domain simulators and transversal simulators, based on equations domain, able to generate data and status of the physical layer of each urban network, plus ii) event based simulators which may properly represent SCADA functionalities and network operational layer and iii) a contingency generator to inject natural, technological and malicious adverse events in networks and SCADA models.

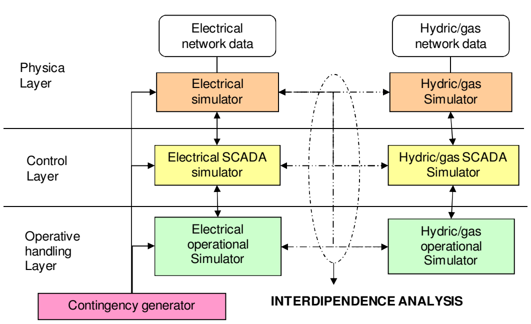

Figure 1: Simulation Environment

Each urban network model is under construction, starting from a basic network and adding devices and functionalities in incremental way, to include local generation sources and reconfiguration strategy. Models intend to predict efficiency and QoS of each network , from the point of view of the network public utility, utilities of local generation sources, local storage and passive customers. Models are built in two steps: i) to represent the physical networkand its SCADA as an isolated network and then ii) to represent its interdependencies with the other two nets. At this stage, we are representing, in an incremental way, into the models: a) local electricity sources, such as mini hydro, shared with water network and gas co-generators shared with gas network; b) active components of water and gas network energized by the electrical grid; c) ICT which support and interconnects SCADA devices of each network; d) local gas sources as bio- methane.

2.1. Smart electrical grid : planning & operation scenarios

Table 1 shows the main planning & operation scenarios for the smart electrical grid.

The scenarios reflect the following considerations: i) the integration of local sources may present high variability in producing energy. For instance, solar and wind energy, depending on weather conditions, are intermittent; ii) the high variability of renewable energy requires means to reduce the power imbalance due to the mismatch between the available renewable power and the load.

Table 1: MV Smart Grid Scenarios

Subject	Planning scenario	Operation scenario
MV public utility	Power flow inversion at HV/MV station versus HV network	Power flow inversion at HV/MV station versus HV network
	Thermal overload of MV trunks	Outage due to failure or maintenance & FISR
	Voltage variation over ± 10% of nominal value	Voltage variation over ± 10% of nominal value
	Short circuit currents at the active user nodes	
Renawable source producer	Long distance between renewable plant and MV grid connection point (increased connection costs)	Renewable plant disconnection from MV public utility due to failure or maintenance
		Renewable plant disconnection due to voltage variation over ± 10% of nominal value
Passive customer		Voltage variation over ± 10% of nominal value
		Outage due to failure or maintenance

2.2. Gas network: planning & operation scenarios

Currently, gas network is, and it is managed as, a passive network. The most prevalent topology for gas distribution network consists of a simple mono feeder type branched tree with one-way flow from the first gas Pressure Regulating Station PR (UNI CIG 9167, 2009), to the final gas pressure regulating installation PRI (UNI CIG 8827, 2009). In more complex cases (large urban centers with industrial districts) the number of the first gas PRS s is increased, according to load and pressure requirements and to a proper and optimal network balance. The stations are also interconnected one each other to create a mesh, reconfigurable network (UNI CIG 9167, 2009), (UNI CIG 8827, 2009). On particular conditions or on critical faults, an inversion of gas flow may occur in some sections of the network (even the ones used for network reconfiguration), causing pressure reduction and in some extreme cases even the "extinguishing of flame”.

In near future, European technical standards will regulate the injection of biomethane local production into natural gas distribution networks, within safety, reliability, flow and operating pressure network constraints (D.Lgs 28/2001). Such an innovation will transform the current passive gas networks into active networks, with bidirectional gas flows and will change its planning and operation scenarios as in table 2.

Table 2: MP Gas Network Scenarios

Subject	Planning phase	Operation phase
Gas DSO public utility	Designs network in terms of maximum flow Q_{max} and operating pressure is maintained in the outlet system within required limits.	Monitors and controls Q_{max} and P_{min} within the contractual requirements in any point of network.
	Designs network in terms of safety and reliability constrains.	Verify safety and reliability constrains due to local regulations (annual percentage of network inspected for both medium and low pressure network; annual number of measures of the degree of odorized gas; time responses to emergency calls; number and duration of interruption per consumer; gas flow rate within limits to reduce load losses)
	Gas flow inversion (extinguishing the flame)	Monitors imbalance of the network (normal or emergency contingencies)
Producer (active user)	Connection to the network (specifications in terms of flow Q and pressure P)	Disconnection from the network by the utility in the event of faults or maintenance
Passive User		Must not exceed the contracted flow (Q_{max} per consumer)
		Verify compliance with the minimum contractual pressure P_{min}

Even for the gas network there is a strong demand variability between consumption and supply by the Distribution System gas Operator (DSO). The gas demand is variable according to the season (winter/summer), daily temperatures, the production cycle of industrial users, the demands of electricity and thus presents a consumption profile variable. Instead, the contracts for the import/transport/distribution of gas have limited flexibility with fairly linear trend and constant in time. The physical balancing is concerned with the optimal management of gas flows on the network to ensure the safe and reliable operation based on the actual demand for gas. The main effort for the DSO is to ensure a correct balance for the entire period of operation time.

2.3. Water network: planning & operation scenarios

In our urban water distribution network there are no active users and the water flow proceeds normally from the feeders to the consumers. Undesirable situations may occur and fault scenarios and network reconfiguration should be forecasted in order to limit degradation of water flow to customers and even disruptions of network elements and devices (UNI EN 1074-5:2002). The focus here is efficiency and interdependency, then, water contamination is out of the scope. Table 3 shows the main planning and operation scenarios for the urban water network. Certainly, a proper planning of network maintenance drastically reduces the service outage.

Table 3: Water Network Scenarios

Subject	Planning scenarios	Operation scenarios
Public Water Utility	Interruptions of supply from a feeder due to a failure (breakage or malfunction of network elements)	Network reconfiguration (alternate feeder)
	Avoid speed below 0.5 m/s and the water age greater than 10 hours.	Limitations or loss of service
	Overpressure	- Monitoring and remote control - Speed in the pipes below 1.5 m/s - Avoid abrupt operations that can generate harmful pressure waves
Passive User		Limitations of use or lack of service

Flow parameters have to consider physical-chemical-biological requirements for drinking water (i.e. Legislative Decree no. February 2, 2001, n. 31 et seq.), to avoid speed below 0.5 m/s and in any case the water residence times (age) in the pipes greater than to 10 hours. Also overpressure and consequences: water hammer; permissible tolerance range in according to the manufacturer's specification. Speed in the pipes below 1.5 m/s and avoid abrupt operations that can generate harmful pressure waves.

3. URBAN NETWORKS MODELS

Models of each urban network and its SCADA system are under construction. The jointly representation of the physical infrastructure and of its SCADA system in a single model is not an easy stuff, if one would represent the physical network at a sufficient level of detail to adequately compute its efficiency and QoS indicators. A relevant aspect is model validation. To address model validation, we are using domain simulators which can faithfully represent the physical infrastructure, combined with the use of transversal simulators, such as Matlab and Simulink, which can more easily represent physical network and its control system in a single model. Moreover, Matlab and Simulink may easily represent network interdependencies at physical, logical and geographic levels. Models built by domain simulators, one for each urban network, are used to validate Matlab and Simulink models.

3.1. MV smart grid

For the purpose of model validation, two models of the same basic MV/LV smart grid have been built. Models implement the above minimum requirements:

- two HV/MV substations with their protection breakers,
- a set of users (U),
- renewable generators (G),
- a set of prosumers (generators/users) (P)
- and a Low Voltage backbone, with its own set of U,G,P.

Electrical parameters of grid elements and their values are actual ones, including the ones of photovoltaic sources. Table 4 and 5 report some of them.

Table 4: Transformers Parameters

Transformers	TR CP1	TR CP2	TR PRIV1	TR PRIV2	TR PRIV3	TR DISTR
Avvolgimento	Yyn	Yyn	Dyn	Dyn	Dyn	Dyn
V1n [kV]	150	150	20	20	20	20
V2n [kV]	20	20	0,4	0,4	0,4	0,4
Sn [kVA]	25 000	25 000	630	800	630	400
Smax [kVA]	32 500	32 500	820	1040	820	520
fn [Hz]	50	50	50	50	50	50
Vcc% [p.u.]	13	13	6	6	6	6
Pcc% [p.u.]	0,42	0,42	0,76	0,75	0,76	0,81
Po [kW]	22,75	22,75	0,68	0,80	0,68	0,52
Io% [p.u.]	0,2	0,2	1,8	1,65	1,8	1,9

Table 5: Generators and Loads Parameters

Generator	DC1	DC2	DC3	DC4
P [kW]	400	500	50	20
Q [kVar]	0	0	0	0

Load	C1	C2	C3	C4
P [kW]	500	500	50	50
Q [kVar]	242	242	24,2	24,2

Figure 2 shows the load flow computation of the model of the basic MV/LV electrical grid, built by means of PSS-Sincal simulator. While, figure 3 shows the model of the same grid built by Simulink.

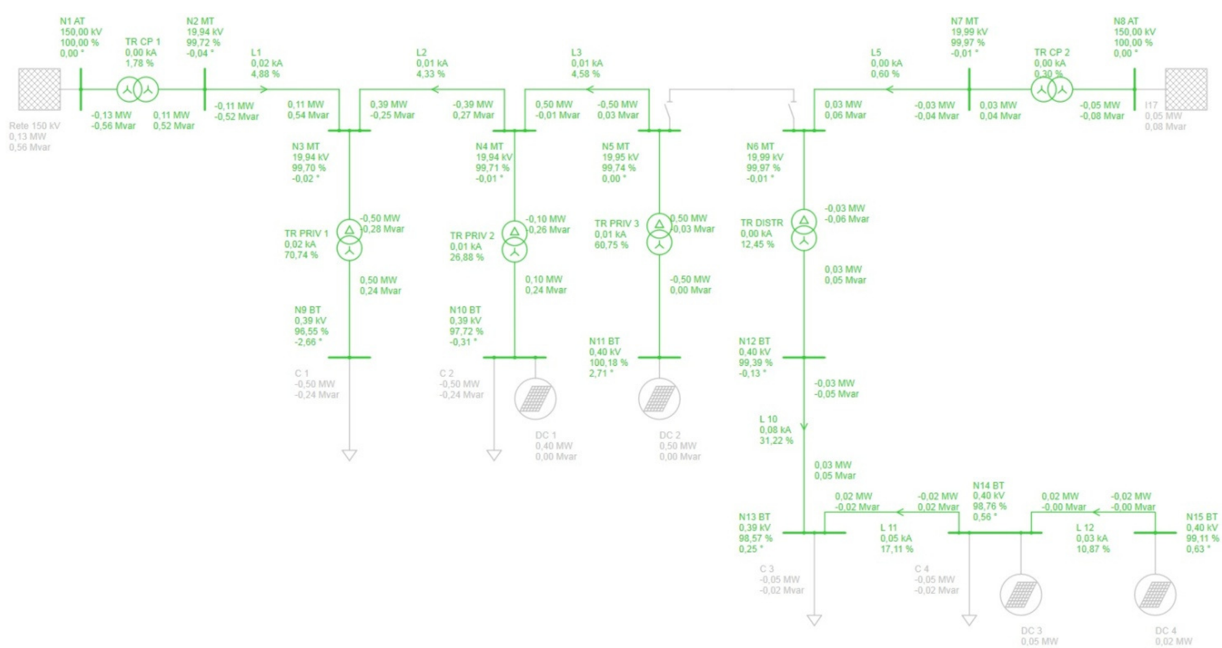

Figure 2: Basic MV/LV Grid Model by PSS-Sincal

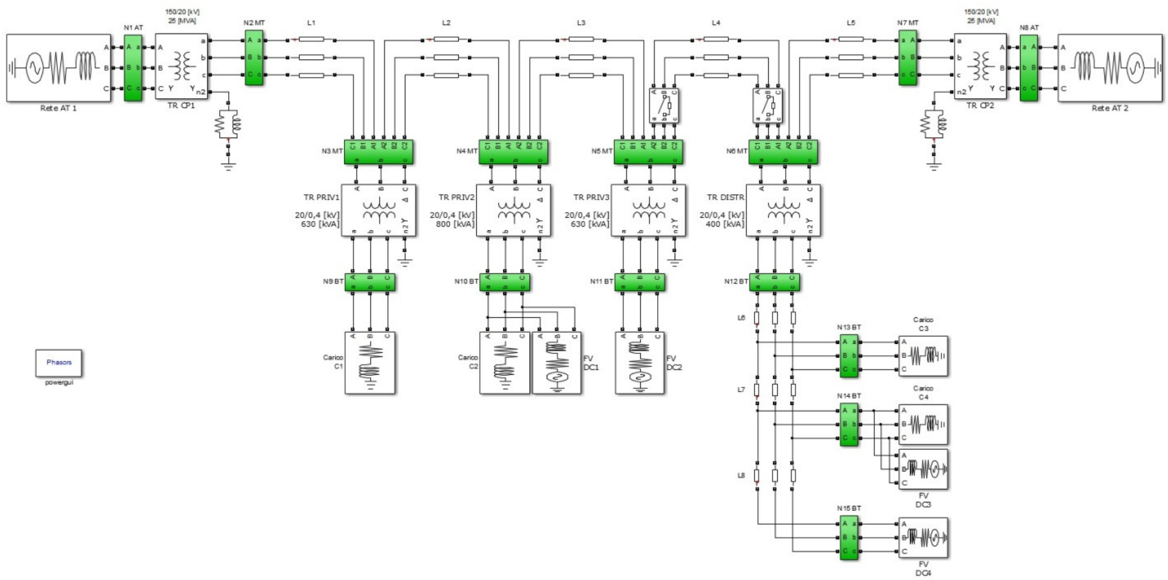

Figure 2: Basic MV/LV Grid Model By Simulink

Table 6 reports the comparative results of load flow computation between PSS-Sincal and Simulink, in terms of voltages on different nodes of the electrical grid and computation errors. Such errors between the two models are very limited, less or equal to 0,25%. Then we consider both basic models and results validated one each other.

Table 6: Comparing Simulink and PSS-Sincal Models

Voltage [kV]	*Simulink*	*PSS SINCAL*	*Error %*
N1 AT	150,000	150,000	0,00
N2 MT	19,946	19,944	0,01
N3 MT	19,941	19,939	0,01
N4 MT	19,944	19,942	0,01
N5 MT	19,949	19,948	0,01
N6 MT	19,995	19,993	0,01
N7 MT	19,996	19,994	0,01
N8 AT	150,000	150,000	0,00
N9 BT	0,386	0,386	0,00
N10 BT	0,391	0,391	0,00
N11 BT	0,401	0,401	0,00
N12 BT	0,398	0,398	0,00
N13 BT	0,395	0,394	0,25
N14 BT	0,396	0,395	0,25
N15 BT	0,397	0,396	0,25

On the validated model of the basic grid, we have introduced physical interdependencies with gas and water networks in terms of mini hydro devices, shared with water network, and gas co-generation devices, shared with gas network, which act as local generation sources.

The main parameters of Mini hydro and gas co-generator used in the models are reported in tables 7,8 and 9. Particularly, a Mini hydro of 0,77 MW installed on the MV subgrid, a Mini hydro of 0,09 MW, installed on the LV subgrid, a co-generator of 20 kW installed on the LV subgrid and a co-generator of 400 kW installed on the MV subgrid.

Table 7: Mini Hydro Parameters of LV Subgrid

Turbine	1 x Francis
Height (H_n)	70 [m]
Flow (Q)	0,100 - 0,150 [m^3/s]
Installed Power	90 [kW]
Yield (η)	80 %

Table 8: Mini Hydro Parameters of MV Subgrid

Turbine	3 x Francis
Height (H_n)	210 [m]
Flow (Q)	0,52 [m^3/s]
Installed Power	2x315 + 1x135 [kW]
Yield (η)	70 %

Table 9: Gas Co-Generator Parameters

Electrical power [kW]	*Thermal power [kW]*	*Electrical yield [%]*	*Thermal yield [%]*
20	39	32,23	62,90
401	549	38,08	52,14

On such models we are investigating indicators of efficiency and quality of electricity, in the planning and operation scenarios of table 1. For example, the model which implements the planning scenario "power flow inversion at HV/MV station versus HV network" may support decisions about location and size of the local sources, to avoid power flow inversion. Here, we shortly describe the model which implements the operation scenario "Fault Isolation and System Restoration (FISR) process", which may help in optimizing the reconfiguration of the grid on its permanent failure. The FISR model includes the electrical grid and its SCADA system. A three phase permanent failure is supposed to occur on the electrical trunk n. 2 of the MV grid (Figure 3). The consequent short circuit current causes the opening of protection breakers of the HV/MV substation on the left of the picture, the complete de energisation of its subgrid and the triggering of FISR process execution over SCADA system . The FISR process consists of the re-energizing step by step the segments of the electrical grid from the feeder downstream.

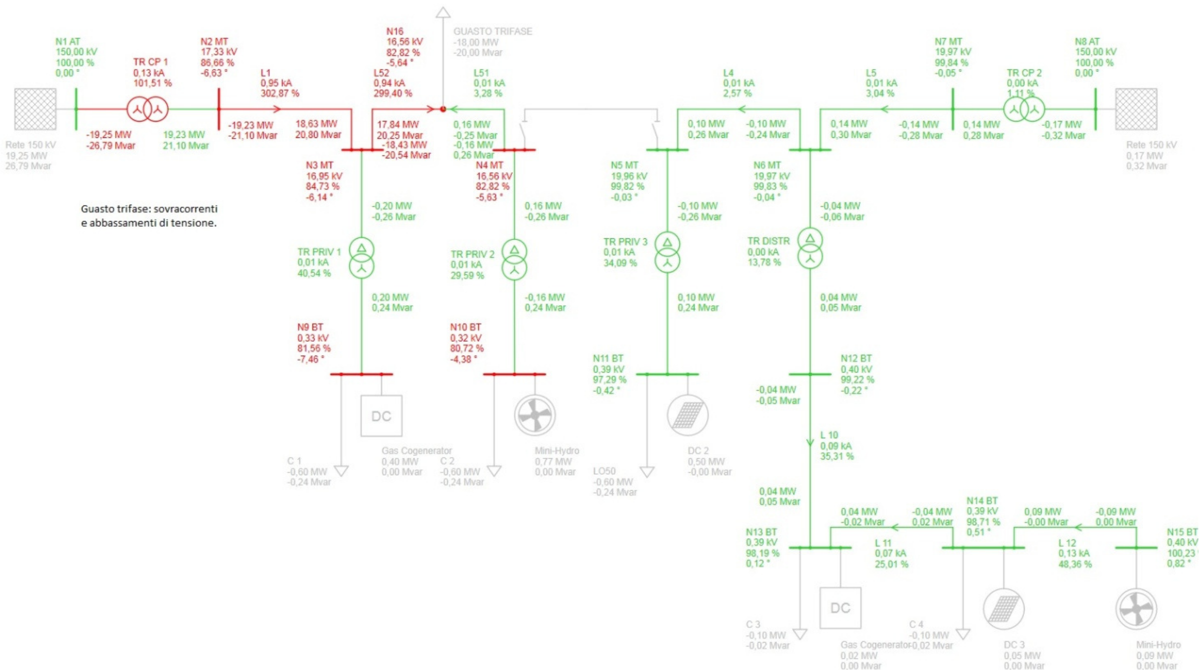

Figure 3: A Failure on the Electrical Trunk N. 2 opens the Protection Breakers and triggers FISR over SCADA System

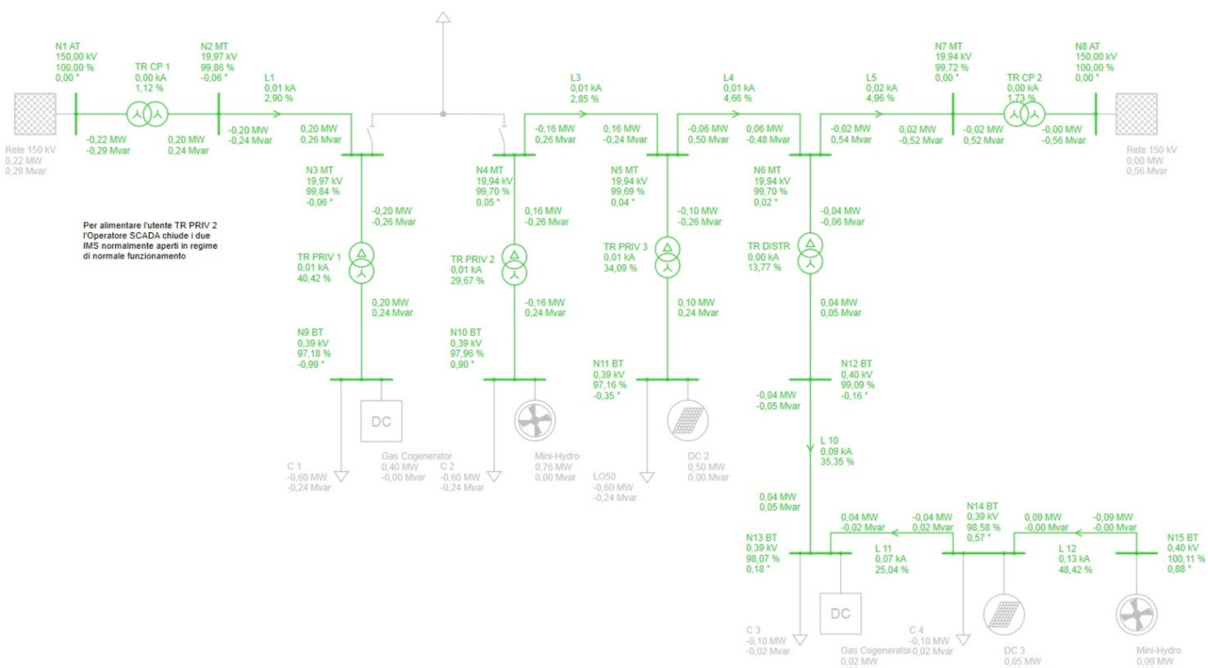

Figure 4 - Grid Reconfiguration on Complete Execution of FISR over SCADA System

Once it comes to the segment containing the faulty line, the feeder breaker trips again, thus signalling the faulty segment has been detected. Once the fault is localized, the faulty segment is isolated, the faulty line is repaired and the normal configuration of the grid is restored by toggling line switches in their normal state.

Figure 4 shows the grid at the end of FISR process. The duration of FISR process depends on the SCADA functioning and may increase under ICT contingencies and cyber attacks. The time the FISR process takes influences directly the electrical grid QoS. One of QoS used by electricity utilities is *Tn*:

$$Tn = \sum(KVA*Duration)/Installed\ KVA$$

Tn is indeed an equivalent time of complete loss of electricity for all the customers while executing FISR. More the FISR process takes, greater the *Tn* is.The model simulates FISR procedure and its consequences on the grid. The FISR detects the segment to which faulty line belongs, isolates the segment and restore original configuration after line reparation. To do this remotely, dozens of commands are sent by SCADA to RTUs who open and close switches.

Besides the aggregated QoS indicators used by electrical companies, models also calculate more detailed indicators such as time of energy loss for each customer, loss of power on trunks and transformers and the percentage of distributed generation respect to the total load.

3.2. Gas network

The model of the gas network has also two feeders: two interconnected first gas PRS that feed portions of a branching network to supply different types of users and/or PRI:

- Industrial Consumers (IC) (directly connected to medium pressure network) or thermal power plants;
- Home consumers, connected to final gas pressure regulating groups PRI_f in which the upstream pressure of 5 bar is reduced to the value of 23 mbar (each PRI may feed even hundreds ofconsumers);
- Small industrial PRI_i (upstream pressure is reduced to a range between 50 and 200 mbar). In the model a CHP 401/549 kW with consumption of 105.3 Nm^3/h at 200 mbar has been included;
- Specific consumers with specific values of pressure – flow PRI_u. An example could be represented by a cogeneration unit (in the model a CHP 20/39 kW with consumption of 6.2 Nm^3/h at 50 mbar);
- BIOMETHANE1 that identifies the “active user” type by entering biomethane into the natural gas distribution network.

In the physical model is also entered a branch of the interconnection to be used for network reconfiguration following particular eventualities/faults. To implement the model was used NEPLAN, a powerful software with up-to-date calculation algorithms including Newton-Raphson and Hardy-Cross methods. A load flow simulation was performed on the model developed and the result is shown in fig.5. The characteristic data of each section (diameter, thickness, length, coefficient of roughness, friction coefficient lambda linked to relative roughness and Reynolds number) are known for DSO pipelines.

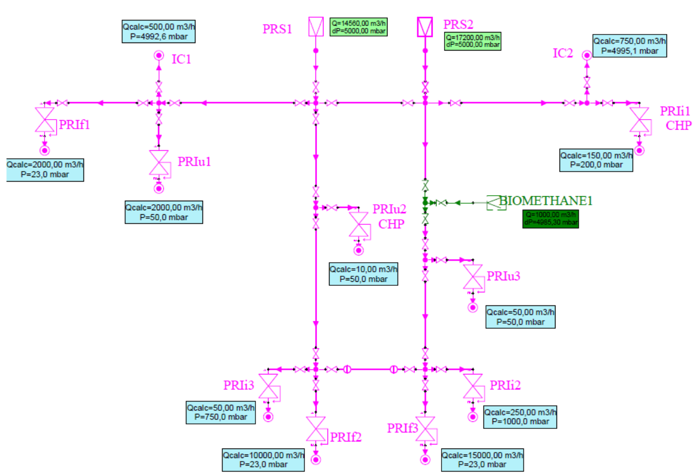

Figure 5: Load Flow of the Gas Network in Normal Conditions by Neplan

In normal operating conditions, the network is balanced, and network main parameters such as pressure, flow, pressure drop and gas speed inside of pipes for each point/node/component of the network are measurable or calculable. Assuming a failure in one of the components of the network, it is possible to isolate the failure and perform a reconfiguration of the network by means of remote controlled valves in order to ensure continuity of operation. Obviously, the failure isolation and reconfiguration procedure may change depending on failure location. For example, if the failure affects the first gas PRS is possible to act on the upstream and downstream valves to isolate it and the supply continuity is ensured by reconfiguration based on the meshing of the stations. If the failure affects a middle section that would isolate an entire trunk (1. Failure) in fig. 6, it is possible to operate the valves upstream and downstream of the affected section and act on valves (normally closed) to make a network reconfiguration (2. Reconfiguration) by means of SCADA system.

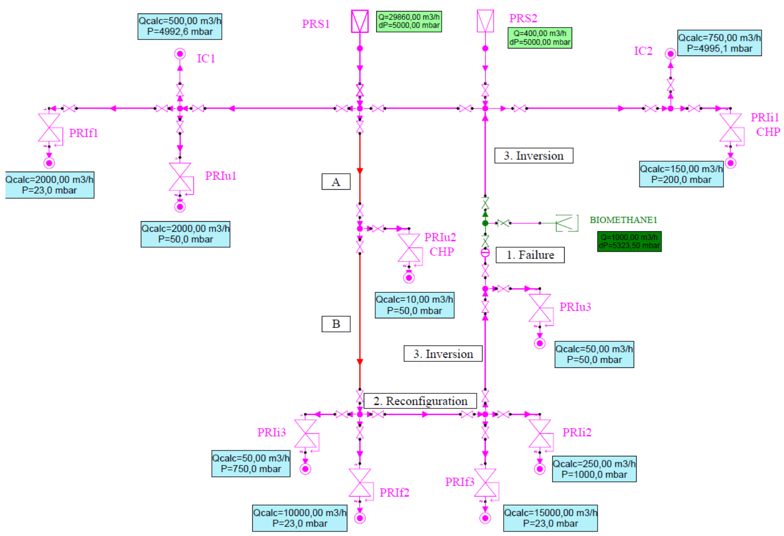

Figure 6: Load Flow of the Reconfigured Gas Network on a Failure.

It is clear that in the portion (3. Inversion) there is a gas flow inversion. At the same time it can be seen that the first gas PRS is subjected to an overload, however, within the limits of design capacity. The different colors of A and B pipes indicate the criticality of the network in such pipes because they do not meet design constraints of pressure and/or speed of the gas inside the pipes.

3.3. Urban Water network

The urban water network model, at this stage, has been developed by using EPANET 2.0 software, provided by the EPA (Environmental Protection Agency). Figure 7 shows such a model, which, in agreement with the general framework described above, satisfies the following minimum requirements:

- Two sources (CP1, CP2), each one capable by itself to feed the whole network when necessary, as it could be in a failure scenario. In normal operating conditions, as shows in figure 7, the left branch is fed by CP1 and the right one is fed by CP2. The pumps P1 and P2 are normally switched off in order that the left branch results disconnected from right one, and the links that connect them to the rest of the network are normally closed. The pump P3 is normally active, and allows the right branch to be fed.
- Public, commercial, and industrial consumers (L1-L5), for a district that serves about 10,000 inhabitants-equivalent, with an expected daily water requirement of 240 l / inhabitant • day.
- Valves V1 and V2: V1 represents a Pressure Breaker Valve (PBV) that simulates a mini hydro plant, V2 a Flow Control Valve (FCV), which limits the flow to the tank, to preserve the speed of the water in the pipes within the specified limits (0.5-1,5 m/s). Each link presents also the possibility to be open or closed.
- Two tanks, PV1 and PV2 that are capable to feed respectively, left branch and the right one for a few hours. To do this, it isn’t necessary the use of pumps, because each tank is capable to feed the branch tanks by gravity. Normally, tanks are refilled when the load in the network is low as typically occurs during the night.

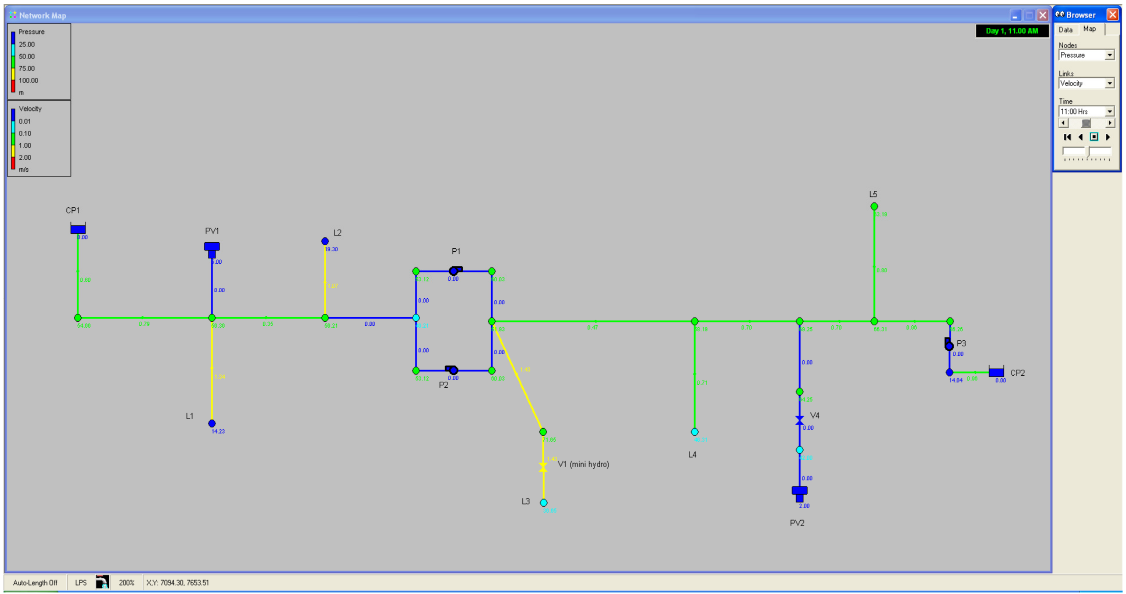

Figure 7: Load Flow of Water Network in Normal Operations by Epanet

A reconfiguration of the network, that may occur on a contingency, in which a single source feeds the whole network is shown in table 3. To reconfigure the network, the following operations have to be performed by means of remote control valves: a) to exclude a source (e.g. CP2); b) to open links upstream and downstream of the pump P1; c) to activate the pump P1.

The reconfigured network is shown in figure 8.

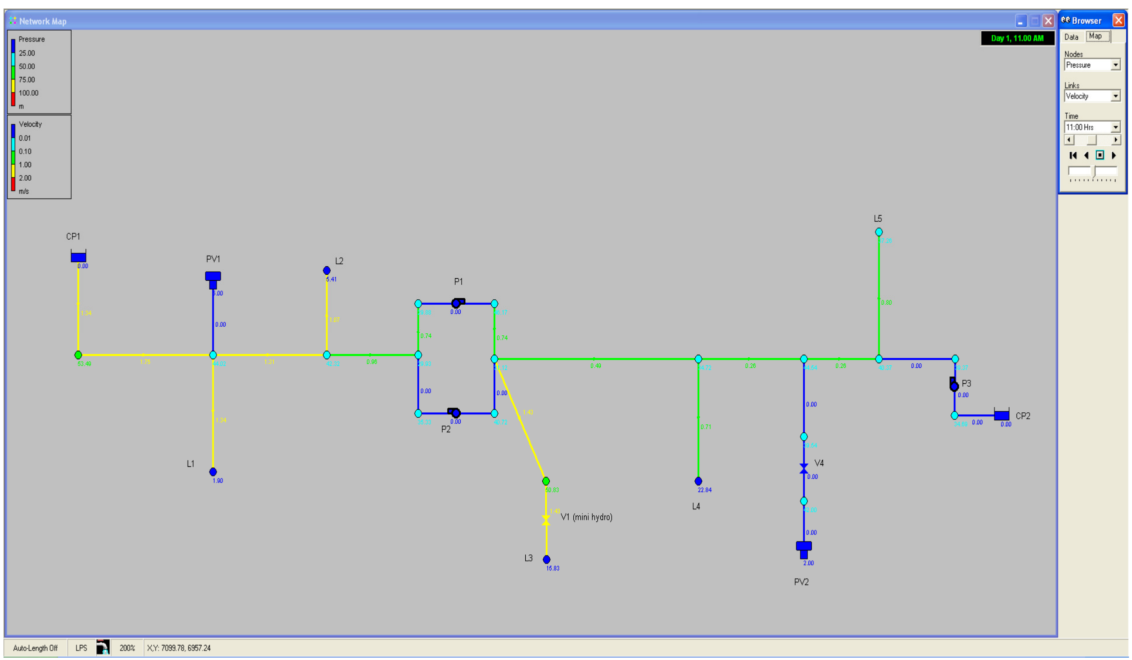

Figure 8: Reconfiguration of Water Network : a Single Source (CP1) feeds the Whole Network

4. INTERDEPENDENCY ELEMENTS

Current models are built to be conceptually interconnected one each other to represent interdependencies among the three urban nets, at physical, logical and geographic layer. Her, we discuss the main elements of interdependency to be represented in our models,

At this stage, we are considering a) distributed electricity sources, such as mini hydro, shared with water network and gas co-generation shared with gas network; b) active components of water and gas network energized by the electrical grid and c)ICT which support and interconnects SCADA devices of each network.

Regarding gas network, the mutual dependencies between the electrical and gas network can be easily identified and represented. Cogeneration units CHP and natural gas thermal power plants or natural gas combined cycle turbine CCGT using natural gas fuel for the combined production of heat and electricity.

A change in the functioning of the above systems has an impact on the electricity grid production. More obsolete gas networks essentially consist of mechanical adjustment with electromechanical type for measurement and data acquisition systems. The dependency from the electrical grid regarded the registration systems of gas network measures, such as volume, pressure, temperature and level of odorized gas. SCADA system was basically a measurement and data acquisition system. The technical evolution and also the increasingly stringent minimum requirements imposed by national authority for electricity and gas have led to current solutions in which each component of the gas network is managed with electromechanical actuators (valves, pressure regulators, ...) and controlled by electromechanical/electrical/electronic transducers (temperature, volume, pressure, odorized, clogging filters, ...). SCADA system of the gas network has become extremely complex and consequently also vulnerable, highly dependent on the electrical and ICT networks.

Regarding water network, the main mutual dependencies with the electrical grid, at physical layer, are the mini hydro plants and the electrical supply of the active components (such as the pumps and remote controlled valves) of water network, and the electrical energisation of SCADA devices. Dependency also arises at logical level by means of ICT technology which support IP based solution for SCADA systems.

5. CONCLUSIONS AND FUTURE WORK

We are developing integrated models of interdependent urban networks to compute their efficiency and quality of services in planning and operation scenarios. Models take into account interdependencies and proper functioning of SCADA when the FISR process is needed to detect, isolate permanent failures on the physical networks and to reconfigure to mitigate the effect of outage on networks stakeholders(public utilities, local generation and passive customers). FISR duration depends also on SCADA command delivery time. Models are under development in incremental fashion. Final models intend to simulate load shedding procedures, which route physical flow by using optimized load scheduling algorithms, which account local storage and cost for customers. In determining routing features, models play a big role. I.e. for the smart grid, they intend to answer how much storage could reduce the power imbalance or how much storage is needed to achieve a required energy reduction. It can be shown that most of the reduction in the power imbalance can be achieved with relatively small storage capacity. Representation of different forms of energy storage are currently under investigation, with their location and their size within the MV network.

The scalability of described models in planning and operation scenarios on the city of Catania, it is a very important step. The role of electricity, gas and water utilities, as stakeholders of SINERGREEN Project, becomes more and more relevant in extending and tuning scenarios and models according to their actual needs.

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MODELLING OF SOCIAL INFLUENCE WITH DEVS AND CELL-DEVS FORMALISM

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ABSTRACT
The reactions of populations to the dissemination and propagation of information are, up to now, not modeled appropriately. There is however an interest in the ability to simulate and accurately measure the impact of information on population. The SICOMORES project objective is to provide solutions to artificially generate structured social networks of realistic population and simulate the effects of information on population, with a propagation algorithm of the effects across networks. The intention is to go further than current models which generally reduce the individuals of a population as simple obstacles or information transmitters without enough nuances in their behaviour and the influence they can have on a message. . In this article, we recall first the use of discrete modelling approaches in the social influence. Then we present models for human information treatment and propagation using DEVS and Cell-DEVS (Cellular DEVS). Finally, we present a simulation of the impact of information on individuals using CD++, a simulation tool for DEVS and Cell-DEVS.

Keywords: DEVS Formalism, Social Influence, Human Behaviour Modelling, Diffusion Models

1. INTRODUCTION

We observe that major works about modelling and simulation within social science, especially for social, organizational and cultural influences on opinion information spreading over a population, do not use specification languages to describe their models. These models are specified in the shape of math formulas and then directly coded using classical programming languages. The specification language can be a missing link. For instance, the DEVS formalism (Discrete EVent system Specifications) (Zeigler 1976), being general enough to represent dynamical systems, can provide an operational semantics applicable to this domain.

In 1970ŝs, Professor Zeigler introduced this method that has proved successful. It represents: (1) a complex system from an interconnected collection with more simple subsystems; (2) a separation of the model from simulator, simulation algorithm are automatically generated according to defined models.so, the advantage is that it supports formalism interoperability. This formalism is open, flexible and offers a large extension capacity.

According to recent works (Garredu et al. 2011, Ameghino et al. 2001), it has been proved that DEVS formalism might be qualified as a multi-formalism thanks to its opening capacity, to its capacity to encapsulate others modeling formalisms. In one heterogeneous system, it is possible to use modeled subsystems from different formalisms, differentials equations, neuron networks, continuous systems. In PADS (parallel and distributed simulation) community, DEVS is widely spread as a modeling specification as it supports hierarchical, modular model representation. It also supports valid simplification, abstraction, and aggregation. Furthermore, extensions of the DEVS framework have been developed to handle variable structure, probabilistic, cellular, and logic-based representations (Sarjoughian et al. 2001).

This paper intends to present the premise of modelling and simulation of the impact of influence activities on individuals in social networks using Cell DEVS M&S formalism. The intention is to go further than current models which generally reduce the individuals of a population as simple obstacles or information transmitters without enough nuances in their behaviour and the influence they can have on a message. Cell-DEVS is a combination of CA (Cellular Automata) with the DEVS (Discrete EVent system Specifications) formalism that allows the definition of complex cell based systems. It appears especially suited to this study that takes into account several layers of social graph related with geographical networks. CD++ is a modelling and simulation tool that implements DEVS and Cell-DEVS. We use CD++ to build a model of influence of information on individuals in social networks.

In more detail, this paper will participate in the definition of a set of models that addresses the entities and the structure of a population. It will begin by representing the discrete modelling approaches including DEVS and CELL-DEVS Formalism. In addition, it will provide models of individuals with DEVS and groups of individuals characterized by a set of state variables (e.g. Using Maslow to construct the behaviour of an individual) and the mesh between the individuals within a social network. At last, the final part concerns the conclusion and a presentation of our future works.

2. BACKGROUND

2.1. DEVS Formalism

The DEVS formalism for modelling and simulation (Zeigler et al. 2000), is based on discrete events, and provides a framework with mathematical concepts based on the sets theory and systems theory concepts to describe the structure and the behaviour of a system. With DEVS, there is an explicit separation between a model and its simulator: once a model is defined, it is used to build a simulator (i.e. a device able to execute the model's instructions). DEVS knows two kinds of models: the atomic models, which describe behaviour, and the coupled models which describe a hierarchy. The tiniest element in DEVS formalism is the atomic model. It is specified as:

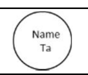
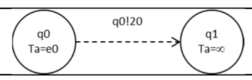
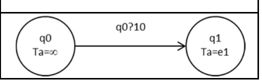
$AM = < X, Y, S, ta, \delta_{int}, \delta_{ext}, \lambda >$

The semantics for this definition is given as follows. At any time, a DEVS atomic model is in a state $s \in S$. In the absence of external events, the model will stay in this state for the duration specified by ta(s). When the elapsed time e= ta (s), the state duration expires and the atomic model will sent the output $\lambda(s)$ and performs an internal transition to a new state specified by δ_{int} (s). Transitions that occur due to the expiration of ta(s) are called internal transitions.

However, state transition can also happen due to arrival of an external event which will place the model into a new state specified by δ_{ext} (s,e,x); where s is the current state, e is the elapsed time, and X is the input value. The time advance function ta(s) can take any real value from 0 to ∞. A state with ta(s) value of zero is called transient state, and on the other hand, if ta(s) is equal to ∞ the state is said to be passive, in which the system will remain in this state until receiving an external event.

Table 1 show the graphical notation to define the behaviour of atomic models.

Table 1: DEVS graphical notation

State	Internal Transition	External Transition
		

2.2. CELL-DEVS

Cell-DEVS (Wainer 2009), has extended the DEVS formalism, allowing the implementation of cellular models with timing delays. It improves execution performance of cellular models by using a discrete-event approach. It also enhances the cell's timing definition by making it more expressive. Each cell is defined as an atomic model using timing delays, and it can be later integrated to a coupled model representing a cell space, as showed in Figure 1.

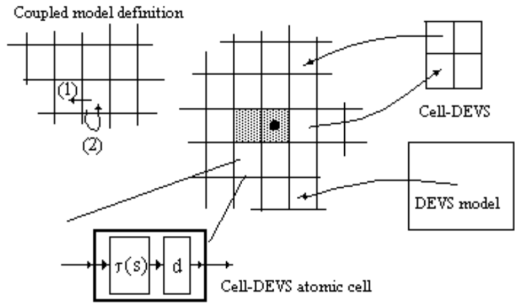


Figure 1: Informal Description of Cell-DEVS

Once the cell behaviour is defined, a coupled Cell-DEVS can be created by putting together a number of cells interconnected with their neighbors. A cellular model is a lattice of cells holding state variables and a computing apparatus, which is in charge of updating the cell state according to a local rule. This is done using the present cell state and those of a finite set of nearby cells (called its neighborhood).

Each cell uses N inputs to compute its next state. These inputs, which are received through the model's interface, activate a local computing function (t). A delay (d) can be associated with each cell. The state (s) changes can be transmitted to other models, but only after the consumption of this delay. Two kinds of delays can be defined: transport delays model a variable commuting time (every state change is transmitted), and inertial delays, which have preemptive semantics (scheduled events can be discarded).

2.3. CD++ Toolkit

CD++ (Wainer 2002), is a modelling and simulation toolkit that implements DEVS and Cell-DEVS theory. Atomic models can be defined using a state-based approach (coded in C++ or an interpreted graphical notation), while coupled and Cell-DEVS models are defined using a built-in specification language. We will show the basic features of the tool through an example of application. CD++ also includes an interpreter for Cell-DEVS models. The model specification includes the definition of the size and dimension of the cell space, the shape of the neighborhood and borders. The cell's local computing function is defined using a set of rules with the form: {POSTCONDITION} {DELAY} {PRECONDITION}. These indicate that when the PRECONDITION is satisfied, the state of the cell will change to the designated POSTCONDITION, whose computed value will be transmitted to other components after consuming the DELAY.

3. HUMAN BEHAVIOUR MODELLING

3.1. General approach

Human behavior modelling as individuals, in groups, and in societies is the subject of several fields of researches; social science, economics, epidemiology and military service because it has such an important role in many aspects of daily life. Scientific literature abounds in heterogeneous and highly specialized, theoretically founded concepts of human cognition, emotion and other behaviour aspects. There are many lines of research on such models, which span several disciplines, have different goals, and often use different terminologies and various approaches. Human behaviour modelling or human behaviour representation (HBR) is an important field of study in military service research (Fei et al., 2007), robotics [(Kubota and Nichida, 2006)], brain-computer interface (BCI), human machine interface (HMI) and some specially oriented anthropology studies. Human behaviour models are often represented by finite state machines, rules, fuzzy rules (Dorsey and Coovert, 2003), artificial neural networks, multi-agent based modelling (Sun, 2007). The need for a variety of modelling paradigms stems from the fact that the different domains of knowledge needed to represent human behaviour cannot be done by only one paradigm.

3.2. Human Behaviour Modelling in military application

In military operations, the Human Behaviour Modelling or Human Behaviour Representation is an important field of study; the human has always been recognized as a key factor. Numerous examples illustrate how the actions of an individual or a group of individuals defeat into victory or how difficult it is to sustain operations in extreme climates. Current military missions need simulation models that can capture and foresee the behavior of humans acting in social units, ranging from small groups, cultural and ethnic groups, and entire societies. Models could be used to predict the effects of actions intended to disrupt terrorist networks, to predict the response of insurgents and the local population to the presence of friendly forces in a given area, or to predict the effects of alternative diplomatic, military, and economic courses of action on the attitudes and behaviors of the population in a region of interest (Zacharias et al. 2008).

There are numerous tools for human behaviour modelling that can be involved in the domain of military simulation of peace keeping or stabilization time. Most of them are tackling Political, Military, Economic, Social, Infrastructure, and Information (PEMSII) System by Diplomatic, by Intelligence, Military and Economic (DIME) actions on the region of interest System (Zacharias et al. 2008).

- Integrated Battle Command program (IBC); supports the commander's intuition, judgment, and creativity using flexible, intelligent decision aids in todayǿs complex operational environment. IBC proposes an interactive process that involves humans in the loop to guide the search for solutions.
- Pre-Conflict Anticipation and Shaping (PCAS); project examines the technical computer support for designing strategies for forming, or combining several different models representing relevant information and knowledge.
- CLARION (Connectionist Learning with Adoptive Rule Induction ONline); this tool is a cognitive architecture for connectionist/neural representation of implicit knowledge and semantic representation of explicit knowledge. It is provided for explicit representation of static knowledge as well as acquisition of sub symbolic knowledge through learning over time.

3.3. Using DEVS for Human Behaviour Modelling

Human behaviour can be difficult to understand and predict, thus it can be qualified as a complex system. DEVS is a well-defined formalism which has numerous ad-vantages over other formalisms in the modelling of complex dynamic systems. A few related works have provided DEVS models of human behaviour that we will use with slight modifications; (Seck 2004), present a DEVS based framework for the model-ling and simulation of human behaviour with the influence of stress and fatigue, (Faucher 2012), proposed a first approach using G-DEVS formalism for Civil-Military Cooperation actions (CIMIC) and Psychological actions (PSYOPS), which are actions of influence that take precedence over combat.

The purpose of this work is to go beyond previous works by providing a simple model but more performant and accurate which will allow us not only to model the behaviour of an individual, but also the simulation of the propagation of an information among a group of individuals and its influence on their behaviour.

This model (Figure 2) is describing the influence of message on the behaviour of an individual and potentially its dissemination. The first state consists in being in contact with another agent in its social network neighbourhood and calculating the strength of connexion between them. When the message is received, it creates an impact on the individual which change its behaviour eventually depending on the strength of the message (Faucher 2012). Then, if the message strength is still strong enough the receiver is preparing on its turn to transmit the message to its network neighbours considered as target info.

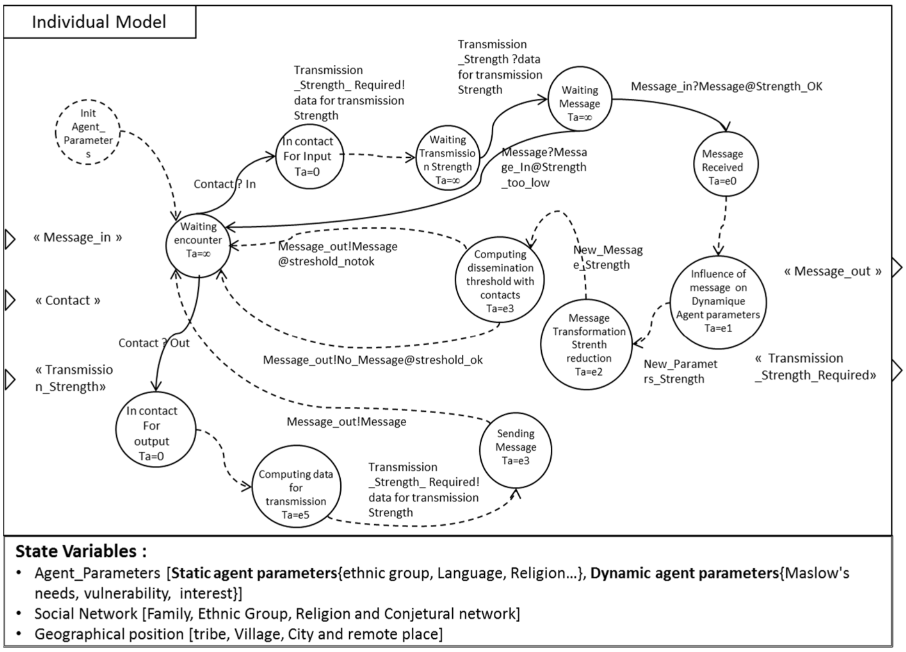


Figure 2: DEVS individual model

4. INFORMATION DIFFUSION MODELLING

4.1. Diffusion Models

4.1.1. General Approaches

The study of information spread and propagation of ideas, and influence in a social network has a long history in the social sciences (Rogers 1962, Coleman 2005), with the advent of computers with sufficient storage and computational power, this network diffusion process has become an emerging research area in computer science (Domingos 2005). Propagation models are designed to reproduce the phenomena that can be observed in social networks, in the viral marketing and the spread of disease. Communication between users of these actors in networks gives rise to a number of issues such as the discovery of the sphere of influence, the initial choice of diffusers for maximum dissemination or the identification of links to remove to limit the spread.

Most information diffusion models proposed recently are extensions of Independent Cascade model (IC) (Goldenberg et al. 2001), and Linear Threshold Model (LT) (Granovetter 1978). The two models characterize two different aspects of social interaction. The IC model focuses on individual (and independent) interaction and inþuence among friends in a social network. The LT model focuses on the threshold behavior in inþuence propagation; each individual has two mutually exclusive and exhaustive behavioral options available. For example, in Granovetterȏs classic example, each individual chooses whether or not to join a riot. In addition, each individual is assumed to observe the behavior of all other individuals.

4.1.2. From Epidemics Spreading to Information Diffusion

In the past, the propagation was mainly studied in the epidemiological field to better understand the process of propagation of infection in certain conditions. Classical disease-propagation models in epidemiology are based upon the cycle of disease in a host: a person is first susceptible (S) to the disease. If then exposed to the disease by an infectious contact, the person becomes infected (I) (and infectious) with some probability. The disease then runs its course in that host, who is subsequently recovered (R) (or removed, depending on the virulence of the disease). A recovered individual is immune to the disease for some period of time, but the immunity may eventually wear off. Thus SIR models diseases in which recovered hosts are never again susceptible to the disease.

Sotoodeh et al. (2013), presented a general model of information diffusion, which is based on epidemic diseases. It is a result of developing SIRS deterministic model and including compartmental assumption.

Bouanan et al. (2014), presented an analogy between the dissemination of information among a group of individuals and the transmission of infectious disease between the individuals themselves. In addition the authors introduced the simulation of information diffusion using CELL-DEVS Formalism.

4.2. Modelling of Information Propagation in the context of PSYOPS actions using CELL-DEVS

In this section, we will introduce the PSYOPS Actions based on studies done by social scientists and we will simulate the spread of information through conversations between pairs of individuals within a small group in the context of PSYOPS operations with CELL-DEVS.

4.2.1. PSYOPS Actions

Psychological Operation (PSYOPS), planned activities using methods of communication and other means directed at approved audiences in order to influence perceptions, attitudes and behaviour, affecting the achievement of political and military objectives, (McLaurin 1982). It affects the behavior of a target by means of cognition or emotions.

Psychological operations aim at elaborating and spreading out a message that must be read, listened to and understood by the info-targets in order to get the desired effect, that is, influencing the info-targets to get from them the desired behavior by the modification of their attitudes, by acting on their perceptions, [N°069/DEF/CICDE 2008].

The info-targets are the people to whom psychological messages are intended. They are divided into intentional info-targets, that is the info-targets towards whom the messages are directed and non-intentional info-targets who will receive the message, but whom the analysts had not thought of, when designing the message. The intentional info-targets can be direct (they receive the message directly from the means of conveyance) or indirect (the message is propagated to them through social networks) (Faucher 2012). A message can generate in the info-targets, reasoned thoughts, spontaneous feelings and emotions and/or reflex behaviours, depending on the means used to spread the messages and the content of the message.

4.2.2. Proposed Model

4.2.2.1. CELL-DEVS Definition

The following is the formal definition for the CELL-DEVS model defined in Part 1.

CD = < X, Y, I, S, ɗ, N, d, ŭint, ŭext, Ǖ ǝ, D >

X = Y = Ø

S is the set of possible states for a given cell. Here a cell has a variable that contains four digits.

- First digit represents message transmission; 1, message received and 2, message not received.
- Second digit, is the mental factor, in this case we simulate the individual attitude.
- Third digit symbolizes the family network
- Fourth digit represents the religion network

N = {(-1, 0), (0, -1), (0, 1), (1, 0), (0, 0),}

d = 100 ms

Ǖ N→S is defined by the rules presented in table 2:

In this section, we present a simple model of the information impact using the formalism CELL-DEVS in order to show the feasibility to use DEVS and CELL-DEVS in social influence modelling. In more detail, we define the state of the individual as a value contains four digits; two digits represent static parameters (religion network, family network, languageé) and the others digits represent dynamic parameters (mental factors, Maslowȏs needsé). To develop a simulation model, we chose as static parameters religion and family network and individual attitude and state of message as dynamic parameters.

Table 2: Definition of rules

State Parameters value	Rules
1.1.Y.X	Two neighbors or more that have S=1.X.Y.X
1.0.Y.X	One neighbor that has S=1.X.Y.X
1.0.X.Y	Three neighbors or more that have S=1.X.Z.Y (Z!=X)
0.X.X.X	Other combinations

4.2.2.2. CD++ Implementation

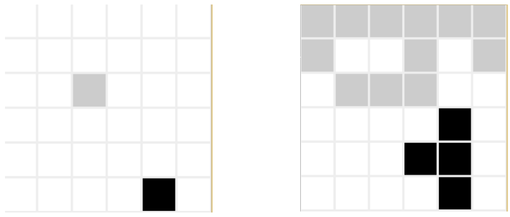


Figure 3: Execution result at time 00:00:000; 00:00:700

The model is intended to study the propagation of information and its impact within a group of individuals. Assume there is 6×6 mesh of cellular automata (CA). Each individual, residing in (i,j) node, is equipped with a number with four digits indicating different Parameters of the individual.

Each cell may represent one of two categories: one is person who did not receive the information represented by white color; the other is the person who received the message represented by black or gray color. Initially we have two sources of information which contain two kinds of messages. At the end of the simulation we can see that the message represented by gray color is received by a large number of individuals while the second message is received just by 3 individuals (figure 3). The individual can be opposed to the information and/or person that is transmitting the message and/or favourable to the emitter and message content. The simulation results show on the right picture of Figure 3 that depending on the opinion of individuals and the configuration of the social networks some individual can be reached by the information where some other not. This test is very simple; it is based on the abstract geographical situation of individuals and it takes into account only one dimension of a social network. We have not introduced yet the graph representation for defining the multilevel social network links between individuals or groups. Nevertheless the approach already shows how we can use DEVS and CELL-DEVS formalism to model a complexes phenomenon in particular social influence.

CONCLUSION

This paper introduced Formal Modelling and Simulation of the impact of Information on Individuals in a group. We have presented how DEVS and Cell-DEVS can be very useful techniques for modelling and simulating of Social influence. At the individual level, the DEVS model proposed is very simple keeping raw Maslow parameters as state variables and being simply influenced by arriving messages. In its turn the individual model can transmit the message after having potentially transformed its strength according to several criteria. The Cell DEVS structure then use these models of human extremely simplified and start building on top of its connected modules to form Cell-DEVS network. In addition, the separation between the model and simulator followed by DEVS and CD++, has enabled the modeller to concentrate on building the behavioural model on one side and preparing the spreading logic on the other side using the CD++ toolkit. The model shows a correct, even very simple, human behaviour impact regarding information perception and treatment.

PERSPECTIVES

The main perspective remains the definition of a multi-level social network. In detail the real social network is complex, it can refer for e.g. to the family environment, work, religion, geography to transport the information from one individual to another. The final result will be the combination of several networks graphs.

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INTEROPERABILITY REQUIREMENTS FOR DEVELOPING SIMULATION SOLUTIONS FOR INNOVATIVE INTEGRATED SYSTEMS

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ABSTRACT

This paper aims at describing an innovative approach to simulate the interaction among sensors, antennas and electronic equipment; the paper focuses on the case study of an innovative mast integrating different sensors and systems to be adopted by modern military vessels.
In particular, requirements and reference architectures to be adopted in order to support interoperable simulation are proposed for the models related to vessel board systems. Such approach is developed in order to ensure interoperability of the different models (i.e. communications, radars, Optoelectronic and Infrared sensors etc.) considering mutual interferences as well as interaction with other vessel systems; this approach allows evaluating the overall effectiveness, electromagnetic interferences, compatibility and operational procedures respect operations.
The authors present a technological solution based on HLA (High Level Architecture) simulation enabling interoperability and leading to the creation of a federation for evaluating and validating results achieved during the experimental analysis; the latter is led over the proposed innovative integrated mast in order to understand the effectiveness of this solution with possibility to conduct comparison with other vessel configurations.

Keywords: Modeling & Simulation, HLA, Interoperable Simulation, Electromagnetic Interference, Integrated Mast, Vessel Virtual Prototyping, Radar & Naval Sensors, Electronic Warfare Systems

1. INTRODUCTION

Sensors, Communication, Control Systems and all the ICT resources represent the core of most modern complex systems including trains, planes, cars, military system; it is evident that their integration is often critical due to the interaction and interference among the different subsystems; in addition these systems often requires to guarantee simultaneous use of the different elements and subsystems often generating a very large spectrum of operational modes and configurations, pretty hard to predict and regulate. This introduces the necessity to develop solutions for addressing these aspects by creating a joint technical comprehensive representation of the new systems even considering the functions and operational scenarios to be faced (e.g. failures and emergencies).
From this point of view it is evident the potential to use interoperable simulation enabling the possibility to consider even stochastic factors and to integrated multiple elements in the (e.g. Man-in-the-Loop, Hardware-in-the-Loop, Software-in-the-Loop).
The authors in this paper address this problem with special attention to the case of modern military vessel; indeed, today, a frigate or a destroyer is fully equipped with a large number of antennas and devices that need to be properly designed and located around to support the different functions. These functions are strongly referring to the operational procedures and modes (i.e. Fire Control Problem) and need to be combined in order to guarantee reliability, effectiveness and efficiency (Kaempf 1996; Chalmers 1993).
This research is especially motivated by on-going researches related to the development of new solutions for military vessels able to integrate almost all the sensors in a compact and effective mast infrastructure.
The proposed approach is based on interoperable simulation and the paper identified in the High level Architecture (HLA) the most suitable technological infrastructure; obviously it becomes fundamental to define the related requirements for giving directions to model developers of different systems/subsystems.
This approach allows developing a technical comprehensive simulation integrating the board devices models (i.e. communication systems, radar, shooting range); this simulation aims at optimizing the characteristics and the design related to the systems, subsystems and whole vessel platform, keeping into account different operational modes and configurations.

2. DESIGN AND INTEGRATION THROUGH INTEROPERABLE SIMULATION

From this point of view there are different approaches devoted to support the design of these components in reference to naval military vessels; traditionally each single system was designed by itself (e.g. surveillance radar) and located over the ship just considering its weight and volume for guarantee space availability and

ship stability (Salvesen et al.,1971); after completing this preliminary draft design studies are carried out in order to check also electromagnetic compatibility with ship infrastructures and other elements (Maiuzzo et al., 2005). Therefore in vessel design, the process should be much more integrated and the whole military ship should be considered by itself as a weapon system (Panchal 2005;Cao, Du, Zeng 2007).
Therefore usually new vessel design involves many different actors representing different companies with specific interests on diverse components (e.g. propulsion, ship building, weapon systems, combat systems, etc.); in addition the stakeholder list includes also different Institutions and Authorities including the branches of the Navy such as Acquisition Directorate, Warfare Development Command, etc. (Cebrowski, Garstka, 1998).
However this process is affected by a high risk to fail due to the high number of factors to be considered (i.e. line of sight, interferences, unexpected procedures, etc.), when this happen it is necessary to redesign the solution (e.g. moving a sensor) or to accept an operational limitation (e.g. incompatibility to carry out some simultaneous actions); these case are involving very high extra costs and could provide problems in operations (Moyst, Das, 2005); so it is evident the benefit provided by creating a technical comprehensive interoperable simulation.
By this approach, it becomes possible to provide a guideline to the different stakeholders to develop new system models in order to be ready for being federated in an interoperable simulation and to conduct the above mentioned analysis and test (Wang et al., 2009).
Indeed it is pretty common to have simulator for the different sensors and systems, however often these models are designed for specific purposes and lack in terms of interoperability; for instance there are radar simulator designed to evaluate the coverage of the antennas that don't have the capability to consider the interference with communication systems (Jin, Liu, Yu, 2013).
The possibility to create a joint simulation of new vessels in operational conditions, considering realistic interactions among different systems and subsystems, represents a major advantage to support design, engineering of the ship along its development life cycle.
For guaranteeing this result it becomes evident the necessity that the models of the different systems should be interoperable for being ready for integration within the vessel simulation for testing concepts as well as functions (Bruzzone et al., 2013; Bruzzone et al., 2003). Interoperability guarantees the possibility to combine the models also with real equipment in integration phase and evaluation of new technological solutions (Bruzzone et al., 2012); even the capability to federate such models with training equipment and/or operational multi resolution simulators provide an useful support to test the effectiveness of the new vessels in complex scenarios or versus new Concept of Operations (Bruzzone et al.,2013b; Gilman, 2004; Longo et al. 2013-a, Longo et al., 2013-b).

3. INTEGRATED MAST AS SOLUTION EXAMPLES

Actually one of the most important issues that affect the equipment of modern military vessels are those related to electromagnetic interferences and competition among different devices for their best position on the ship, for example in terms of line of sight, radiation hazard (RADHAZ), signal covering and accessibility for maintenance (Orem 1987).
This is mainly the reason why there are several recently developed integrated masts: these configurations allow overcoming the traditional approaches, based on trade-off solution, which inevitably lead to a reduction of sensors performances. Often the hollow structure is based on external allocation of sensors and antennas, while cables, electronic devices cabinets, necessary power sources and supporting systems are located internally; often the whole system is built in composite materials with a snub-conic shape on its top as well as a radome hosting the antenna for satellite communications (SATCOMs), while at the base normally the Identification Friend or Foe (IFF) with circular configuration are located (Van Werkhoven and Van Achen, 2010).
These solutions are divided by levels and could include planar sensors, rotating sensors such as navigation radar, navigation lights and passive sensors (an electro-optical system that allows panoramic patrolling and Electronic Surveillance Measure), multifunctional radar, communication systems for net-centric skills and 3D radar for aero-naval patrolling. In some other configuration the mast cabinet hosts IFF, electronic devices for radar sensors and systems for radar communications and data links (Mouritz and Gardiner 2001). The system also includes radar with planar sensors for volumetric searches, radar with the same characteristics, but devoted to sea surface patrolling and a passive thermal camera that, combined with an electro-optical passive sensor, provides panoramic patrolling. In particular an example of devices and sensors composing an integrated mast is summarized in the following list:

- Satellite communication systems: LRIT, TT 3000 E, Immarsat Standard C, Immarsat Standard Mini-M, Capsat Fleet, Fleet 77, Fleet 33, Jue 85, Immarsat Standard Mini-C, Immarsat Regional BGAN, Immarsat GAN, SCANSAT Sailor SC 4000 Iridium
- Communication Systems in several kinds of bands: SSAS, Radiotelefoni VHF, Radiotelefoni SSB
- Optical and laser communication systems: MM-fiber, GaAs-Laser, LED, MM & SM-fiber, InGaAsP FP-laser, InGaAsP DFB-lasermplifiers, WDM-Systems
- Thermal cameras; cool thermal imagers and uncool thermal imagers
- Laser Range Systems: fixed or mobile laser systems

- Fire detection: Electro-Optical Fire Control System (FCS)
- IFF Systems
- FLIR (Forward Looking Infrared) Systems: long wavelength systems, mid-wavelength systems, short-wavelength systems
- Active radars
- Electronic Support Measures (ESM)
- Flare detectors
- Electronic warfare systems

Due to the the growing density of electrical and electronic systems onboard contemporary military vessels, that need to coexist with detection sensors emitting signals in the same electromagnetic spectrum, several studies and researches have already been led about devices electromagnetic compatibility: in 1998 Dixon described an innovative electromagnetic compatibility (EMC) approach developed in order to mitigate risks deriving from the relaxation electric field emission requirements aboard naval platforms (Dixon, 1998). One year later a powerful evaluation technique referred to military vessels inductive equipment was invented paying particular attention to high power HF transmitter (Sispal et al. 1999). Furthermore in 2002 it was developed a software devoted to design radiating systems onboard and even to test their EMC combining Method of Moments and Physical Optics techniques (Obelleiro et al., 2002), while in 2003 Raghu described requirements for the correct implementation of EMC practices (Raghu, 2003). A survey about ultrawide-band radar was led in 2004 (Mokole et al. 2004) and one of the first techniques for simulating EMC on naval units was presented in 2005 (Zhou and Xie, 2005).
More recently in 2006 Dymarkowski formulated an electromagnetic interference (EMI) matrix related to an Hydro-acoustic system and a Radio-location in order to organize the whole vessel devices test plan (Dymarkowski et al., 2006). One year later he continued his work describing disturbances affecting ship weapon control system, underwater surveillance system and passive defense system, also identifying their electromagnetic noise resistance and their standardization (Dymarkowski et al. 2007).
The exploitation of data-mining technology for predicting electromagnetic compatibility on naval ship systems and improving anti-jamming measures was introduced in 2007 (Yu-Feng et al. 2007), while in the last year a powerful instrument to reduce marine VHF (Very High Frequency) communication band radiation was provided by an electronic field simulation software (Jim et al. 2013). Finally some researchers have recently measured radiated emissions of ultra wide band surveillance radar (Johnk R.T. et al. 2013).
Technological innovation has also allowed improvements in marine warfare electronic systems through a softkill effectiveness analysis, such as that developed by Lancon in 2011.
Furthermore, the increasing quantity of electronic devices that have to coexist on modern military vessels has recently determined the design of an integrated mast combining the whole onboard equipment. The Advanced Enclosed Mast Sensor System, developed at the end of the nineties, gathering vessel antennas and other onboard equipment, allowed to reduce maintenance and life-cycle costs and even radar signature (Benson, 1998). Few years later some researchers created the model of a four side cone shaped mast in order to test the its structural answer in a wind tunnel at the variation of the wind pressure (Yao et al. , 2002). Steps forward of technology have allowed to improve integrated mast system: in particular in 2010 a mast characterized by multifunctional material and composites technology was installed on UK aircraft carriers (Kane et al., 2010). In the same year an inverted model method was developed to test mast structure stress in case of ship sway: such analysis was devoted to improve the system shape design (Yao et al., 2010). In parallel the system shock resistance was also evaluated under air explosion thanks to high order, monotone and finite element algorithm which is called Flux-Corrected-Transport (Li et al. 2010).

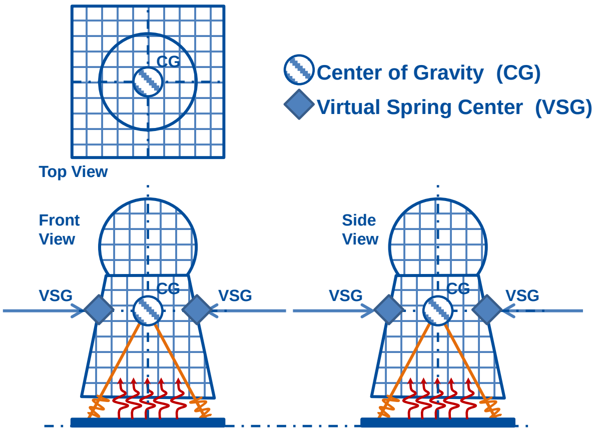

Figure 1: Drawing of Apparatus for mechanically isolating integrated sensor arrangement module above cabinet module of a ship

Integrated mast designed by Thales Nederland represents an important example of this technology solution: it includes communication antennas, radars and electro-optical sensors (Van Werkhoven and Van Achen, 2010) and since the following year it has been provided with an “Apparatus for mechanically isolating integrated sensor arrangement module (ISAM) above cabinet module (CM) of the ship” where the ISAM is proposed with several spring dampers headed to a point in horizontal plane containing its centre gravity (patent owned by Hogeman et al. 2011) as proposed in figure 1.
In addition radar cross section of naval vessels mast platform has been recently reduced thanks to a technological solution based on a wedge structure (Ho L.J., 2013).
Among detection sensors gathered by such innovative vessels masts there are infrared sensors, acoustic sensors, laser sensors, radar, sonar and thermal cameras. At the end of the nineties, for example, it was designed an innovative Staring Infrared Panoramic Sensor

(SIRPS) in order to detect low-flying targets (Barrios et al., 1997). Few years later some researchers invented a powerful infrared sensor system combining new focal plane arrays with effective signal processing algorithms (Brusgard 1999). In addition the first active array multifunctional radar to be used for tracking, detection and even illumination of low-flying anti-ship missiles was introduced in 2003 (Fontana, Krueger, 2003). Other systems guaranteeing information to be integrated from different sources and then distributed in a secure manner or identifying surface threats were developed respectively in 2004 (Shaw et al., 2004) and 2007 (Stottler et al., 2007). In the same years Thales developed a new infrared system for search and track (Grollet et al., 2007). Fire detection and situational awareness, instead, represented the goal of new multisensory equipment to be installed on the Navy vessels (Minor et al. 2007). In particular fire detection was improved one year later using multicriteria technology (Hammond et al., 2008). Furthermore unexpected variations in data collected by others sensors could be identified by using a integrated Position, Navigation and Timing system (Woodward, Webb, 2009). Detection referred to naval vehicles since 2010 has been performed through electro-optical sensor systems (Van Valkenburg, Van Haarst, 2010) or thermal imaging (Akula et al., 2011). About electro-optical sensors, the problem of their integration in ship combat management system has been addressed in this context (Ten Holter et al., 2011). In addition in 2012 researchers have developed a model of complex event detection in shipboard surveillance (Liu et al., 2012), while a simulation model has been created in order to evaluate onboard wireless sensor network performance (Kdouh et al., 2012). Finally a possible approach for facing issues related to surface and underwater detection has been addressed using passive acoustic sensors technology (Sutin et al., 2013).

4. INTEROPERABILITY APPROACH AND STANDARDS

As already anticipated the use of interoperable simulation allows considering interferences and interactions among the different systems; from this point of view the first step is to identify the interoperability standards to be adopted. In this case the authors identified High Level Architecture (HLA) as the most appropriate solution for this context even considering the long experience in applying it in several sectors including marine domain (Bruzzone, Bocca 2006; Massei, Tremori, 2011).
Indeed it is important to state there are other existing approaches in this area including previous DIS standards (Distributed Interactive Simulation) and approaches such as Test & Training Enabling Architecture (TENA), Common Training Instrumentation Architecture (CTIA); therefore it is evident that DIS approach for distributed simulation is focusing on data exchange among different simulation providing not a very effective approach for addressing the current problem where the issue is not to connect simulators, but to define guidelines for developing new models and guarantee real interoperability among them; from other point of view the other distributed approaches are currently often used mostly by proprietary and specific applications. It is evident that the use of HLA is currently the unique simulation approach addressing interoperability for our application context that benefits from modern concepts, solid standard (recently updated in 2010) and strong directive from major customers (e.g. NATO STANAG 4603).
Indeed the HLA was originally promoted by US Modeling and Simulation Office since 1996 (at that time Defense Modeling and Simulation Office) and it was presented in several contexts both nationally and internationally for guarantee maximum diffusions (McGlynn, 1996; Ratzenberger, 1996). HLA was used in several applications and it further evolved consolidating its releases in 1.3 and NG; the RTI (Run Time Infrastructure) was distributed through DMSO, while some company developed commercial releases in international markets (i.e. Pitch Technologies). In 2000 the Institute of Electrical and Electronics Engineers (IEEE) emitted the first version of the actual standard (IEEE 1516) as extension of the original DoD Documentation by addressing HLA frameworks and rules, Federate Interface Specifications and Object Model Template (OMT) specifications.
In addition additional support documents were developed such as IEEE 1516.3-2003, “Recommended Practice for High Level Architecture Federation Development and Execution Process (FEDEP)”, followed in 2007 by IEEE 1516.4, “Recommended Practice for Verification, Validation, and Accreditation of a Federation an Overlay to the High Level Architecture Federation Development and Execution Process”. Recently, in 2010, it was published the latest 1516 standard version that introduce some significant advance in terms of dynamic models and incrementally growing federations and it represents the most appropriate approach for the integrated mast modelling and technical comprehensive ship simulation; indeed NATO STANAG 4603 was introduced after 2006 in order to evolve from previous DIS (Distributed Interactive Simulation) standard (STANAG 4482 and IEEE 1278).
Hence HLA standard represents a philosophical approach to Modeling and Simulation (M&S) and it includes HLA rules, Object Model Template (OMT) and Interface Specifications, so it requires that modelling experts adopt this approach; therefore through Object Model Templates it becomes possible to define the structure to develop Federation Object Model (FOM), Simulation Object Model (SOM) and Management Object Model (MOM).
Indeed, the proposed research is focused on FOM definition since it is devoted to identify specifications and reference architectures related to onboard systems

models: the final goal, indeed, consists of integrating such models in a federation composed of different interoperable simulators and then testing their effectiveness, their interactions with each other and with vessel platform systems (for example in terms of interferences) and their compatibility with naval unit configuration in different operative modes.

5. INTEROPERABLE SIMULATION AND MODELING REQUIREMENTS

Therefore while technological interoperability aspects are fundamental it is important to outline that HLA approach don't requires to know details about internal structure of the different federate models; this aspect is pretty important to guarantee confidentiality of sensitive information related to technologies of the different system and subsystems that often belong to different companies with different industrial and commercial interested. By other point of view it is evident that interactions and interference in our context deal with different physical aspects that need to be addressed in the models such as:

- Electromagnetic Compatibility: the different emission could generate interferences with corresponding degeneration on radar and communication performances; in addition power supply or distribution could generate peak charges and/or interference, under specific conditions, creating problems to other systems
- Line of Sight in Different Spectrum (Optical Line of Sight, IR Line of Sight): EO/IR sensors (Electro Optical and Infrared) are stabilized and move to detect and track sensors, in their motion during operation it is fundamental that they could explore and track assigned areas and targets, so this aspect need to be addressed and it is necessary even to consider the influence of the different aspect to verify interference (e.g. ship emissions could deteriorate IR system performance, launch of flares could blind FLIR in some conditions).
- Physical Dynamics (Motion, Sea Keeping, Vibrations): for instance a large rotating radar antenna located at the top of the integrated mast could influence motion and introduce vibrations.

Do these issues the proposed Federation Object Model should enable to faces different aspects including electric and electromagnetic components; indeed it is necessary that the models should include algorithms able to consider the devices and sensors dynamic mutual compatibility (Groves 2014).

It is important to consider the interaction with other naval platform systems and its infrastructures: this aspect should be analyzed with reference to real operative conditions in the maritime environment, corresponding to operations while the instruments are working simultaneously to carry out specific tasks.

It is also necessary to be able to simulate dynamically the physical aspects, related to onboard masses static, dynamic stability and vibrational effects (Chen et al., 2006); indeed masses disposition and rotation over the vessel platform even influences the whole ship motion and vibrations. The optical elements are also strongly influenced by the infrastructures, but also by the different modes and actions carried out dynamically during the operations; this affects sensor effectiveness in different vessel configurations and operative modes and it is necessary to include these elements in the simulation; in similar way the laser communications and tracking are affected by line of sight and boundary conditions related also to the on-going operations for instance due to smoke (Alam, Bal, 2007). In addition the IR sensors are also affected by these aspects and they result even more sensible to objects overheating or high temperature emissions that could make neighboring device effectiveness to decrease drastically (Powell et al., 2000).

Based on these considerations it is suggested to adopt the architecture proposed in figure 2; this CVIF includes potentially several simulators including among the others:

- Sensor Simulators
- Communication System Simulators
- EW (Electronic Warfare) System Simulators
- ESM (Electronic Support Measures) System Simulators
- Weapon System Simulators
- Vessel System Simulators
- Vessel Sub-System Simulators
- Vessel Infrastructure Models
- Environmental Models
- CMS (Combat Management Systems)
- CGF (Computer Generated Forces)
- Ship Simulators (e.g. training equipment)
- Electromagnetic Simulation Models
- Optical Simulation Models
- IR Simulation Models

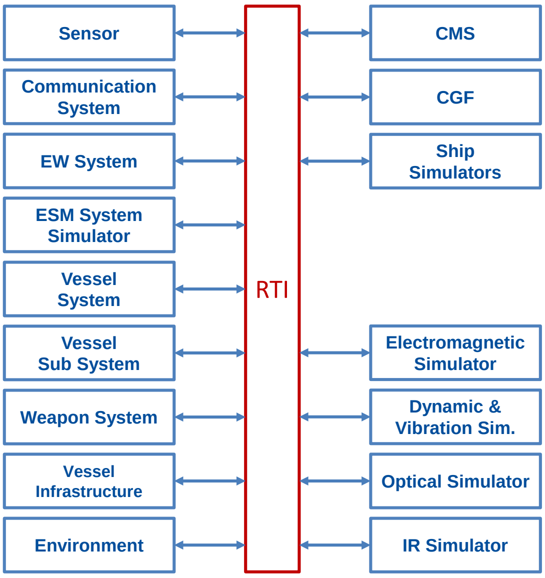

Figure 2: Technical Comprehensive Vessel Interoperable Federation

It is interesting to outline that the adoption of HLA allows conducting simulation experiments by federating models as well as real equipment. The use of CGF and the inclusion of CMS are fundamental to create realistic scenarios; for instance it is suggested to adopt Intelligent Agents such as IA-CGF (Intelligent Agents Computer Generated Forces) to create dynamic stochastic complex scenarios (Bruzzone, Tremori, Massei, 2011). In the federation it should be defined who is in charge of addressing transversal analysis; this activity is defined as I3S (Interactions and Interferences Interoperable Simulation); there are multiple possibilities such as:

- Each Federate is evaluating in its own model, internally, capabilities deriving from other element dynamic configuration and operation mode; for instance the FLIR (Forward Looking Infrared) system detects its capability to track a specific CGF considering internally the impact of the ship dynamic geometry and emissions.
- Some System Federate is in charge of managing specific aspects; for instance the Vessel Infrastructure Model is computing line of sight of each sensor versus each target
- Specific Interaction Simulation Models (SISM) are developed to address crucial aspects affecting interference and interaction; the IR simulation model addressed all the aspects related to capability estimation within IR Domain

The authors suggest keeping the structure flexible to avoid problems in adapting the federation to the integration of different models, but to respect interoperability requirement compatibility as proposed by the FOM presented in the following; therefore the authors recommended that if applicable the use of specific simulation models should be adopted to guarantee more effectiveness during the VV&A (Verification, Validation and Accreditation) procedures and testing. In any case the FOM proposed structure provides the requirements that guarantee to properly simulate this context by introducing into the different models the attributes and capabilities to handle the interactions; indeed this corresponds in adopting the following approach in defining the FOM; each Federate should include at least the following objects with corresponding attributes representing their system (e.g. Light Detection And Ranging LIDAR):

- ***Physical Object***
  - Name: for example Laser Range Finder
  - ID: code that uniquely identifies the object
  - Type: for example detection sensor, communication system etc.
  - Status: for example active, full power, etc.
  - Mass
  - Position expressed in meters of its barycenter from father object (the vessel) barycenter in terms of three-dimensional Cartesian coordinates x, y, z, and aeronautics angles α, β, γ. If the object is composed of more components it has to be defined the position of all such components split up
  - Inertia moment along axes x, y and z. If the object is composed of more components it has to be defined the moment of inertia of all such components split up
  - Current translation speeds and rotations along/around axes x, y, z respectively or the first derivatives of three-dimensional Cartesian coordinates x^1, y^1, z^1 and first derivatives of aeronautics angles α^1, β^1, γ^1
  - Current Accelerations identified by the second derivatives of three-dimensional Cartesian coordinates x^2, y^2, z^2 and by the second derivatives of aeronautics angles α^2, β^2, γ^2
  - Vibration spectrum over the three different axis
  - Vibrational Absorption
  - Electromagnetic Absorption
  - Current Shape/Configuration including cubicles affected by the current configuration (e.g. smoke)
  - Temperature
  - Emissions in IR Spectrum
  - Electromagnetic absorption

- ***Electromagnetic Object***
  - Operational Conditions: tracking, scanning, etc.
  - Mode (e.g. line of sight, sky wave, etc.)
  - Power
  - Frequency
  - Carrier
  - Pulse width
  - Pulse Repetition Frequency

Federation Object Model also includes the definition of interactions among different entities within the Federation; an important interaction class is represented by ICCR (interaction class communication request). The interactions parameters and related definition are reported as follows:

- Time: when the communication happens
- Source: What object transmits the communication
- Destination: What object receives the communication
- Content: content of the communication, for example a message
- Specific Communication mode: characteristics of the communication, for example in terms of frequency and signal power
- Configuration and operative mode: configuration and operative mode of the communication system at that time instant

The following interaction class is related to the possibility of two objects located on different vessels to see the one the signal of the other; this is defined as ICSR (Interaction Class Sensor Request). The interactions parameters and related definition are reported as follows:

- Time: when the signal is sent
- Source: What object is looking
- Destination: What is looking to the object

- Specific Looking Mode: characteristics of the sensor, for example in terms of power and frequency
- Configuration and operative mode: configuration and operative mode of the sensor in that time instant

The entity in charge I3S will react to these interactions through the following interaction class defined ICRR (Interaction Class Request Response):

- Time: when the signal is received by the entity
- Entity: getting this information
- Original Source: original source of the request
- Destination: original target of the request
- Perception type: the type of the signal received by the entity (e.g. directional ESM, visual light signal, radar detection).
- Type of request (e.g. IISR, IICR, Reactive IISR and Reactive IICR)
- Success: the target is correctly seen by the sensor or not (probability of success is determined)
- Failure reason: for example too long distance, sensor carrying out another operation, other devices obstructing view field of the sensor, other devices electromagnetic interferences or too high functioning temperatures damaging the sensor under exam
- QoS: Quality of the service in percentage between 0 and 1

Based on this approach the I3S in charge for the specific aspect (e.g. means that based on Electromagnetic SISM) will generate a set of interactions corresponding to the moments when this actions is perceived by the different players interested on this element; for instance if the originating sensor of the ICSR is a Radar, it will get back a ICRR from the Electromagnetic SISM confirming success or not of his action on a target and it will inform other potential systems interested with other ICRR (e.g. the target ESM system will receive a ICRR about this contact if it is active).

6. CONCLUSIONS

The proposed approach allows developing an interoperable simulation able to federate different models for addressing interference and interactions among systems and subsystems; the use of HLA guarantees technological and conceptual interoperability as well as solid standard base; in addition the modelling approach for managing the interactions is flexible and could integrate multi resolution simulators for multiple applications.

The introduction of a joint comprehensive simulation over these technical aspects provides a strategic advantage in development of new vessels; considering the interests demonstrated by different users, this approach could lead to the evolution of legacy simulators to become really interoperable, reducing vessel development costs and times.

The authors are currently working on implementing a solution for the case study related to an integrated mast in order to validate the proposed approach and to conduct integration testing activities.

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