THE 6TH INTERNATIONAL DEFENSE AND HOMELAND SECURITY SIMULATION WORKSHOP

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AGOSTINO BRUZZONE
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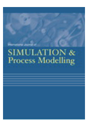

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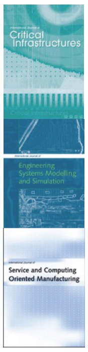

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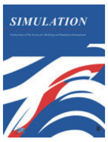

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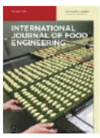

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Co-Chairs' Message

Welcome To DHSS 2016!

Welcome to the International Defense and Homeland Security Simulation (DHSS 2016) Workshop! This year as simulation experts from around the world, we meet for DHSS workshop in the wonderful framework of Larnaca, Cyprus.

DHSS 2016 articles cover different technical topics related to Defense and Homeland Security. In particular, this year there are contributions that range from the architectural design of combat systems (by using simulation based approaches) to models describing hybrid conflict environments, from safety and security in road transport to cyber-attacks to critical infrastructures and from interoperable simulation for disaster management (by using intelligent agents) to forced population displacement. The contributions come in the form of new methodologies, advanced applications on real case studies as well as in terms of state of the art reviews.

By reading all the different articles, it is clear that Modeling & Simulation is able to act as "trait d'union" between different needs mostly related to design, training (including the use of serious games) and decision support.

In DHSS Workshop, simulation provides the right approach to understand what is currently needed in the Defense and Homeland Security sector in terms of new architectures, support to operations, training and analysis of both military and civilians.

As tradition, the high scientific quality of DHSS articles is proved not only by the work done by the authors and reviewers (each paper has received two blind reviews) but also by the fact that papers are indexed in one of the most important scientific data bases in the world (SCOPUS).

Again, welcome and we hope you will find many useful topics in these proceedings and to meet your defense and homeland security training, analysis and operational needs and you will enjoy the wonderful framework of Larnaca!

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ARCHITECTURE-ORIENTED COMBAT SYSTEM EFFECTIVENESS SIMULATION MODELING

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ABSTRACT
Combat system effectiveness simulation (CESS) is a special type of complex system simulation. Their models feature multiple disciplines and are rich in domain knowledge. To develop such simulation models, model composability must play a central role where legacy models can be systematically reused and efficiently developed. Domain-friendly modeling is also a requisite for facilitating model development. Traditional modeling methodologies for CESS are either domain-neutral (lack of domain related consideration) or domain-oriented (lack of openness and evolvability) and cannot well fulfill these requirements together. Inspired by the concept of **architecture** in systems and software engineering fields, we extend it into a concept of **model architecture** for complex simulation systems, and propose a model architecture-oriented modeling methodology in which model architecture plays a central role. In this methodology, toward achieving model composability, domain-neutral M&S technologies are used to describe model architecture to improve model evolvability, and domain-specific modeling (DSM) is employed to aid domain experts. Two layers of model architecture, i.e. domain model architecture (DMA) and application model architecture (AMA), are differentiated and explicitly represented in a concrete model architecture-oriented CESS modeling framework.

Keywords: domain-neutral, domain-oriented, architecture, model architecture, model architecture-oriented

1. INTRODUCTION

Combat systems are typical complex systems. Combat effectiveness is one of the most important metrics in acquisition and overall design of various combat systems like aircrafts, warships, submarines, air defense systems, etc. Recently, simulation, instead of theoretical analysis and real experimentation, has become the most prominent approach to evaluate the effectiveness of combat systems (Zimmerman 2014). Combat system effectiveness simulation (CESS) is therefore a special type of complex system simulation of great importance. CESS simulation models are featured with multiple disciplines and intensive knowledge. Developing a useful CESS simulation is obviously non-trivial. The corresponding modeling methodologies should not only support the discipline-specific and user-friendly heterogeneous modeling, but also provide the capabilities to compose a new simulation from existing simulation models so as to both reuse the intensive knowledge within different simulation models, and provide rapid response to the simulation acquisition needs.

Traditional methodologies used in CESS can be roughly divided into two categories. One is domain-neutral and application-specific. It uses some unified modeling and simulation mechanisms with a powerful infrastructure and a model library containing domain-specific model components. The simulation applications are supposed to be assembled in a way of infrastructure plus components. Examples include standardized simulation protocol like HLA (Hemingway et al. 2012; Seo et al. 2014), model specification standard-based like SMP2 (Lei et al. 2009), and universal modeling formalism-based like DEVS (Zeigler, Hall, and Sarjoughian 1999; Seo et al. 2014). The second category can be called domain-oriented by providing a CESS-oriented simulation system, within which different simulation applications can be composed from built-in components and configured with application specific parameters. Prominent examples include EADSim (Azar 2003), SEAS (Trevisani and Sisti 2000; Miller and Honabarger 2006), FLAMES (Niland 2006), etc.

Each category by itself lacks some capabilities significant to CESS modeling. For the domain-neutral methodologies, the domain friendliness is limited since the universal property across different domains is the design focus of various protocols, specifications, and formalisms. In addition, the relationships among different model components are missing from both technologies and components themselves. Therefore, it's not easy to reuse the behavioral patterns formed by several related components. This shortcoming, however, is well treated in domain-oriented methodologies. Each CESS simulation system focuses on one or several application domains and provides a consistent strong model architecture, which describes possible model components and their relationships in the CESS application domains and provides some extension mechanisms to support new components development and integration. These domain-oriented simulation systems still have some limitations worth mentioning, including: 1) they are developed mostly from a software engineering viewpoint. Each has a software architecture in which the model architecture is embedded. There is no explicit, formal, or platform-independent representation for the model architecture and lack open modeling methods and specifications. Therefore, it is not easy to extend and evolve the model architecture. 2) The behavioral models are mostly black-box implementations. Users have to resort to the model documents, if there are any, for understanding their dynamics. The round-trip between the model documents and implementation codes is too difficult to carry out by simulationists. To modify or extend the model behaviors, which occurs frequently in CESS applications, the users must ask system vendors for help. 3) Each is only applicable to a certain domain, ad hoc in essence, and is not scalable to other domains.

In this research, to tackle the above problems found in CESS practice with traditional modeling methodologies, we propose a model architecture-oriented modeling methodology by employing several technologies provided by model driven engineering paradigm to meet the modeling requirements of CESS. In Section 2, the background and related work are described. In Section 3, the model architecture-oriented CESS modeling methodology and a concrete modeling framework are proposed. In Section 4, conclusions and future work are briefly discussed.

2. BACKGROUND

2.1. Defining CESS

Effectiveness is the ability of a system to accomplish a certain mission. To evaluate the effectiveness of a certain combat system, a CESS needs to construct a mission environment. A typical mission of a combat system is to attack some enemy combat systems or defend some assets from attack by enemy combat systems. A combat system's model usually consists of two kinds of components. The first one is within physical or information domain, including models of platforms, sensors, weapons, measures, communicators, etc. We call these physical models since their functionalities and behavior patterns are relatively stable across applications. The second one is within cognition or social domain, including course-of-actions, formations, situation awareness, combat planning, combat rules, etc. These models are called cognitive models since they are largely determined by the commanders and combatants within the simulation and highly variable in different applications.

A typical experiment based on CESS is like the following. Some performance parameters of the combat system under investigation, e.g., RCS (Radar Cross Section) of the combat platform or range of the sensor on board, are changed while keeping others constant. By monitoring the changes occurring in the combat outcome, the effectiveness of the combat system can be evaluated. The typical purpose is to provide quantitative support for choosing the optimal design alternatives for the combat system in question.

CESS falls to a special and large category of military simulations. The opposing forces on each side are limited to a few. Each side only accomplishes one mission in an experiment so as to make the influence of the combat system on the overall combat outcome more prominent. In this regard, CESS is an engagement-level simulation, compared to the mission-level and above where there are many missions within each side (Sjoberg 2009). In CESS, human is not in the loop. That means the relevant behaviors of combatants, i.e. cognitive behaviors, have to be completely represented in the simulation.

2.2. Modeling requirements of CESS

Models are always crucial to simulation, especially to complex simulations like CESS. It is better to solve the most difficult part of each simulation problem at model level rather than implementation level. From both essential and practical points of view, CESS shows three kinds of important modeling requirements.

1. Model composability.

Model composability is an extensive explored topic in defense simulation area (Davis and Anderson 2004). In CESS domain, there is great benefit to realize model composability. Generally speaking, any combat system can be used to accomplish many missions. To comprehensively evaluate the effectiveness of a combat system, a couple of simulation applications are supposed to be constructed. There are many overlaps across these applications that give rise to lots of opportunities to reuse and compose models. For example, the possible missions for a fighter aircraft include air combat, ground attack, surface attack, air-defense breakthrough, antisubmarine, etc., while a warship is probably meant to fulfill missions like surface combat, air defense, sub defense, and so on. To evaluate their effectiveness, different simulation applications should be created. The effectiveness used to trade off the design alternatives shall come from a synthesis of all possible combat outcomes. The chance to reuse and compose models exists not only among simulation applications created for a certain combat system, but among applications for different combat systems. For instance, a warship model created for surface attack simulation of a fighter aircraft can be reused in an air defense simulation of a warship although the conditions and focus change.

2. Domain specific modeling

CESS as a complex simulation consists of many different kinds of model components. Each may belong to a distinct domain. To clearly represent the behaviors of each component and their interactions to facilitate understanding and validation of the models by the analysts, different formalisms ought to be exploited to represent behaviors of each model component in a natural way. The modeling methodology should be able to couple them together. Among these, a clear separated modeling between physical domain and cognitive domain is necessary. For the physical domain, the emphasis is mainly on choosing appropriate formalisms for each kind of components and coupling different formalism-based models together semantically. In the cognitive domain, different combat platforms have different cognitive behavior patterns. Furthermore, the modelers would be the analysts or users since the cognitive behaviors change across applications. In this regard, the methodology shall provide combat platform specific and user friendly modeling capabilities.

3. Model evolvability

Since modeling and simulation has been applied into CESS for decades, model evolvability issue becomes more and more significant. In many organizations, including some academic institutes dedicated to applied modeling and simulation research, it has become necessary to both develop and evolve simulation models. Although the concept of model evolvability in general encompasses a lot of connotations, the requirements emerged from CESS gives more focus on the simulation models' potentials to be evolved in a convenient way. That is, the aim is to make simulation models more understandable and modifiable in order to meet the new demands not considered at the outset of a simulation development project. In most cases, CESS simulation models are developed in a document-plus-code way, where documents are used to capture the conceptual and mathematic models; codes are the implementation of these models. The link between conceptual models and codes are often very weak. It is not easy to keep both consistent. When the first inconsistency unavoidably occurs, the models begin to 'die'. Because of this, the simulation models are supposed to be represented abstractly, formally, and platform-independently, and model transformation and code generation should be applied where possible.

2.3. Model driven software and system modeling

Simulation models are in essence a special kind of software. Most of the above CESS modeling requirements can be handled well in a representation level using software-modeling methods. Model-driven engineering (MDE) is a recent outstanding advancement in the software engineering domain, and has been successfully used in systems and simulation modeling fields. By raising the abstraction of the computerized model representation to platform-independent and domain specific level, MDE can contribute much to solving CESS modeling problems. Currently, there are mainly two approaches for realizing MDE. One is model driven architecture (MDA); the other is domain specific modeling (DSM).

1. MDA and SMP

MDA is the OMG (Object Management Group)'s solution for MDE. For modeling, MDA adopts a bottom-up strategy. The UML (Unified Modeling Language) is prescribed as the modeling language for all kinds of platform-independent models (PIMs). MDA also provides several related technologies to support the transformation from PIM to platform-specific model (PSM) and code generation. For domain specific modeling requirements, MDA provides two kinds of metamodeling mechanisms, one is light-weighted UML profile-based metamodeling, and the other is directly metamodeling based on MOF (Meta-Object Facility). In the former, all the modeling capabilities provided by UML can be inherited. In some cases such as domain specific software, this is a big advantage. For other cases like system simulation, however, this may become a downside due to the significant differences between simulation models and common software. For this reason, in system simulation areas, there are cases where the MOF-based metamodeling approach is chosen. Simulation modeling platform (SMP) is one representative instance.

SMP is a simulation model specification standard maintained by European Cooperation for Space Standardization (ECSS) (Sebastiao and Nisio 2008). The main objective of SMP is to provide a platform-independent simulation model specification to facilitate simulation model portability and reuse it across different simulation applications within European Space Agency (ESA) and ECSS. SMP mainly consists of three parts (ECSS 2011). The first one is a simulation model definition language (SMDL), which itself is a metamodel based on MOF. The modeling capability provided by SMDL is actually very similar to the UML's structural modeling features, like class-based, component-based, and interface-based, etc. What has been missed in UML is partly supported by the SMDL, like instance modeling, assembly modeling, and schedule modeling. The rest is supported by the simulation component model (SCM), which is the second part of SMP. SCM views models, simulator, and simulation services all as components. The simulation services include time keeper, event manager, link manager, and many others necessary for simulation modeling which are not included in UML. The interfaces of these components are defined in detail by SCM. The third part of SMP is a C++ mapping specification, which maps the platform-independent SMDL and SCM into C++. The semantics of SMP modeling language is articulated in such a translational way. With SMP, design-based integration and composition of simulation models can be easily fulfilled. The behavioral modeling, however, is not well supported, since it is not within the design objectives. Nonetheless, SMP is very helpful for solving the model composability and model evolvability problems.

2. Domain specific modeling

MDA is in essence technology-oriented, whereas domain-specific modeling (DSM) (Kelly and Tolvanen 2008) is problem-oriented and follows a top-down strategy. The objective is to support the modeler in modeling the problem using domain specific and human-friendly languages. Different from MDA which generally prescribes UML as the 'official' model language for every domain (via profile-based metamodel extension mechanism), for DSM, there is no pre-existent modeling language at the beginning. The languages are designed from scratch for a domain scope. The first step is to analyze the domain requirements and concepts. The second step is to use a certain metamodeling language to describe the domain concepts and their rules to get a domain-specific metamodel, which actually defines a domain-specific modeling language. The third step is to create the visual representation or concrete syntax of the language. The forth step is to define the code generators for model checking, codes, documentation, etc. To make the code generator development easier, it is necessary to provide a domain-specific framework or component library. The model representation based on DSM tends to be a higher-level abstraction. In this way, the user can conveniently specify the models and have a good understanding of the behavior described within the model. DSM is mostly appropriate to be applied in a certain well-defined domain, e.g., within a company or organization.

DSM is actually a special approach to domain engineering. As stated earlier, CESS is a knowledge intensive domain. Following the idea of domain engineering (Harsu 2002), the knowledge in CESS can be divided into domain invariant knowledge (DIK) and application variable knowledge (AVK). DIK refers to the knowledge common to the domain, but not specific to a particular application, whereas AVK is the knowledge specific to one or several applications but not qualified to the domain level. The main interest of applying DSM is in cognitive domain since there is much more AVK in it than in physical domain. In this regard, even the entire physical domain knowledge can be viewed as DIK, which can be pre-implemented separately. Specifically, for a set of physical domain models, there can be many possible combat course-of-actions and command decision choices in cognitive domain. In addition, for different combat systems, there may be different cognitive behavior patterns. Most importantly, the analysts have to create cognitive models themselves since these models are mostly mission related. The CESS modeling methodology should ease the cognitive modeling task as much as possible. DSM does provide a good solution.

3. MODEL ARCHITECTURE-ORIENTED CESS MODELING METHODOLOGY

3.1. Architecture and model architecture

Architecture is a frequently seen term in many domains, such as building, software, and system engineering. There are numerous definitions of architecture (CMU-SEI 2014). Here we adopt the definition provided by ISO/IEC/IEEE for systems and software engineering (ISO/IEC/IEEE 2011). Architecture is the "*Fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution*." An architecture is what is fundamental to a system — not necessarily everything about a system, but the essentials.

A complex CESS is a system. Its architecture shall include essential elements like a simulator, simulation services, and simulation models; and essential relationships between simulator and simulation models, and those among different simulation models as schematically shown in the left part of Figure 1. Since the simulator, simulation service, and relationships between simulator and simulation models are largely determined by the M&S technology chosen, the remaining complexity will mainly lie in simulation models and their relationships. Following the definition of architecture of a system, we define model architecture of a simulation system as follows:

Definition 1 Model architecture *of a simulation system is the fundamental concepts or properties of the simulation system in its execution environment embodied in its model components, their relationships, and principles of building or evolving these models.*

For the principles of building or evolving models, we refer to the modeling methods used to support the description and representation of model architecture, including model specifications, formalisms, and languages.

In a sense, model architecture is the kernel of a complex simulation like CESS. Model architecture is also the key to resolve the modeling problems encountered by CESS and other complex simulations. As mentioned in the previous section, for a domain-oriented simulation system, the model architecture can be divided into a Domain Model Architecture (DMA) and many possible Application Model Architectures (AMAs), which is shown in the right part of Figure 1. Each AMA will reuse the DMA via customizing or extending. To achieve maximum reuse, the DMA ought to be designed in an abstract way at the application domain level. What is common to various AMAs is extracted and built into a DMA; a DMA only contains abstract knowledge to be reused in AMAs.

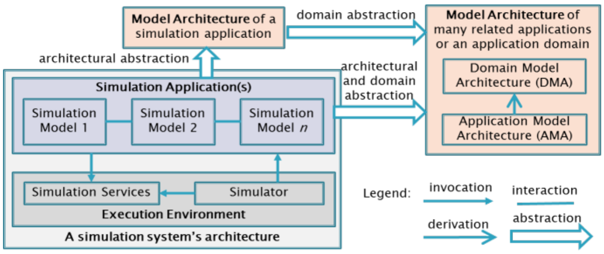


Figure 1 from simulation's architecture to its model architecture

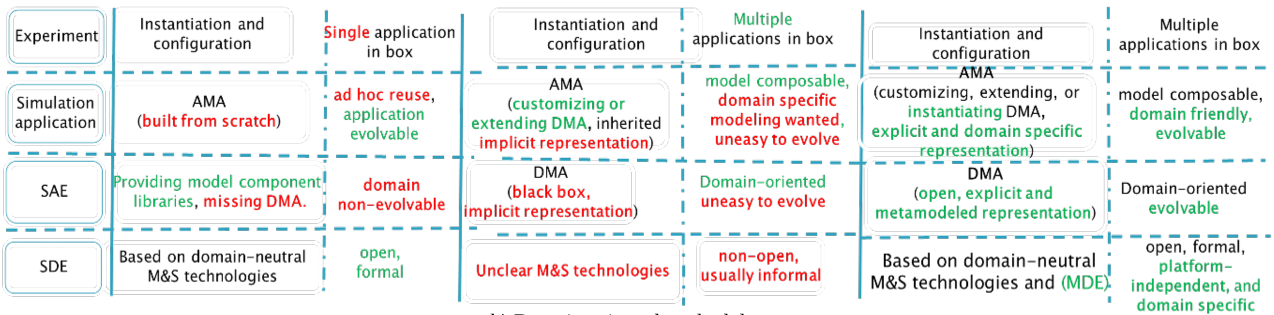
Towards this goal, DMA and AMA can be defined similarly to model architecture:

Definition 2 Domain Model Architecture (DMA) *is with a domain-oriented simulation system. It is the fundamental concepts and properties of the simulation application domain in its execution environment embodied in its model components, their relationships, and principles of building or evolving these models.*
Definition 3 *In a domain-oriented simulation system, an* Application Model Architecture (AMA) *is the fundamental concepts or properties of a simulation application in its execution environment embodied in its model components, their relationships, and principles of building or evolving these models. The model components and their relationships are designed with reuse by either customizing or extending those of DMA. The principles are the same with those of DMA.*

3.2. Toward a model architecture-oriented CESS modeling methodology

3.2.1. Traditional methodologies and their limitations

From the viewpoint of model architecture, traditional CESS modeling methodologies can be structured as shown in Figure 2 (a, b) with four logic layers generic to simulation modeling, including experiment, simulation application, simulation application environment (SAE), and simulation development environment (SDE) layer.
The main characteristic of domain-neutral methodology is its emphasis on certain domain-neutral M&S technologies, either simulation protocol standards, model specification standards, or universal modeling formalisms. Although some powerful simulation development environments provide general or domain-specific model component libraries for reuse, they do not account for DMA. Modelers have to develop one AMA and corresponding model components for each set of application requirements from scratch. Across different applications within a given domain, the AMA developed for one application is unrealistic to be reused in another application for both theoretical reasons, like parsimony principle applied to modeling, and practical reasons, like cost and design complexity. One special advantage of domain-neutral methodology is that the AMA is evolvable since there is an open and standardized representation. However, since there are few domain level considerations in designing an AMA, semantically revising the AMA according to the new application requirements is rather intractable. Domain-neutral methodology is essentially application-specific, and only one certain application can be well supported by the resulting simulation system.
Domain-oriented methodology usually takes composability as the primary objective; the DMA is designed with all the domain modeling requirements in mind. The AMA corresponding to a certain simulation application would mostly be to customize or extend the DMA. In this way, the domain model components and their relationships are reused to a greater extent. As a result, the efforts required for AMA development are greatly reduced. In practice, each specific methodology will be embodied in a powerful simulation system or simulation application environment. Their shortcomings include: 1) the model architectures, especially DMA, are not explicitly represented, which prevents the modelers from extending the model architecture systematically. 2) There is no formal, platform-independent representation of both model architecture and component behavior, which prevents the analysts from completely understanding the models underground and the system from evolving as necessary. 3) There are few domain-specific modeling supports both for physical domain and especially for cognitive domain; the cognitive modeling method provided to users is mostly either configuring rules or handwriting tactical behavior scripts, which lacks either user-friendliness or flexibility.



a) Domain-neutral methodology b) Domain-oriented methodology c) Model architecture-oriented methodology

Figure 2: Traditional CESS modeling methodologies from the viewpoint of model architecture

3.2.2. Model architecture-oriented CESS modeling methodology

From the viewpoint of CESS modeling requirements, domain-oriented methodology is generally more useful than domain-neutral methodology since the most challenging requirement, model composability, could be well supported by DMA. Each specific domain-oriented system simulation is developed mostly from the standpoint of software engineering. Domain-neutral M&S technologies are not given enough prominence as in domain-neutral methodology. This makes achieving model evolvability and composability, but leaves much to be desired. For domain-specific modeling requirement, both methodologies show little awareness of its importance or lack systematic modeling mechanisms. Taking into account these concerns, we propose a *model architecture-oriented methodology* to overcome those limitations found in traditional ones (see the c part of Figure 2). This methodology basically follows ideas from domain-oriented methodology and incorporates powerful M&S technologies found in domain-neutral methodology and introduces several steps:

1. To center domain-oriented simulation systems on model architecture

Practices tell that simulation model architecture is the bottleneck of CESS and other knowledge intensive complex simulations, and should be oriented in the first place from the domain-level viewpoint. Model architecture is the kernel assets that should be well represented and conveniently evolved. Either viewing CESS from a standpoint of software engineering or thinking CESSs simply being another application of some powerful M&S technology will do few helpful to solve those CESS problems.

2. To divide model architecture into DMA and AMA

For knowledge-intensive simulations like CESS, it is better to have a separation between domain level knowledge and application level knowledge to simplify application modeling. Model architecture is supposed to be divided into clearly separated DMA and AMA. DMA only represents domain level knowledge, i.e., DIK; while AMA only represents application level knowledge, i.e. AVK, by reusing knowledge within the DMA.

3. To incorporate DSM into model architecture

As discussed in the earlier section, DSM is a good means to improve domain friendly CESS modeling in general and cognitive modeling in particular. Since model architecture is broadly defined as those essential to a simulation system, it is rational to view domain specific metamodels as part of DMA and domain specific models as part of AMA. This would extend the relationships between DMA and AMA to instantiation in addition to extension and customization.

4. To model DMA and AMA using domain-neutral M&S and MDE technologies

Modeling DMA and AMA using appropriate modeling formalisms and representing them explicitly with a platform-independent and open model specification will greatly ease modelers semantically understanding the concepts and relationships in model architectures, and facilitate model composability and evolvability.

Compared to the domain-oriented methodology as shown in the part b of Figure 2, model architecture, DMA and AMA in specific, is the focus. Different kinds of M&S technologies are applied to model and represent various pieces of the model architecture where appropriate. DSM is applied to improve application level cognitive modeling friendliness. To support DSM, certain metamodeling technologies should be incorporated in simulation development environment layer.

3.3. Model architecture-oriented CESS modeling framework

Guided by the ideas of the model architecture-oriented methodology, a concrete model architecture-oriented CESS modeling framework used in practice is shown in Figure 3. The modeling task is explicitly divided into two layers: domain modeling and application modeling. Domain modeling is mainly toward pre-implementing the DIK for CESS. The product would be the DMA of CESS, which is essential to a CESS simulation system and common to the CESS domain. Application modeling is going to extend or instantiate the DMA, the product would be the AMA, in which the AVK specific to each application is embodied.

The CESS model architecture is modeled from three viewpoints, i.e., structure, physical behavior, and cognitive behavior. The main requirement for structural architecture modeling is model composability. At the domain level, the DMA defines the fundamental abstract model components common to each CESS application. Most importantly, the structural relationships among these components, including composite, aggregate, interface, and event relations are also deliberately designed and defined in an abstract manner. At the application level, the relationships among different concrete model components are largely determined by the relationships defined in DMA. The possible composite space would be greatly reduced, so as to confine the possible semantic invalidity problem to the lowest level. To accomplish this, some powerful structural modeling formalisms, e.g. object-oriented and component-based, are applied. For syntactic composability, the structural architecture is diagrammatically described by a couple of UML class diagrams and formally represented using SMP in a platform-independent way. A UML profile for SMP makes the SMP representation transformed from the UML class diagrams automatically. The SMP representation can be generated into C++ representation automatically.

Physical behavior modeling describes the behaviors within the physical domain for each concept defined in the structural architecture and the dynamic relationships among these concepts. As for the modeling methods, different kinds of behavior modeling formalisms can be employed according to their specificity, including Statecharts, discrete event, activity diagram, sequential diagram, design patterns, etc. Since the model components defined in the structural architecture are at either an abstract domain level or a concrete application level, the physical domain behaviors of these model components are divided and described in DMA and AMA levels respectively. In fact, physical domain behaviors are relatively less variable compared to cognitive ones, most of the physical domain behaviors can be implemented into DMA. Consequently, at the application level, the main requirements for physical behavior architecture modeling are in extending or modifying the physical behaviors defined in DMA in a user friendly manner. This can be achieved by behavior inheritance and override capabilities provided by UML, and by relevant code generators specific to the behavior diagrams used. For UML behavior diagrams, UML profile is employed again to add domain-specific extensions and make the code generators more specifically designed. The target physical behavior model representation language is C++, too.

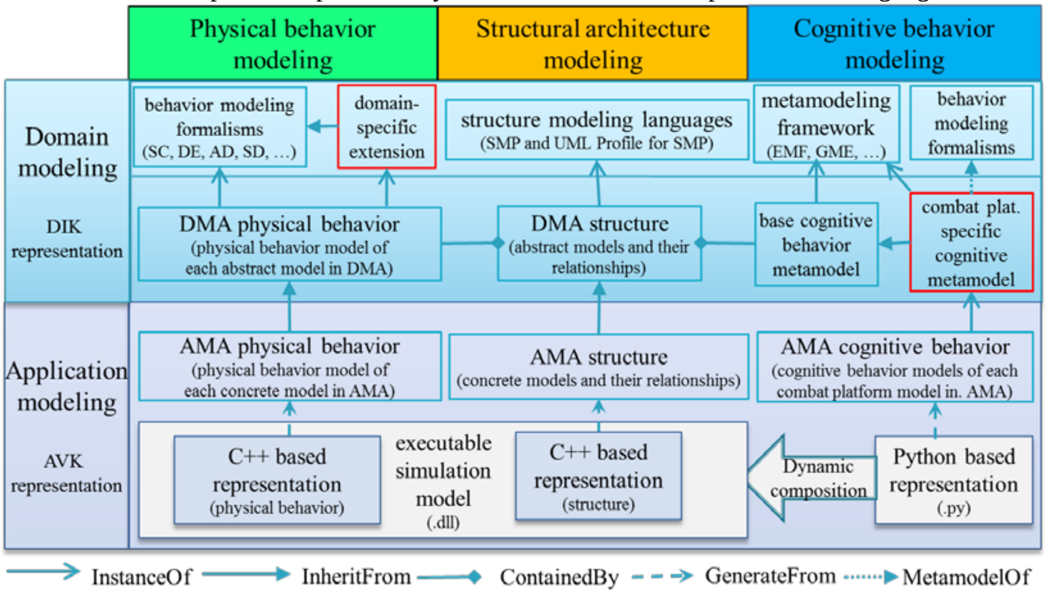


Figure 3: Model architecture-oriented CESS modeling framework

The third aspect is the cognitive behavior modeling. Both physical behaviors and cognitive behavior are behaviors performed by the model architecture concepts or objects. However, there are fundamental differences between them. The physical behaviors are largely determined by the natural laws and constraints, while the cognitive behaviors are mainly up to the free will of human beings, which means that the latter are highly variable across applications. Consequently, there are relatively few common behaviors at the domain level. What can be done at the domain level is to define a cognitive behavior modeling language for each combat platform type based on some behavior modeling formalisms with combat platform specific extensions. For instance, a fighter aircraft behavior modeling language can be designed based on Statecharts; a warship behavior modeling language can be designed based on Petri Net; etc. As abovementioned, DSM method and supportive metamodeling frameworks (e.g. EMF and GME), are employed to realize these languages. Base cognitive behavior metamodel is the common metamodel representing fundamental modeling elements and mechanisms found in various combat platform specific behavior metamodels. In fact, it refines the DMA, and is responsible to participate in the composition relationship with structural DMA. At the application level, distinctly different from in physical domain modeling, the analysts create cognitive behavior models with these combat platform specific cognitive modeling languages. In other words, the pertinent cognitive behavior metamodel is instantiated in the application modeling layer. Each combat platform specific cognitive model representation will be transformed into a Python-based representation, which is dynamically composed with the model architecture.

4. CONCLUSION AND FUTURE RESEARCH

Combat system effectiveness simulation (CESS) is one special and significant type of system simulation. The challenge confronted by CESS is both functional such as structure and behavior abstraction and non-functional such as composability, multi-domain specificity, and evolvability. The non-functional one is more difficult to overcome due to it being comprehensive, fundamental, and not directly related with a project's aim. Whatever problems would be, solving them in an abstract modeling level is almost a must. Traditional domain-neutral and domain-oriented modeling methodologies all suffer from some limitations toward the non-functional requirements of CESS. There should be a methodological shift to solve the CESS problems. The main contribution of this research is that a model architecture-oriented modeling methodology for CESS is proposed. The crucial role of model architecture is recognized and developed. By incorporating domain-neutral M&S technologies and domain-specific modeling methods into the representation of the concrete CESS model architecture, the problems encountered in traditional methodologies-based CESS practice (i.e. limitations on composability, domain-specificity, and evolvability) can be mitigated to a satisfactory extent. After more than five years research and development, most of the CESS model architecture (especially DMA) and the modeling framework have been realized (Lei et al. 2013; Li et al. 2013). As a result, a CESS-oriented simulation system named WESS has been implemented and applied to non-trivial CESS applications.

In the next step, the CESS model architecture will evolve according to the continuous application requirements within the CESS scope. For physical behavior models described using UML diagrams, there needs to be relevant code generation tools constrained by the structural architecture to make these behaviors fully formal and evolvable. For cognitive behavior models, DSM is a rather new approach. Even though we have done some exploratory work toward this direction, there should be much more work to make it practical. Among them, one is to provide each combat platform type a domain specific modeling language and modeling tools, for instance, an EMF/GMF/OCL/Acceleo-based aircraft combating cognitive modeling language has been prototyped; the other is to borrow pertinent modeling concepts from some cognitive architectures like Soar (Zacharias, Millan, and Hemel 2008), to improve cognitive behavior modeling capabilities for more complex cognitive behaviors.

ACKNOWLEDGMENTS

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THE PROPOSAL OF SECURITY AND SAFETY MANAGEMENT SYSTEM WITH FUZZY LOGIC SUPPORT

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ABSTRACT

This paper presents the implementation of the fuzzy logic into the security and safety solution in the soft targets. The primary structure of safety and security tool is described in the first part. This tool has been implemented into specific object; for example, for object without security and safety solution (soft targets). In the next part, the primary rules for the use of fuzzy logic are defined. The aim of this paper is to define the primary layout for software which could help operators with decision-making process. The article also proposes and describes the solution for system application of security requirements by understanding the soft targets threats. The system solution is different for each organization and object; however, the main structure is the same.

Keywords: object security, safety, soft targets, solution

1. INTRODUCTION

Soft targets are objects that do not have special security and safety measures in place. Soft targets are specified as objects with a large number of visitors in one place at the same time, and special security measures are not implemented into those locations. One of the main causes of danger is uncontrolled visitors movement in soft targets. People, who visit soft targets, are a source of risk. Soft targets include cinemas and theatres, shopping centres, schools, universities and other buildings (Duricova, L. Hromada, M. 2016). In safety category, special safety requirements are defined and this category is specified with categorization. Safety requirement for schools, authorities, cinemas, theatres and others. In this paper, the requirements for software proposal are specified.

This research concentrates on the system implementation, which has been applied into soft targets. The current situation could be different in other countries. In the Czech Republic, the current state could be presented as a system without any special security requirements. The soft targets have problems with financial resources that could be used towards security techniques and with knowledge about efficient measures. These statements are based on studies which have been done in soft targets such as shopping centrums, schools, hospitals and others (Fennely, L. Perry, M. 2016 and Duricova, P. L. Hromada, M. 2015 and Duricova, L. Hromada, M. 2016).

Soft targets could apply basic principles of management to manage processes because the structure is similar as a commercial and industrial organization aiming to gain/earn a profit. The management processes are implemented into organization because of the certification defining organization quality. The certification is based on definition rules for management and guaranteed fulfillment of standard which is authorized; for example, British Standard BS OHSAS 18001/2007, Occupational Health and Safety Management Systems. Risk is a subjective concept that needs to be viewed and quantified on an individual basis (Sennewald, Ch. Nailie, C. 2016). This research defines processes which could be implemented into software. The level of security and safety situation at soft target depends on the correct setting of measures. The software has to know the processes that occur at the soft target on daily basis and also the ideal situation. The ideal situation is represented by the values that are used for the fuzzy statements. The fuzzy statements are used for the decision making process (Duricova, P. L. Hromada, M. 2016).

The reminder of this paper is organized as follows. In Section 2, we defined the elementary principal of the proposal software solving. This part describes analytical tool which will be used in software as supported software tool. In Section 3, we defined elementary principles of fuzzy logic which will be used in the proposal. This section is divided into three parts (fuzzy logic principles, algorithmic examples and the defuzzification methods). Algorithmic examples describe the implementation of the security and safety principals into fuzzy logic. The last section concludes this research paper.

The paper proposes one system solution that could effectively manage security and safety situation in the soft targets. The software could supply missing knowledge to management of the soft targets. The fuzzy logic is the modern theory which belongs to artificial intelligence field (Ross, T. J. 2010).

2. THE PROPOSAL OF THE SECURITY AND SAFETY SOFTWARE

The proposal of software is divided into three parts. The first part analysis the current conditions and state. After that, the system could derive parameters which define security and safety state in object. These objects are categorized into groups which will be implemented in a risk state. The risk state can occur in object in the future. Firstly, the object must be evaluated, and then the object can be included into the software. The next part defines immediately corrective actions and also permanent corrective actions which have to be done by the operator.

The groups of these objects are specified with similar characteristics. The integration is based on law requirements, owner or manager requirements and technical requirements. Occupational Health and Safety (OHS) and Fire Protection (FP) is defined in law requirements (Duricova, L. Hromada, M. Mrazek, J. 2016). Each safety and security measure has tie with one of the next category:

- People and animals – this category is about life and health protection. First is human life, then animal life (Duricova, L. Hromada, M. Mrazek, J. 2016).
- Surrounding and environment – it is about requirements for safety and security in the surrounding. It is divided in different sections: environment, work places, public places, crowded places and others (Duricova, L. Hromada, M. Mrazek, J. 2016).
- Material things and machines – it is about using machines and working with things, and about requirements for use and development. Development of things, buildings, machines, as well as product requirements are included in specific requirements (Duricova, L. Hromada, M. Mrazek, J. 2016).
- Information – this section is about classification, use, transfer and about removing information as well (ISO/IEC 27001:2013).

The next part explains the principle of analytical tool. Analytical part specifies elementary requirements for analytical tool which can derive inputs parameters for the main software tool.

2.1. Analytical part

The analytical part considers the state identification of object which derives the inputs to the software. After this analytical part, the object is valued with characteristic number and coefficient. In this process, the objects are not evaluated by fuzzy rules because it is supported action for software.

RPE - Risk Probability and Effect				
	Interval	The Explanation	The definition	The advantage
Risk	1 - 10	What kind of negatives event is threatened?	The description of negatives events. It depends on the kind of event. It is precisely identified by the same distinguishing features. We will define this identify project from characteristics.	It can be applied in some others specifics object by the purpose.
Probability	1 - 10	How much percent is probably that this event can happen?	For this analytical part we must prepare analytical tools from analytical methods, which will be prepared assessment of the probability, based on past incidents and other contexts.	We can use some others analyses from others specialists. It will be compatible.
Effect	1 - 10	What happens it after the event?	We can identify some other risk after the first security incident. We anticipate response from others stakeholders and we must prepare scenarios. Precautions will must be lest financing costs as corrective actions or repair.	We must make the linking with other analytical tools and we make it compatible.
		How is damage?		
		How is hard to repair it?		

Figure 1: The description of RPE calculation (Duricova, P. L. Hromada, M. 2015)

The calculation of the RPE is based on similar foundations as calculation in systems of quality and it is called RPN. RPE is about Risk, Probability and Effect. These three indicators have values in interval from 1 to 10. Risk represents kind of event or security threat. The Probability represents percentual probability of event that can occur in the object. The Effect describes what consequences for object and visitors, or society this event could have. The RPE is non-dimensional quantity. This tool could be transferred into software which is based on fuzzy logic (Duricova, P. L. Hromada, M. 2015).

The inputs for RPE analysis are focused on the primary identification of the problem and surrounding where the problem is. This problem has main causes, and causes have special conditions where it makes problem.

The specification document defines state and location of the object. It is suggested with numerical value. This numerical value will be calculated by equation which we will determine by examining in the future research.

The object of analyses	**Specification**	**Coefficient**
State	CZ	*It must be specify for the future*
	SK	
The town / City	Prag	*It must be specify for the population and attractiveness for attackers*
	The large city	
	The medially city / town	
	The small town	
	The village	
The surroundings	With the presence of a potential offender	*It must be define analytical process for special location in town*
	With the possibility of a potential offender	
	It is clean surround	
	It is surround with security option	
The object	The specification	*It is individual*

Figure 2: The specification of the object, surrounding, town and state (Duricova, P. L. Hromada, M. 2015)

The specification and coefficient are connected in analyses. We use numerical value for better valuation for further processes and we could make this processes more practice than before.

3. FUZZY LOGIC IN THE PROPOSAL

It is necesery to examine every object; however, the aim is to examine and determine the security parameters. The fuzzy logic can be used, because it is necessary to know and work with a lot of plans and a lot of experts in one system. There is also a wide range of numerical values, and technical components. It is important to define parameters and a lot of values, that is main reason to use fuzzy logic (Takagi, T., Sugeno, M. 1985).

This system will be compatible with other methods, therefore every input and mechanism can be set up. Then it is the implementation of results from other groups of security to support solutions.

This proposal will be used in computers and will be connected with other objects in network. It depends on categorization that will be defined in the first part of analytical process. This software have to accept input parameters directly from the object in real time. The groups are for example: cinemas, shops, schools and other. On the other side, next group of inputs are requirements from law requirements and other standards that company have to accept. The software consists from a lot of subsystems. These subsystems consider the technical components and processes. Firstly, each expert has to know a lot of information about domain such as region, building, and situation. Then the expert needs to connect it. The proposed solution is a one system that will make decisions based on skills of experts. The proposal of system should be user friendly. We choose fuzzy logic because of reasons which are described in the previous section (Duricova, L. Hromada, M. Mrazek, J. 2016).

3.1. Fuzzy logic principles

Fuzzy logic is the logic that can work with a lot of values. The fuzzy logic examines whole range of values. It is important to implement expert findings and translate it to fuzzy logic. That means, we must define a range for the decision support.

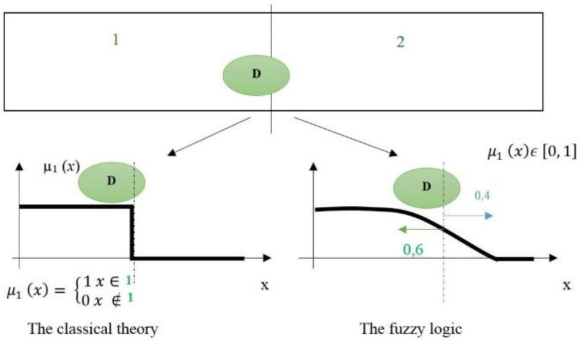

Figure 3: Basics of fuzzy logic (Duricova, L. Hromada, M. 2016).

The differences between fuzzy logic and classical theory can be seen in figure 3. In the classical theory, we can have only two values (1 or 0). It means, element D belongs or does not belongs to group 1. On the other hand, the fuzzy logic knows about each value in the interval from 0 to 1. Fuzzy logic has special rules and symbols operating with mathematical operations. They are called fuzzy statements. The truth of statement depends on value which is defined in interval between 0 and 1. In fuzzy logic, we use linguistic variables. The values of linguistic variables can be marked as element of plurality (Zadeh, L. A., 1965).

Inputs are numeric values which are in fuzzy process transferred to fuzzy sets. With fuzzy sets, we can make special fuzzy operations which are represented by rules. The process is reversed on the end. We have fuzzy set in which the numeric values must be defined (see Figure 4). We know more methods for defuzzification. For example, the center of gravity, the mean of maxima and other methods (Driankov, D. Hellendoom, H. Reinfrank, M., 1993).

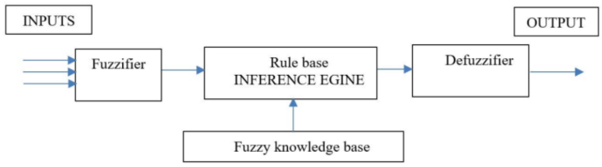

Figure 4: The main principle of fuzzy logic (Duricova, L. Hromada, M. 2016)

Classical theory uses two values and it is based on binary logic (0, 1). On the other hand, the security and safety solving is not based only on two values. These two values describe ideal situation in security and safety solving; however, operator in building needs more values for the definition of real situation. The real situation is more difficult and the decision making is based on more information and values. These values represent the degree of support (Duricova, L. Hromada, M. Mrazek, J. 2016).

3.2. Algorithmic examples

Fuzzy rule is mentioned in the next text: "if (fuzzy statement) and (fuzzy statement) then (fuzzy statement)" (Driankov, D. Hellendoom, H. Reinfrank, M., 1993).

- If (temperature=high) and (oxygen=low) then (ventilation= high).
- If (door4=open) and (mode=secret) then (camera4=start recording) and (voice prompts=on).

These examples describe using of linguistic variables in the proposal.

When we have been working with the statement, we will use logical operators. It will describe the interrelationship between these groups of variables; in security solutions known as special characteristics. Each object has a property with certain values. It is not about binary system; however, it indicates a relation between the object and characteristics. It is obvious that in each object is a risk; therefore, we have to determine the value which represents this risk. On the other hand, when we know about law requirements, we can set up normal interval by legislative. The limits can be set by the subsystem in the proposal (Klir, G. J., Yuan, B., 1995).

Interpreting if-then rules is a three-part process. This process is explained in detail in the next section (Rohan, 2016):

- Fuzzify inputs: Resolve all fuzzy statements in the antecedent to a degree of membership between 0 and 1. If there is only one part to the antecedent, this is the degree of support for the rule.
- Apply fuzzy operator to the multiple part antecedents: If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1. This is the degree of support for the rule.
- Apply implication method: Use the degree of support for the entire rule to shape the output fuzzy set. The consequent of a fuzzy rule assigns an entire fuzzy set to the output. This fuzzy set is represented by a membership function that is chosen to indicate the qualities of the consequent. If the antecedent is only partially true, (i.e., is assigned a value less than 1), then the output fuzzy set is truncated according to the implication method.

In general, one rule by itself does not do much good. What the proposal need are two or more rules that can respond another. The output of each rule is a fuzzy set. The output fuzzy sets for each rule are then aggregated into a single output fuzzy set. Finally, the resulting set is defuzzified or resolved to a single number (Rohan, 2016).

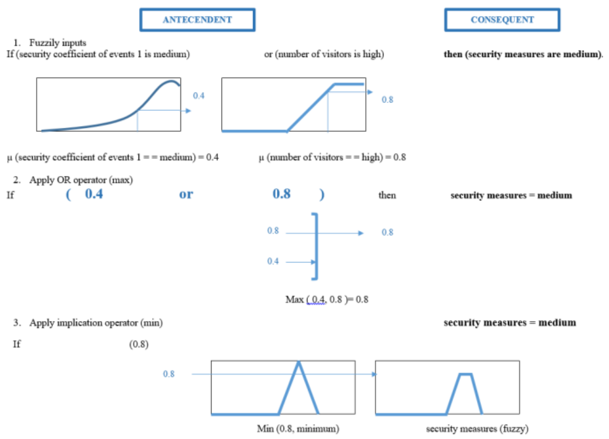

Figure 5: The principle of the fuzzification

Software will detect safety and security measures and it will optimize it for more effectively.

- If (security coefficient of event X is high) and (number of visitors is high) then (security measures are high).

The degree of support for the variable "security measures" is defined by fuzzy set "high". The degree of support for the variable "security coefficient" is defined by fuzzy set "high" and the degree of support for the variable "number of visitors" is defined by fuzzy set "high". The underlying idea, with increasing number of checks of propositions in premise; the more suggestions could be derived. For the degree of support for the truth of the fuzzy proposition "security measures are medium", the fuzzy implication must be defined. The fuzzy statement defines the degree of support for the fuzzy rule. The defuzzification is process in which the numeric value is determined from the interval (Duricova, L. Hromada, M. Mrazek, J. 2016).

3.3. The defuzzification methods

For defuzzification, different methods are possible to choose among several possible definitions. In this paper, one of the primary methods of defuzzification will be presented.

Defuzzification is based on converting fuzzy grade to on a single number. This is the last part of the process.

One of the defuzzification method is based on weighted average method which is valid for symmetrical output membership functions. In figure 6, we can see formed maximum membership value in each function (Duricova, L. Hromada, M. 2016).

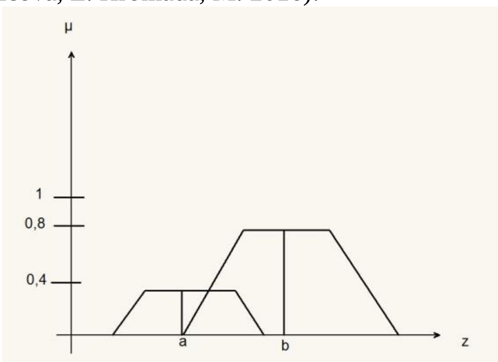

Figure 6. Defuzzification with Weighted Average Method (Duricova, L. Hromada, M. 2016)

The next equation formulates principle of this defuzzification method (Duricova, L. Hromada, M. 2016).

$$z^* = \frac{\sum \mu_c(\bar{z}) \times \bar{z}}{\sum \mu_c(\bar{z})}. \tag{1}$$

In the next equation, the example of a model that is depicted in graph.

$$z^* = \frac{a(0{,}4) + b(0{,}8)}{0{,}4 + 0{,}8}. \tag{2}$$

In this process, more methods, which are not described in paper, can be used. For example:

- Centre of gravity.
- Height method.
- Middle of maxima.
- Centre of sums.
- Centre of the largest area.
- First or last of maxima.

4. CONCLUSION

Detectors have special functions and works at technical bases. These detectors can be based on infrared, electrical, roentgen or other physical measurements.We can use detectors and linked them to the proposed system. It is, for example, system from company NICE. After the integration of detectors, the system will be more efficient. However, we must understand physical phenomena of these detectors because we have to know the state of normal or alarm situation, and state of threaten. We propose a set of rules that consists of technical rules and also law rules. The conditions in object will be defined and then we can optimally set the security and safety parameters. The impact of this solution is system solving of situation with technical and management support. Object managers can make decisions with this solution which contains expert knowledge of each object. Therefore, it is possible to make decisions quickly and more efficiently (Rosenberg, F., 2014).

In the further research, the subsystem for analyzing incidents in the soft targets will be defined. The parameters in this subsystem can be also defined and will be used in the main software. These parameters will identify the probability of the incident in soft target.

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CYBER ATTACKS ON SCADA OF CRITICAL INFRASTRUCTURES BY AN HYBRID TESTBED

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ABSTRACT

With the emergence of the Internet of Things, SCADA (Supervisory Control and Data Acquisition), which constitutes the nervous system of Critical Infrastructures (CI), are becoming geographically distributed and more vulnerable to cyber attacks. SCADA boundaries to be protected are going well beyond the single plants.

In the paper, an hybrid test bed is used to conduct cyber attacks on SCADA and to analyze consequences on it and, in turn, on its physical CI. The hybrid test bed is constituted by hardware devices and simulative models. Hardware devices are in charge of representing actual SCADA devices, while simulative models represent interdependent physical CI. The test bed is completed by an open source platform which reproduces cyber attacks, includes typical SCADA cyber protections and monitors SCADA data flow. Simulative models represent an interdependent active electrical grid, a gas and a water network in an urban district. Continuity of supply of grid customers under cyber attacks is investigated.

Keywords: SCADA, cyber security test bed, hardware in the loop, simulation models, decision support system

1. INTRODUCTION

Over recent years, SCADA system adopted in Critical Infrastructures (CI), such as smart grids, water, oil and gas distribution networks, have become more complex due to the increasing number of interconnected distributed devices, sensors and actuators, often widely dispersed in the field and the larger amount of information exchanged among system components. Such systems need to be flexibly and securely configured, monitored, and managed to prevent the increasing of risks due to both operational errors and cyber-attacks, including intrusions and malware that could compromise their operations or even result in disasters.

With the emergence of the Internet of Things generation of SCADA, the boundaries of the protected infrastructures are growing well beyond the single or aggregated-plant, mono-operator vision. Instead of monolithic systems, deployed on geographically constrained spaces, these systems are characterized by a considerable degree of capillarity, being dispersed over wide geographic areas, with increasingly small coverage as they progress towards periphery. This poses new challenges because, as the boundaries of SCADA expand towards households, they involve several other operators, such as telecommunications or utility providers, in a scenario that naturally demands the introduction of multi-tenancy mechanisms.

Successful cyber attacks against SCADA systems might put industrial production, environment integrity and human safety at risk. SCADA systems include simple functions such as “on/off,” sensor capability, communications capability and Human Machine Interface (HMI) that connects them to people operating the system. SCADA more and more often have connections to Internet Protocol (IP) networks, including the Internet in some cases. Even those physically and logically disconnected from other systems may be locally or remotely accessible and have vulnerabilities to be exploited. SCADA access and control points are also frequently located in remote and unmanned areas of the utility system. Since SCADA systems directly control physical CI, availability and reliability come first, whereas in ICT networks a significant stress is on confidentiality of information. Protection in SCADA must be achieved in resource constrained environment, in which channel bandwidth is very narrow and devices have a limited computational power, whereas in contrast timeliness of response is fundamental. Since resources are bounded and at the same time delays are unacceptable, many security measures that work well in ICT networks could not be used as is in SCADA networks (Cruz 2015). Additional programs like anti viruses risk slow down systems excessively. Cryptography, especially public-key, could be too heavy, both computationally and because of the traffic it creates, if it is applied to SCADA legacy components or to SCADA remote devices which typically have limited computational power. In fact, SCADA, being born as isolated systems, carry the burden of a legacy of trust in the network and thus they lack the tools for monitoring and self-protection that have long been integrated in ICT networks. For instance, their logging capabilities are geared towards disturbances rather than security attacks. Contrary to ICT network devices, SCADA systems are designed to run for years on end, without a reboot. This complicates the application of software patches and makes even forensics after an attack problematic because the system cannot be taken down and analyzed at wish.

The paper discusses an hybrid test bed to investigate the continuity of supply of an electrical grid, in case of cyber attacks, within an overall scenario of modernized urban networks. Modernized urban networks will ideally enable the integration of small distributed generation sources and will increase the customer's 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. The increased use of SCADA ideally improves efficiency of modernized urban networks through a dynamic optimization of their operations and resources. Modernization of urban networks is a big long term challenge, for social, economic and technical reasons and it is far away to be realized. Now days, even the term "smart grid" has still to find a proper definition that fully includes its aspects of innovation and efficiency.

A Service Level Agreement (SLA), between each urban network operator and its customers, grants the continuity of supply, with an allowed maximum number of hours of interruptions in a year. Anomalous operation of SCADA, due to cyber attacks, may cause longer delays in continuity of supply and even cause the loss of supply of large part of customers. Moreover severe consequences on physical networks and on the public health could result from loss/fake observability and controllability of the physical CI.

The hybrid test bed is constituted by hardware devices and simulative models. The hardware devices are in charge of representing actual SCADA devices, while simulative models represent interdependent physical CI. The test bed is completed by an open source platform to reproduce cyber attacks, typical SCADA cyber protection and to monitor data flow. Physical CI consist of interdependent active electrical grid, gas and water networks in an overall scenario of an urban district.

Denial of Service (DoS) and Man In The Middle (MITM) cyber attacks on SCADA are conducted and consequences are computed in terms of degradation of continuity of supply of grid customers.

2. CYBER ATTACKS ON SCADA

SCADA system performs its functionalities by a communication infrastructure which connects PLC/ RTU devices to the SCADA Control Centre (constituted by one or more HMI and SCADA Control Server). The communication infrastructure employs different technologies and communication protocols changing over time, i.e. serial communication links, Ethernet, Wi-Fi, ModBus, DNP3 and OPC protocols. Particularly, here we focus on ModBus protocol. ModBus, originally designed for the control of single processes at a low speed on serial communication links, with the emergence of IP networks and Modbus on TCP/IP, makes SCADA no longer isolated but subject to the inherent weaknesses of such protocol, in terms of lack of authentication or weak authentication (i.e. default credential setup user/user) and lack of encryption (data flow in clear).

SCADA systems are vulnerable to cyber attacks at *host level* and at *network level*.

At *host level*, vulnerabilities are due to operating systems and application software. Among them buffer overflow and SQL injection may cause i) abnormal behavior and/or block of program executions (i.e. monitoring systems no longer updated or displaying incorrect data); ii) modification of data base contents that compromises database applications, data validity and may allow possible fraudulent procurement of access credentials.

At *network layer*, vulnerabilities are due to communication protocols, which typically miss authentication and encryption and expose services on the network.

That lays the foundation for cyber attacks including the following types, under consideration:

- Denial of Service (DoS). It consists in sending numerous access requests to a service exposed by a server (i.e. PLC/RTU), within a short amount of time, up to exhaust its resources and slow down the service response up to block the service itself.
- Man In The Middle (MITM). It consists in intercepting the data traffic exchanged between i.e. HMI and SCADA Control Server or between SCADA Control Server and PLC. To accomplish this, an attacker inserts himself in the middle of the conversation between the two parties gaining access to information that the two sides are exchanging. The net effect is that the attacker can then pick up the system access credentials, read and / or modify commands or monitoring data unbeknownst of the involved parties.

2.1. Cyber attack steps

To effectively conduct cyber attacks, part or all of the following steps have to be performed:

- *information gathering,* to gather information on the target object (i.e. IP address, MAC address, open services, the used software versions,...). For that, sniffing tools and penetration testing can be used, such as: Nmap, Ettercap, Wireshark.
- *vulnerability disclosure*, as a result of information gathering a variety of information, such as services exposed by a server and /or

the installed software versions can be got. Other more detailed vulnerabilities can be then searched, by tools such as Nessus and Metasploit;

- *choose the best attack strategy*; often, a sophisticated attack is not needed but a simply exploitation of vulnerabilities or weak basic setup could be enough to expose SCADA to effective attack vectors;
- *run the attack*, that means to move from study and analysis to the actual attack running;
- *consequence evaluation*, on the SCADA system and on the physical CI;
- *hide attack traces*, upon completion of the attack the traces of the activities carried out have to be erased so as to leave the smallest possible number of clues.

3. HYBRID TEST BED

Hybrid Test Bed (HTB) is used to represent meaningful portions of actual SCADA system, submit it to actual cyber attacks and then analyze and evaluate the consequences on SCADA, in terms of observability and/or controllability of the physical CI, and then in terms of CI resilience.

Figure 1 shows the Hybrid Test Bed, constituted by hardware devices and simulative models, where i) hardware devices are in charge of representing the portion of SCADA devices under cyber attacks; ii) specific domain simulators and transversal simulators, based on equations domain, generate data and status of the physical layer of each urban network, and SCADA control and operational functionalities; iii) an open source platform reproduces cyber attacks, typical SCADA cyber protections and monitors the data flow.

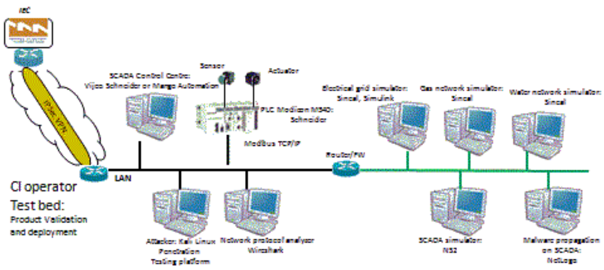

Figure 1: Hybrid Test Bed

HTB is based on a switched Local Area Network (LAN) to implement an Ethernet communication infrastructure between SCADA devices.

3.1. Attack process by hardware devices

The left part of figure 1 shows the hardware devices used for reproducing and monitoring cyber attacks on SCADA. SCADA system architecture, proposed in HTB to investigate cyber-security issues, is represented by an HMI, a SCADA Control Server and a PLC/RTU.

HMI, developed on a dedicated machine, is a graphical user interface, for SCADA operators to monitor (e.g. visualize possible alarms caused by fault of the physical network) and send, in real time, control command to field equipment like PLC/RTU by means of SCADA Control Server.

The aim of SCADA Control Server is threefold. It communicates directly with PLC/RTU, collects data from them and interfaces with HMI to transfer monitoring and control information.

SCADA Control Server and HMI console are by Schneider-Electric and belong to the Vijeo software suite.

PLC is a local processor on the field, which collects data (electricity measures) from RTUs constituted by a large amount of sensors and receive control command from HMI to regulate field actuators (e.g. electrical breakers) of RTUs. PLC is by Schneider-Electric. Particularly, it is a Modicon M340, constituted by a DIN standard rack with 4-slot, populated by CPU cards and links to connect to the field and the SCADA Server. The Modicon M340 includes the following modular cards:

- for CPU functionalities: BMX P34 CPU B, with USB interface for programming capabilities, and Ethernet interface for connection to the SCADA Server;
- for electrical supply;
- Input / Output, for field devices connectivity;
- for Ethernet connectivity: BMX NOR 0200H, to connect additional SCADA network segments.

The integration of the Modicon M340 PLC in SCADA architecture via Ethernet network allows a wide choice of operating modes:

- remote diagnostics and monitoring of the PLC via integrated web server;
- remote diagnostics and monitoring of the PLC via SCADA server;
- changing configuration parameters and creating / downloading / uploading control programs, via Ethernet network, using the Unity Pro software;
- interaction with configuration file using the FTP protocol, for hardware setup involving the card (BMX NOR 0200H).

Unity Pro, proprietary software by Schneider - Electric, provides basic PLC operations (i.e. IP address assignment, PLC monitoring and actuation logics).

The connectivity through the USB port is used for PLC basic setup, while Ethernet connectivity is used both for configuration system and SCADA Server.

A dedicated machine is used to perform network attacks. It is equipped with Kali Linux distribution that supplies different, ready to use, attack tools. Ettercap belongs to one of these tools and we use it to conduct some MITM attacks. Specifically, MITM ARP Poisoning, described in a following section.

To detect cyber attacks, a Network Intrusion Detection System (NIDS) is used. NIDS is an open source tool named Snort [2], that is supplied by Security Onion. Security Onion is a Linux distribution for intrusion detection system, network security monitoring and log management. Snort analyzes the real time network traffic. It is composed by: i) one or more probes, for monitoring; ii) a server, that receives all information collected by the probes; iii) a management workstation, which interfaces NIDS and administrator. Particularly, in our HTB the above three items are collapsed in one single machine which include them all: performed probe, server and client functionalities.

3.2. Attack consequences by simulative platforms

The right part of figure 1 shows the simulative platforms for representing consequences of cyber attacks on the physical CI.

Some computations such as flow efficiency requires a deep knowledge of the physical, control and operational layers of CI. To represent such layers both domain simulators for physical CI and SCADA simulators are needed. CI physical layer are represented by means of domain simulators, such as PSS-SINCAL of Siemens. The control and the operational layers of CI, which regards SCADA functionalities, communication protocols, or even SCADA traffic patterns are represented by means of NS2 open source simulator and via Mathlab-Simulink.

4. HTB INTEROPERABILITY AND HETEROGENEITY

In modernized urban networks, the electrical smart grid, characterized by continuous phenomena interacts with its SCADA, characterized by discrete phenomena. Such an heterogeneous system of system is expected to interoperate with other heterogeneous networks, such as gas and water network, both characterized by continuous phenomena, each one relying on its own SCADA system, characterized by discrete phenomena.

Simulation environments to represent such a challenging issues, due to the complexity and heterogeneity of phenomena, need the cooperation of specific domain simulators, based on equations domain, able to generate data and status of the physical layer of each urban network, and event based simulators and actual devices for representing SCADA functionalities and CI control and operational layer, have to cooperate in HTB (Figure 1). In fact, current domain simulators, such as electrical load flow simulators, and gas and water network simulators, typically do not model SCADA. On the other hand, the operating mode of each urban network, specially of the smart grid, has an impact on its own SCADA system. Thus, such an integration of physical and ICT components of the operational urban networks requires similarly integrated simulation frameworks. Moreover, HTB has to represent the cyber attack process. Contingency generators, i.e. to represent cyber-physical threats and the propagation of their effects on SCADA devices, are modelled by threats generators, emulation or actual mock ups of the related ICT based devices.

The use of standards based approaches (HLA, IEC 61850, CIM, etc.) ideally facilitates the interoperability of different simulators that are acquired or developed over time, as well as the exchange of simulation models. However, the implementation of standards by themselves does not grant the adequate implementation of any modelling issue, such as the efficiency computation of interoperable but heterogeneous physical networks and their SCADA.

Currently just offline communication among such simulators has been implemented, by means of Excel and HTML exchange formats. The work is on going to reach a full integration of the simulative platforms and between them and the hardware devices for cyber attack process.

5. MOVING CYBER ATTACKS BY HTB

The first activity carried out to conduct any kind of cyber attack is the Information Gathering especially addressed to discover PLC vulnerabilities and weak configurations.

Using the suite of penetration testing tool provided by Kali Linux and especially using the Nmap tool, it is possible to verify that Modicon M340 PLCs networked via the Ethernet interface exposes the following services:

- HTTP service
- SNMPv1 service
- FTP service
- Modbus service

With this information (Figure 2), strategies of attacks can be planned:

- exploiting inherent weaknesses of the protocols used in the services exposed in operation
- exploiting vulnerabilities in software versions
- try to saturate the CPU and RAM resources in order to create malfunctions.

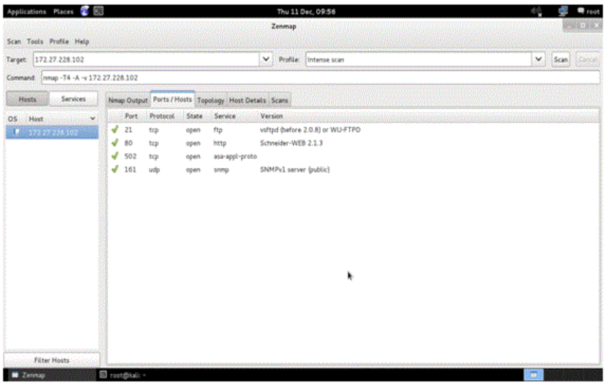

Figure 2: PLC services by Nmap

5.1. Protocol violation

This kind of attack performed against the PLC device is one that falls under the category called " Breach of protocol ". As the Modbus TCP / IP does not have an authentication mechanisms, effectively it allows anyone to access the device and change the configuration.

Using a graphical tool available freely on the net and totally legitimate because normally used for regular verification and configuration, false Modbus commands can be sent and unintended actions can be forced.

We used the tool Modscan32 to change the status of the PLC registers and other parameters (Figure3).

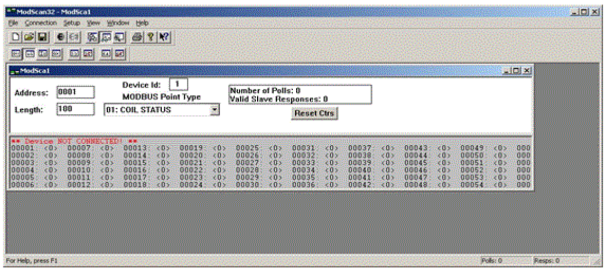

Figure 3: Status of PLC registers by Modscan32

5.2. Exploitation of bad configuration of SNMP service

Using Nmap tool, for the Information Gathering, it can be found that the PLC device exposes the SNMP (Simple Network Management Protocol) version 1 service. SNMP protocol is used for the network management and operation. Its architecture is the following: a server machine performs some queries on one or more target machines through reading (get) or write (set) commands to obtain status and configuration information or to impart configuration commands.

The credentials used for such activities are called community strings and typically differ from the reading (read) and the write (write) activities.

The default value is set as public, which allows anyone on the network to make reads and writes.

In our case, using the SNMPcheck tool with the '-w' option, it has been possible to verify that the PLC is configured precisely with the community string public for the "write" mode.

```
root@kali:~# snmpcheck -t 172.27.228.102 -c public -w
snmpcheck v1.8 - SNMP enumerator
Copyright (c) 2005-2011 by Matteo Cantoni (www.nothink.org)

 [*] Try to connect to 172.27.228.102
 [*] Connected to 172.27.228.102
 [*] Starting enumeration at 2014-11-26 11:39:18
 [*] Write access enabled!
 [*] Checked 172.27.228.102 in 0.13 seconds
```

Figure 4 - PLC configuration by SNMPcheck

Using the SNMPset tool, it is possible to change some information (i.e. the system name, the IP address) on the PLC (figure 5).

```
root@kali:~# snmpset -c public -v 1 172.27.228.103 .1.3.6.1.2.1.1.5.0 s LAB
iso.3.6.1.2.1.1.5.0 = STRING: "LAB"
root@kali:~# snmpwalk -v 1 -On -c public 172.27.228.103
.1.3.6.1.2.1.1.1.0 = STRING: "TELEMECANIQUE BMX NOR 0200 REV0160 Modicon M340 Et
hernet 1 Port 10/100 RJ45"
.1.3.6.1.2.1.1.2.0 = OID: .1.3.6.1.4.1.3833.1.7.255.23
.1.3.6.1.2.1.1.3.0 = Timeticks: (147690006) 17 days, 2:15:00.06
.1.3.6.1.2.1.1.4.0 = STRING: "HASH(0x124dc78)"
.1.3.6.1.2.1.1.5.0 = STRING: "LAB"
.1.3.6.1.2.1.1.6.0 = ""
.1.3.6.1.2.1.1.7.0 = INTEGER: 79
.1.3.6.1.2.1.2.1.0 = INTEGER: 2
```

Figure 5: PLC IP address and name by SNMPset

5.3. Denial of Service attack

A Denial of Service (DoS) attack , carried out by means of SYN Flood, has been conducted against the PLC device in order to saturate the capacity in responding to the service requests. Particularly, the attacker sends thousands of requests to open TCP sessions, using SYN packets, to the PLC (the target machine).

The PLC responds to each request with a SYN - ACK packet and wait for the ACK packet in response to consider close the TCP session. Actually, the attacker will never send the ACK packet and then the PLC runs out of memory resources and CPU in a short time so that it can no longer provide the requested services.

To conduct the DoS attack by SYN Flood in our HTB, we used Hping3 tool and the following attack carrier:

hping3 -S -V -flood 172.27.228.102

Figure 6 shows the screenshot from Kali Linux attacking machine.

```
root@kali:~# hping3 -S --flood -V 172.27.228.102
using eth0, addr: 172.27.228.9, MTU: 1500
HPING 172.27.228.102 (eth0 172.27.228.102): S set, 40 headers + 0 data bytes
hping in flood mode, no replies will be shown
^C
--- 172.27.228.102 hping statistic ---
4533491 packets transmitted, 0 packets received, 100% packet loss
round-trip min/avg/max = 0.0/0.0/0.0 ms
```

Figure 6: DoS attack to PLC by Hping3

Particularly, the attack causes the following effects on the PLC at the operational level:

- slow response to service requests;
- significant reduction in the availability of PLC resources;
- service interruption and PLC block.

The effects detected on the PLC under DoS attack are also shown in Figure 7. Using network sniffing tools like Wireshark you can examine the data traffic between PLC and SCADA Server under normal operating conditions and under DoS attacks (Figure 8).

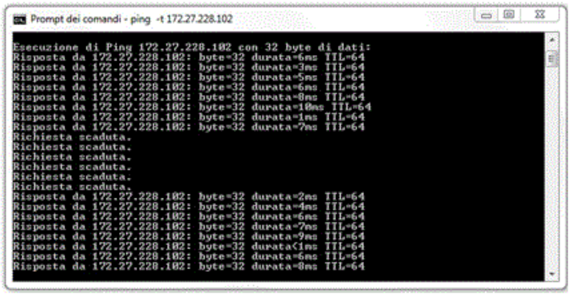

Figure 7: Consequences of DoS attack on PLC

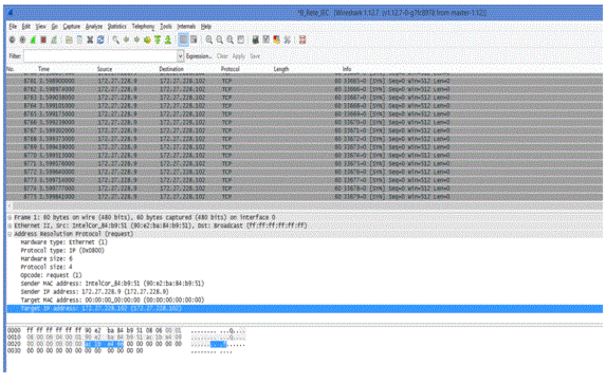

Figure 8: SYN Flood by Wireshark

5.4. Man In The Middle attack

Man in the Middle (MITM) attack has been conducted by intercepting data traffic between the Control Server SCADA / HMI and PLC device.

Specifically, an FTP session to transfer files was open to the PLC and conducted the attack to capture the used login credentials .

The attack was carried out using Ettercap Network packages tool which allows to capture network traffic and analyze its contents in real time. In this way, it was possible to capture passwords, to perform packet injection and to make packet filtering according to our needs.

In a case, the ARP cache is drugged and the attacker capture all traffic flowing between HMI and PLC. When the operator , via HMI , opens an FTP session to the PLC , the attacker is able to see , through the console of Ettercap , the login and password sent in clear in the session.

Figure 9 shows the screenshots of such a test.

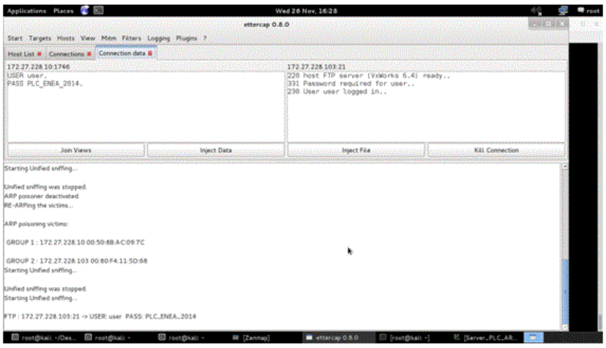

Figure 9: FTP login and password by Ettercap

The described MITM attack exploits the weakness of the FTP protocol that does not provide the encryption of data and therefore it make easier to intercept the traffic and capture the necessary information.

The attacker then manages to capture the login credentials to the FTP service of the PLC thus compromising the confidentiality of the data and gain access to the PLC in order to change the configuration.

Table 1 summarizes the type of conducted cyber attacks, their targets and the used tools within HTB.

Table 1 - Cyber attacks, targets and tools in HTB

Attacks	Targets and tools
Modbus violation	to Modicon 340 PLC (tool: modscan 32)
Misconfiguration	of SNMP protocol to Modicon 340 PLC (tool: SNMP check)
DoS	to Modicon 340 PLC (tool: hping3)
MITM	FTP between SCADA CC and PLC (tool: Ettercap)

6. CONSEQUENCE ANALYSIS BY HTB

We assume a scenario, which includes a minimal topology of three urban networks (electricity, water and gas), that allows to investigate the consequences of cyber attacks on physical networks (i.e. local generation, load shedding) and main SCADA functionalities. (i.e. physical network reconfiguration under anomaly conditions).

The network topology consists of two feeders, each one feeding its subnet. In normal operative conditions the two subnets are separated one each other by 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).

Here we look at the consequences of the cyber attack on the electrical smart grid interdependent at physical layer with gas and water networks by means of mini-hydro, water reservoirs and gas Combined Heat and Power generators (CHP) as components of the basic water and gas networks.

Particularly, a Mini-hydro of 4,5 MW, fed by water network provides electrical energy to the MV sub-grid and two co-generators, fed by gas network provides 20 kW to the LV subgrid and 400 kW to the MV sub-grid.

The full description of the basic MV smart grid model, the load flow computation in normal operation and anomaly conditions requiring mitigations by SCADA system are detailed in (Alonge, 2014). In the following sections just the main issues of them are reported to support the results discussion.

6.1. MV smart grid

MV smart grid model implements two HV/MV substations, with their MV backbones and protection breakers, passive users (loads), active users (renewable generators), prosumers (active/passive users), a LV backbone, with its own set of devices and active /passive users.

Figure 10 shows, as an example, the model and the load flow computation by means of PSS-Sincal simulator.

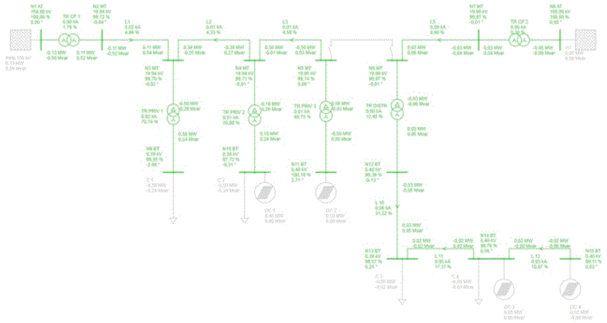

Figure 10 - Load flow model of MV smart grid

6.2. Gas network

The basic gas network has two feeders: two interconnected first gas PRS feed portions of a branching network, to supply different types of users and/or PRI. In the network, a CHP and a Biomethane generator that identifies the “active user” type , which enters biomethane into the natural gas distribution network, have been included. In normal operation, the network is balanced, and its parameters such as gas pressure, flow, pressure drop and speed are measurable or calculable for each network component. Network reconfiguration, in case of contingencies/faults, is possible by acting on a normally open branch. 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.

Figure 11 reports the load flow simulation results in normal operation, by PSS-Sincal.

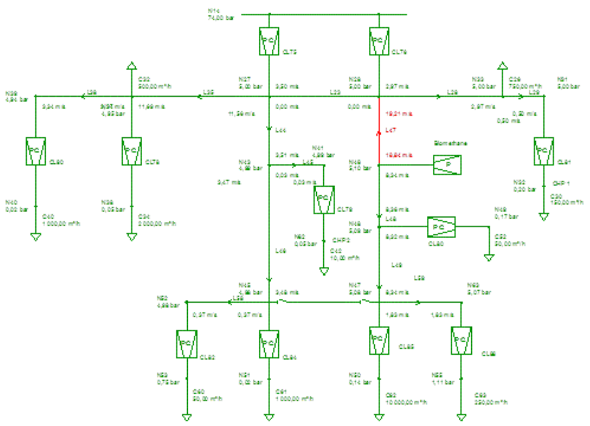

Figure 11- Load flow model of gas network

Operating parameters, such as pressure and flow rate are computed at each node and branch of the network. Also, flow direction is indicated for each branch.

6.3. Water network

The urban water network model has been developed by PSS Sincal (Figures 12) implements two sources, each one able to feed alone the whole network, as in case of a failure scenario. In normal operation, the left branch is fed by one reservoir, while the right branch is fed by the other reservoir.

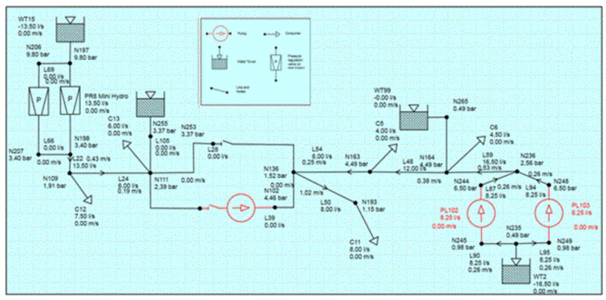

Figure 12 - Water network model

6.4. SCADA functionalities

SCADA, by means of its Remote Terminal Units (RTU) monitors the status of the physical network, implements load shedding, network reconfiguration upon contingencies (Bobbio, 2012).

An example of SCADA functionalities in anomaly conditions of the grid is a short circuit on a transmission line due to natural phenomenon. In this case, SCADA system (Figure 13) executes the Fault Isolation and System Restoration (FISR) procedure.

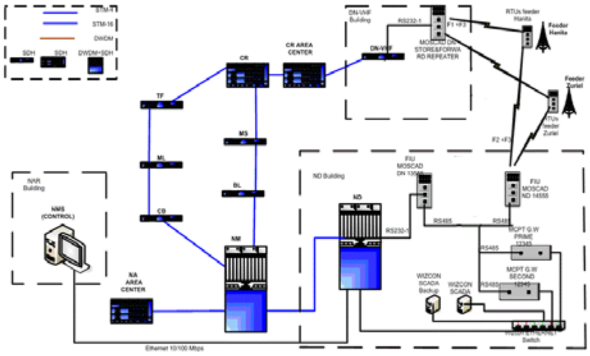

Figure 13: SCADA system of a MV electrical grid

Electrical failures may cause the de-energisation even of large part of electrical customers and need to be located, isolated and repaired quickly and safely. Failure location consists in the progressive re-energisation of electrical sections of the grid, by closure/aperture of circuit breakers, starting from the most upstream section of the grid to the most downstream section of the breaker originally tripped. The process ends when the feeder protection at substation is activated and the faulty section is located and isolated. Finally, on the repair of the faulty section, the grid is restored to its original configuration. FISR procedure is based on grid monitoring, sensing of loss of power, circuit breakers operations, performed throughout Remote Terminal Units (RTUs) and can be compromised by a cyber attack.

Particularly, the duration of FISR procedure can increase under a cyber attack. The time the FISR procedure takes influences directly QoS of the electrical grid. One of QoS used by electricity distributors is

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

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.

RESULTS

To evaluate attacks consequences, we focus on the model of the MV smart grid which simulates a part of medium voltage distribution grid which consists of 7 sections (Ciancamerla 2014). In case of an electrical failure on one of such sections, SCADA detects the sectiont to which faulty line belongs, isolates the section 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. Commands transmission depend on elements state rankings under cyber attack.

Three cases are simulated. First case - no cyber attack, all elements work well, and we suppose line reparation lasts for 5 minutes. Second case - attack (1). In this scenario a RTU is under a DoS attack which makes the SCADA to delay commands by 2 minutes. In the third scenario - attack (2) - the RTU is out of service due to DoS attack and switches are opened/closed manually by maintenance team. Resulting *Tn* values (in minutes) are presented in table 2.

Table 2 - *Tn* values for different sections

	Section number						
Cases	1	2	3	4	5	6	7
No attack	5.28	8.19	6.9	7.09	7.26	20.9	8.58
Attack (1)	7.28	10.1	9.06	10.6	9.0	24.3	10.1
Attack(2)	20.3	14.8	20.3	43.0	48.9	41.7	45.9

Besides *Tn* indicator used by electrical companies, the simulation model of each urban network also calculates more detailed indicators such as time of flow loss for each customer, command transmission times, and many others.

CONCLUSIONS

We are investigating as cyber attacks on SCADA system may negatively impact on SCADA functionalities, requested to maintain the full operability of each urban network. Particularly, we have shown as FISR procedure that SCADA operator execute in case of electrical failure on the electrical grid, can be degraded by cyber attacks.

The investigation has been carried out by the use of HTB. Hybrid Test Bed (HTB) is used to represent meaningful portions of actual SCADA system, submit it to actual cyber attacks and then analyze and evaluate the consequences on SCADA, in terms of observability and/or controllability of the physical CI, and then in terms of CI resilience.

In HTB, Simulative models are in charge of predicting consequences of cyber attacks on the physical CI, by means of appropriate indicators (i.e. *Tn*), giving an indispensible information to estimate risk for customers of urban networks. HTB is also in charge to reproduce cyber attacks and their propagation more realistically then modeling.

Currently just offline communication among such simulators has been implemented, by means of Excel and HTML exchange formats. The work is on going to reach a full integration of the simulative platforms and between them and the hardware devices for cyber attack process.

The work, started within EU FP7 CockpitCI project, is under one of main objectives of the current ATENA Horizon 2020 EU project.

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Representing Adaptive Course Navigation in the Generalized Intelligent Framework for Tutoring

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Abstract

This paper explores the use of Markov Decision Processes (MDPs) in support of adaptive course navigation in the Generalized Intelligent Framework for Tutoring (GIFT). GIFT is an open source architecture for authoring and evaluating Intelligent Tutoring Systems (ITSs) and adaptive course navigation is an AI-based technique which considers attributes of the learner and the instructional context to select actions which will optimize learning. GIFT's current adaptive course navigation model is decision tree-based. Other ITSs primarily use performance as a driver for navigation without consideration for other learner states. The adaptive course navigation model presented aligns closely with the principles of MDPs where a user's current state, possible actions and a reward function determine movement to a future state. Unlike decision trees used which are currently used in GIFT, MDPs also account for multiple states to determine future states and also consider uncertainty in the assessment of learner states.

Introduction

Sottilare (2012) developed an adaptive learning effect model (LEM) to represent optimal interaction between the learner, tutor, and the instructional environment (Figure 1).

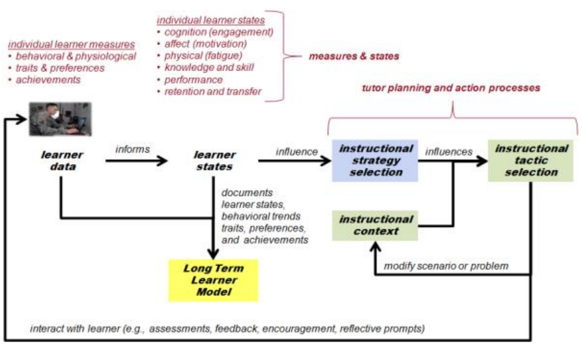

Figure 1. Learning Effect Model (LEM) for Individuals.

This model has been elaborated over time to account for real-time interaction for both individuals and teams (Fletcher & Sottilare, 2013; Sottilare, 2015), assessment of learner competencies across a variety of training tasks involving learning progressions (e.g., marksmanship), and assessment of skill development across long time spans which might include career-wide progressions.

Similar to Vygotsky's Zone of Proximal Development (ZPD; 1978) and tutoring design principles developed by Anderson, Boyle, Farrell and Reiser's (1987) and later elaborated by Corbett, Koedinger and Anderson (1997), Sottilare and Goldberg (2012) envisioned that cognitive load (e.g., working memory) could be optimized by matching the domain competence of the learner and the difficulty/grain size of the problem presented to the learner. In other words, provide more difficult and elaborate problems to highly skilled learners and easier, straight-forward problems to less skilled learners.

From a practical standpoint, three areas of learner assessment are critical in order to provide optimal instruction and expose the learner only to the concepts required for new learning. First, the ITS must understand the level of the learner's prior domain knowledge. Second, it must be able to assess when the learner has mastered new knowledge so they can proceed to new concept or learning objectives. Third, in order to keep the learner motivated and focused on learning, the ITS must understand when new instructional content elicits emotion in the learner which might either enhance (e.g., joy, dominance) or detract (e.g., boredom, frustration, long term confusion) from learning.

The LEM and its associated instructional theory (e.g., cognitive load theory, and component display theory) are central to how GIFT guides instruction. GIFT is a largely domain-independent architecture which is focuses on reuse and best practices to reduce the time and skill needed to author complex ITSs. ITSs developed with the GIFT authoring tools also have embedded instructional theory to optimize the development of learner knowledge and skills.

Component Display Theory (CDT; Merrill, Reiser, Ranney, and Trafton, 1992) arranges instruction into four phases or quadrants to insure the learner: understands basic domain terms and principles (rules quadrant); is exposed to domain-relevant models of success (examples quadrant); can remember information from the rules and examples quadrants (recall quadrant); can successfully apply knowledge to structured application to build skills (practice quadrant).

In addition to CDT, GIFT also uses a decision tree structure to align learner attributes with recommended instructional strategies to optimize learning. This decision tree considers learner attributes such as prior knowledge and motivation/interest to align instructional content. The decision tree is based on a large review and meta-analysis of the instructional literature. For example, the pedagogical request in GIFT for a motivated journeyman in the rules quadrant is for content which is "text/visual information, of moderate difficulty, and of interactive multimedia instructional level 2". The primary drawback to the decision tree structure is that it assumes learner attributes with 100 percent certainty. For example, instructional recommendations based on a learner state of confusion could produce negative learning experiences if it turned out that the learner's actual state was boredom or frustration. A method is needed to deal with uncertainty related to learner state and this is our primary motivation in exploring the use of MDPs within GIFT.

Decision Tree Course Navigation in GIFT

As noted in the LEM (Figure 1), the real-time interaction between the learner and the instructional environment provide the basis for decision-making by the ITS. The tutor's knowledge of the learner is central to optimizing this decision-making. The tutor assesses the learner's prior domain knowledge, analyzes their physical and behavior cues to assess the learner's state, and then uses this information to select strategies and ultimately apply tactics (actions) that can either affect the learner directly (e.g., support, hints, prompts, questions) or affect the complexity of the instructional environment and thereby the learner indirectly.

The part of the LEM that takes action is the domain model. The domain model also assesses the learner's progress toward learning objectives or concepts as they are referred to in the GIFT ontology (Sottilare, 2012). As the tutor decides what to do at the next turn, it considers the learner's states and traits to plan a strategy. It also considers the instructional context (where the learner is in the course) and the recommended strategy (e.g., prompt the learner for additional information) to select a tactic (select and appropriate question and ask it). Next we discuss how tactical decisions are made in GIFT and how those interactions guide the learner through a lesson.

Decision Tree-Based Course Navigation in GIFT

Before exploring a new adaptive method for course navigation in GIFT, we will review how GIFT currently guides learners through a lesson. For this example (Figure 2), we assume a sequential lesson with three concepts (A, B, and C) which must be mastered by the learner.

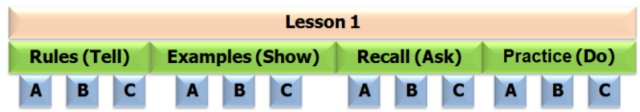

Figure 2. Sequencing of Concepts (A, B and C) in a GIFT Lesson

As noted previously, GIFT uses CDT to adapt course flow for each learner. In our example, the learner must master concepts A, B, and C and each is presented to the learner sequentially in each of the CDT quadrants. For the rules quadrant, the content needed to illustrate the basic terms and principles of concepts A, B, and C are presented to the learner. Next examples of n are presented for all three concepts. After that the learner is assessed on their ability to recall the information provided in both rules and examples. Finally, the learner is asked to apply their knowledge in a practice environment to develop skills and show progress toward objectives (mastery of concepts).

In our decision tree architecture, GIFT examines a tuple composed of a set of learner states (e.g. domain knowledge, cognitive load, and/or affective), an environmental state (where the learner is in the context of the lesson), a set of actions available to the tutor based on the environmental state, and a set of rewards based on progress toward mastery (performance state). The ITS may use all of these attributes to drive its pedagogical decisions in an effort to learn all three concepts in the least time possible. With the exception of the learner's states, all are known with reasonable certainty.

According to Sottilare, Ragusa, Hoffman & Goldberg (2013), the LEM's learner data and states may be further decomposed and used by the tutor to select optimal strategies and tactics. The learner data may include values, preferences, interests, goals, behaviors, and physiological measures which can be used directly by the tutor to make strategic/tactical decisions or can be used to interpret learner states. Sottilare, et al (2013) also note that learner states may include: potential (based on prior domain knowledge); performance; cognitive load; affective states (e.g., personality or emotions); motivational state which is influenced by goals, preferences, and interests; and physical state (e.g., fatigue, level of motor skills). Motor skills may be measured in terms of speed, precision, distance, or adherence to a particular set of procedures or techniques.

In Figure 3, we have a learner who is highly motivated to learn about a particular domain and the learner's knowledge of the domain is moderate (journeyman). For each CDT quadrant, GIFT provides a recommended strategy related to the type of content (e.g., text, visual, case study) to be presented, the complexity or difficulty, and the interactive multimedia instruction (IMI) level. These recommendations are based on a large scale meta-analysis of the training and education literature.

A **Motivated Journeyman** is given:
- High Motivation Journeyman Rule content
  - Pedagogical Request is "**Rule** content with **Text/Visual, Medium Difficulty, and IMI2**"
- High Motivation Journeyman Example
  - Pedagogical Request is "**Example** content with **Case Study, Medium Difficulty, and IMI2**"
- High Motivation Journeyman Recall
  - Pedagogical Request is "**Recall** content with **Short Response** and **Hard Difficulty**"
- High Motivation Journeyman Practice
  - Pedagogical Request is "**Practice** content with **Training Feedback AAR** and **IMI3**"

Figure 3. Examples of Tutor Decisions in GIFT

Agent-Based Approach to Course Navigation

According to Mitchell (1997), an agent-based approach to reinforcement learning is focused on the goal of learning to choose actions that maximize current and future rewards. The desirable characteristics of these agents are: reactive, proactive, and cooperative. Reactive agents should be responsive to change(s) in the environment and active in enforcing policies or rules. Proactive agents should take the initiative to focus on achievement of long-term goals, recognize opportunities, and learn and adapt to optimize learning. Cooperative agents should share information and act together to achieve long-term goals.

For our purposes, in our MDP, the agent should be able to recognize a set of distinct states (S) from which a set of finite actions (A) can be performed. Individual actions (a) should result in movement to a next state (s) and an associated reward (r). At each turn, the tutor will assess the current state of the learner and their performance, and provide a reward based on progress in mastering concepts.

For an agent-based model, Figure 4 shows the relationship between states, actions, and rewards for the learner, the environment (instructional content) and the agent. The agent monitors the state of both the learner and the environment (instructional content) and can change the level of interaction with the learner (e.g., support) or the level of difficulty of the environment.

Rewards can change based on progress toward goals or concepts or by demonstrating higher skills by solving more difficult problems in the environment. Interaction between the learner and the environment is typical of non-adaptive training systems where the learner can observe the environment and act on it, but neither the learner nor the environment can determine rewards. The cumulative value (V^{Π}) achieved by following a policy (Π) from an initial state (s_t) follows:

$$V^{\Pi}(s_t) \equiv r_t + \gamma\, r_{t+1} + \gamma^2\, r_{t+2} + \ldots \equiv \sum_{i=0}^{\infty} \gamma^i\, r_{t+i}$$

where γ ($0 \le \gamma < 1$) is a constant that determines the relative value of rewards. For $\gamma = 0$, only the immediate reward is considered for all states and as γ approaches 1, future rewards are given greater and greater consideration over rewards associated with initial states.

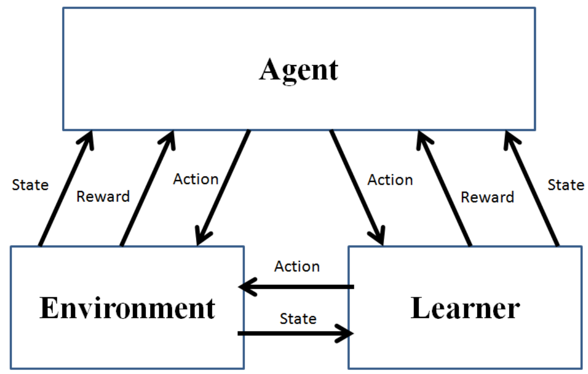

Figure 4. States, Actions, and Rewards

Figure 5 illustrates positive (green arrows) and negative (red arrows) rewards for actions in the environment (specifically in the rules quadrant). In this model the learner is rewarded for taking actions to acquire new knowledge, but not rewarded for going back to review old knowledge.

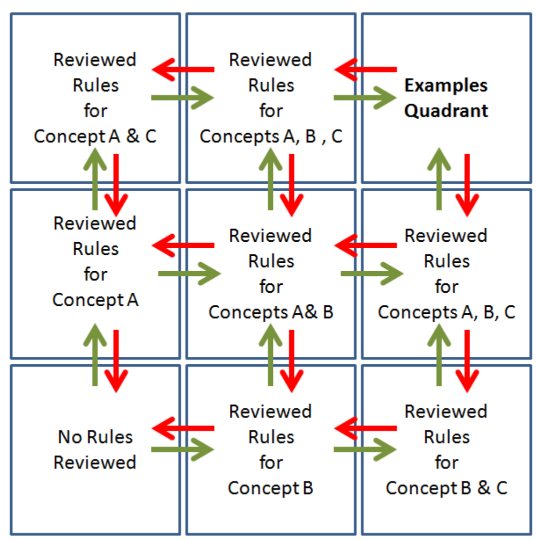

Figure 5. Learner Performance States (progress toward objectives where each box represents a learner's performance state)

The same type of reward system could easily be implemented in GIFT for the examples, recall, and practice quadrants of CDT. Probabilities for a small number of possible actions available in each state could be ascertained over time and the negative assessments in recall and practice could form a reinforcement learning policy similar to the Q function (Mitchell, 1997, p. 374-377). For example, the agent would observe the current state (*s*), and then select an action (*a*) based on learner actions. The ITS would then receive an immediate reward and observe a new state (*s'*). By recording and comparing/contrasting rewards over time, this method allows the tutor to learn how to select highest rewards states and how to avoid incorrect learner state assessments.

Discussion

In this paper, we have contended that the reinforcement learning strategies associated with MDP offer distinct advantages over rule-based or decision-tree based AI solutions. In scenarios where learner states can vary widely and are often difficult to determine, MDPs offer more flexibility in acquiring and analyzing learner data to determine states and matches to optimal outcomes. MDPs also allow for a variety of outcomes/rewards given the same state and action whereas decision trees and rule-based solutions offer only a single path. For instance, we might select a different, but optimal instructional tactic for identical learner states and environmental conditions because the values or preferences in individual learners are different.

A central question to optimizing the selection of strategies and tactics is what desired outcome or outcomes are related to the reward state in our MDP. In our LEM, effect size is a measure for quantifying the difference between the rewards resulting from multiple strategic or tactical options. Learning effect is a measure of the difference between instructional methods on learning gains. For our purposes we have selected four important outcomes: accelerated learning, deep learning and enhanced retention, enhanced performance, and enhanced transfer as discussed below.

Accelerated learning results when adaptive instructional methods decrease the amount of time needed to acquire a unit of knowledge or develop a unit of skill compared to traditional (currently implemented) instructional methods. It may be possible to accelerated learning by skipping old instructional content based on an individual's domain competency. It may also be possible to accelerate learning by understanding when a learner has achieved mastery of a concept and then moving them to the next concept as soon as practical.

Retention is the ability to maintain a level of knowledge and skill to remain proficient in a particular task. Deep learning and enhanced retention can result when learners encounter "desirable difficulties" (Bereiter & Scardamalia, 1985; Bjork, 1988) and are challenged to work harder during initial learning experiences. This invites "deeper processing of material than people would normally engage in without explicit instruction to do so" (Bjork, 1994). The idea that desirable difficulties can gel learning and support longer term retention is a principle adopted within GIFT's pedagogical structure in the form of "indirectness" as defined in the INSPIRE model of tutoring (Lepper, Drake, and O'Donnell-Johnson, 1997). Desirable difficulties are an important adaptive tutoring strategy and they are closely related to Vygotsky's ZPD (1978), but instead of matching the competence level of the learner and the instructional material, we are challenging the learner to reach.

Most structured practice is geared toward enhancing performance. Whereas learning is the acquisition of knowledge and skills, performance is the result of applying knowledge and skill. There is often a divide between practitioners (trainers) and theorists (educators) with respect to performance. The focus for practitioners is to enhance performance to varying levels of automaticity without the need to understand why certain methods are used. Theorists tend to focus not only on what is being done, but why.

Finally, the transfer of skills from one environment (e.g., training system) to another environment (e.g., operational system) is an important element of learning and a consideration for an agent-based system concerned with optimal instruction. The selection of instructional methods may need to vary based on the weight of the desired outcome. For instance, if transfer is more heavily weighted than near term performance for a learner with significant domain experience, we might want to place more emphasis on instructional tactics that align more closely with how the task is performed in the operational environment to promote higher transfer of skills.

A drawback to any adaptive solution is that the ITS author would then need to identify each and every one of the learner state transitions that should result in the delivery of an instructional strategy (e.g., if the learner is frustrated, then the author might adapt the scenario to be easier). In some instances, a defined state transition may happen more than once, in which case, the author would need to provide more than one instructional strategy to choose from and this is an additional authoring burden. Furthermore, each strategy then has one or more tactics (an action based on a plan or strategy) to choose from. While this flexibility allows GIFT to move away from a fixed state diagram and introduce probabilities, it comes at a cost to the author.

The reward structure examined in this paper was limited to optimizing near term reward (discounting) at the expense of life-long learning. There are many instances where near term performance could and should be sacrificed for the sake of learning valuable lessons which allow the learner to more easily retain and transfer knowledge and skills to a broader array of domains. In the same instance, we could also see the possibility of sacrificing learning to enhance the confidence or esprit de corps of low performing learners.

MDP Applied to GIFT

As noted, once GIFT makes a selection based upon an imprecise assessment of a learner's state, there is no mechanism to validate the accuracy of that learner state in the future or to adjust the decision tree to provide another recommendation based on identical conditions. MDPs offer the capability to examine options for moving forward to the next performance state and enable reinforcement learning over the long term to support continuous improvement of strategy and tactics selections.

States and Rewards

So, how should the state, *s*, be represented in an agent-based GIFT? Based on the models shown in Figures 4 and 5, elements of the learner's state and the environment are necessary to select optimal strategies and tactics within GIFT's architecture. For the learner's state, we need to represent the following elements: prior domain knowledge; concepts under instruction; progress toward learning objectives at any time, *t*, in the instructional process; emotional states that are moderators of learning. In defining the components of a state, s, we have noted the importance of four sub-states. These sub-states provide a mix of learner states and a list of potential actions by the tutor where maintaining positive learner states and progress toward learning objectives are associated with higher rewards. The following is a decomposition of the elements of those sub-states:

- *Prior domain knowledge* (competence level = novice, journeyman, expert)
- *Concepts under instruction* (list of concepts = A, B, C; order of instruction)
- *Progress toward learning objectives* (rules reviewed for A, B, C; examples reviewed for A, B, C; recall tested for A, B, C; skills tested for A, B, C)
- *Emotional states* (states observed; negative states moderated; positive states maintained)

Optimizing Actions in GIFT

Movement from one state to another results in a positive reward when a concept is either reviewed (rules quadrant), reviewed (examples quadrant), assessed (recall quadrant), or assessed (practice quadrant). Additional rewards are provided when moving from one quadrant to another, and when demonstrating mastery of a concept within a quadrant.

Below are recommended implementations for an agent-based course navigator for GIFT based on our four desired outcomes: accelerated learning, deep learning and enhanced retention, enhanced performance, and enhanced transfer.

For Q learning (Mitchell, 1997), the agent is attempting to learn an optimal policy (Π^*) where the optimal action (a) in state (s) is the action that maximizes the sum of the immediate reward (r) plus the value of the immediate successor state as discounted by γ:

$$\Pi^* (s) \equiv \text{argmax}\ [r\ (s, a) + \gamma\ V^*\ \delta\ (s, a)]$$

To optimize actions for our accelerated learning outcome, the immediate reward is most important as it lessens decisions to review old material and thereby accelerates learning (see Figure 5). Therefore, $\gamma = 0$ since it reduces the value of the immediate successor state to 0 and rules out any rewards with negative values (e.g., old information).

To optimize actions for our deep learning and enhanced retention outcome, the immediate reward is less important as it increases decisions to review old material and thereby deepens learning (see Figure 5). Therefore, as γ approaches 1, it increases the value of the immediate successor state over the immediate reward.

To optimize actions for our enhanced performance outcome, the immediate reward is important, but so is overall value. Therefore, as γ should be adjusted to optimize the sum of value of the immediate reward and the immediate successor state.

Finally, to optimize actions for our enhanced transfer outcome, the immediate reward is less important than later rewards. Therefore, as γ approaches 1, it increases the value of the immediate successor state over the immediate reward thereby optimizing actions which enable higher transfer from the training environment to the operational environment.

Conclusions

We provided a potential solution for expanding the flexibility and introducing stochastic elements into the adaptive instructional process. This could be done without major changes to the GIFT architecture, but comes with a cost in terms of time and skill in the authoring process. Since each action in the MDP must be accounted for in terms of actions, the MDP solution should also be paired with AI-based solutions for simplifying the authoring process for ITSs.

MDPs from a stochastic point of view are also attractive alternatives to decision-trees based on the ability to project expected value or expected total reward into the future based on known decision chains.

This paper examined elements of the MDP related to the instruction of individuals. The development of MDPs for team-based activities poses a much more significant challenge in terms of complexity. State assessments for teams are more complex and less accurate so generalized rules based on the team instruction literature applied to the initial states in an MDP could lead to some experimental strategies which yield future best practices.

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INCREASED SAFETY ROAD TRANSPORTER

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ABSTRACT
The article is focused on road transport. The most wide spread element in ensuring the continuity and safety of traffic is light-signaling device. The mentioned safety element controls via light signals and that is why we classify it among control systems. It controls the road users by using the states of the light signaling device. It is possible to find some deficiencies between the states that increase the risk of extraordinary incident. After an extraordinary incident, the flow of traffic is disrupted. After analyzing and simulation of corrective measures for specific traffic light systems, it is possible to reduce the risk to an acceptable level. By comparing each state at traffic lights, it is possible to avoid risky situations and minimize the risk of accidents this way.

Keywords: traffic light, road transporter, critical infrastructure.

1. INTRODUCTION

One of the important elements in ensuring of the road traffic safety and fluency is the light signaling device. A widespread alternative of the traffic management is using lights signaling devices. Crossroads controlled by light signaling devices are strongly influenced by the quality of the proposed signal plan. Every crossroad controlled by a light signaling device has to have a fixed signal plan. In the Czech Republic the fixed signals are based on the technical conditions of the Ministry of Transport no. 81 TP "Designing light signaling devices for road traffic. (Martolos J., 2015)

We can find crossroads that are controlled without any fixed signaling plan. These crossroads are equipped with different detectors that control this crossroads. When controlling via these technologies there are only set some priorities for the individual directions and some conditions for the proper operation of the crossroad. However, we can find crossroads with that procedure only in cases where the traffic density is low. Above mentioned roads are not so busy and the number of vehicles is only in hundreds per day.

2. LIGHT SIGNALLING DEVICE

Light signaling devices are mostly set up in order to improve safety on the roads. Just additional reason for their set up is to control the flow of traffic. Due to the conflicting interests of the various participants in traffic on the land roads, it is not possible to satisfy all. Only the legitimate demands of the participants can be satisfied. To be able to initiate a control of the crossroad by light signaling device at least one of the following criteria has to be fulfilled: (Martolos J., 2015)

- Criterion of traffic safety.
- Criterion of traffic intensity from the point of view of vehicles.
- Criterion of traffic intensity from the point of pedestrians.
- Criterion of fluency of traffic of public transport vehicles.

3. CRITERIA OF TRAFFIC SAFETY

In framework of the traffic safety, the light signaling devices are design only for crossroads with many accidents and high load. The above-mentioned crossroads must meet the following criteria: (Martolos J., 2015)

- In last three years there must be at least four traffic accidents per million vehicles entering the crossroad when the crossroad is not controlled via light signaling device
- Evidence of the accident rate based on an analysis where you cannot prevent the occurrence of extraordinary events another way.

From the point of view of safety, it is also necessary to consider the place calling for safety. Most of them are places where children crossing the road to school, etc. The above-mentioned localities need to be assessed individually in order to reflect all necessary conditions according to Czech standards CSN 73 6101 and CSN 73 6110. (CSN 73 6101, 2000)

From the point of view of pedestrians, it is necessary to establish light signaling devices where they pass through roads with more than just one lane in one direction. It should be noted that it is impossible to ignore pedestrian crossings which do not meet the conditions required by CSN 73 6110. (CSN 73 6101, 2000).

3.1. Criteria of traffic intensity from the point of view of vehicles

Light signaling device is effective on condition that the intensity of traffic exceeds the values than are the specified ones. These values are determined by allowed intensities of the uncontrolled crossroad according to CSN 73 6102. This is an average of eight hours with the most loaded traffic of the main and minor road. Roughly, we can assess the crossroad capacity using the chart illustrated on figure 1. Using the calculation, we can assess this fact more accurately. In cases where the access of vehicles on the main road is not, a random one we can take into our account also the possibility of influencing the surrounding crossroads. An individual approach is always necessary.

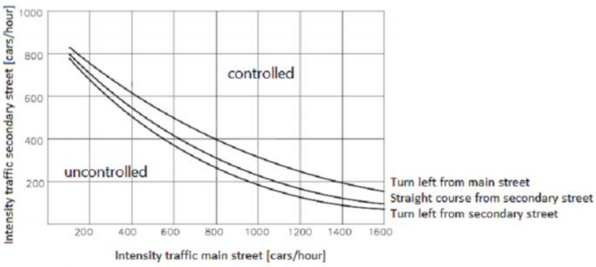

Figure 1 criterion of traffic intensity for the set up of a traffic light (Martolos J., 2015)

3.2. Criteria of traffic intensity from the point of view of pedestrians

Light signaling device is useful if the intensity of traffic on the relevant pedestrian crossing achieves values of an average of eight hours of the most loaded traffic higher than the limit value of the traffic intensity, which pedestrians can, under normal conditions, according to the rules of road traffic pass safely:

- 1100 vehicles per hour - crossing over one or two-lane.
- 1000 vehicles per hour - crossing over the three-lane.
- 900 vehicles per hour - crossing over four-lanes or undivided more directional lane.

Light signaling device fulfill the purpose when it reaches the appropriate intensity of traffic on the relevant pedestrian crossing.

On condition that the above-mentioned criteria are not met then we can assess the set-up of a pedestrian crossing from the following perspective. In the case where pedestrians disrupt the smooth flow of the traffic stream of the coordinated bundle of vehicles. These cases cause an increased risk of dangerous situations because of the unwillingness to allow pedestrians to cross the road.

3.3. Criterion of fluency of traffic of public transport vehicles.

Public transportation is important for each city. All cities prefer this way of transport to the individual car traffic. It is focused not only on improving passenger comfort but also for its attractiveness. Ensuring of the quality of the public transport operation can cause a reduction in traffic load from individual car transport.

For proper function of the public transport there must be taken into account not only the utilization of the public transport vehicles but also the long-term economic perspective. From that point of view, it is possible to arrange financial savings in the number of vehicles operating on the line but also the unnecessary energy consumption during starts.

In all these cases, it is necessary to assess the situations individually. Every crossroad is different. The environment that affects the set-up of a traffic light is different from case to case. Input parameters are indeed still the same, but the process cannot be evaluated the same way.

4. SYSTEM CONTROLLED BY LIGHT SIGNALING DEVICE

In everyday life, we encounter the light signaling device at almost every step. These devices have a variety of applications. We can find its use not only in the road transport but also in other parts of transport as in rail or water transport. In road transport, we often meet the concept of traffic lights, which displayed the particular instructions with color. These instructions are shown in. (Mrazek J., Duricova L. and Hromada M., 2016)

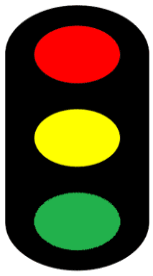

Figure 2 Semaphore [author]

Individual color displays directions that we learned from our parents. Red signal tells us instruction to stop or stand. In case that the red signal lights together with the yellow one, we can prepare for the close change of the signal to green. Green signal tells us that we can go. At the traffic light, we can see that sometimes the only visible signal is the yellow flashing light. It is a situation where it is necessary to act cautiously due to malfunctioning of traffic lights at the crossroad. (Mrazek J., Duricova L. and Hromada M., 2016). Such situations are often very dangerous because of the ignorance or disregarding of the traffic signs.

5. GENERAL CHARACTERIZATION OF THE METHODS

Individual methods can be divided into two categories. In the first category, we are talking about the decomposition approach, which has its own history. At times when this approach was applied, the computer equipment had a very low performance in comparison with the present time. The integration of the second approach is much easier not only for the IT technologies but also "on sight". The reason why this is so is in the complexity. The exact approach is only one step in comparison with the three ones that use decomposition approach. No we learn more about the different steps of the mentioned methods.

5.1. Decomposition approach

In earlier times the computer technology was not so developed. That was why it was necessary to divide the decomposition approaches into three subtasks in order that even less powerful computer could them to handle.
In the first subtask, we must cover the set of flows occurring in solved crossroad by the minimum set of maximal subsets mutually non-collision flows.(Krejci, L., 2011)
This process can be described as the search phase, which runs in two steps. In the first steps, the system searches all subsets of maximum non-collision flows. For this purpose there is created a graph of the collision-free traffic where the flows are converted into a set of vertexes of graphs and collision-free. (Krejci, L., 2011)
Then we leave pairs of conflict flows without connecting edge. The task is to find the most complete subgraphs in this graph. It means to follow the graph vertices, which are joined by an edge with all the other vertices, and it is not possible to find any other peak that would satisfy this condition. (Krejci, L., 2011)
After locating all stages, the second step of the task is coming. The condition for the second step is that all traffic flows entering the crossroad are contained in at least one of the selected pairs. For this reason, it was built a simple linear programming model. (Krejci, L., 2011)
A second subtask is focused on the optimal alignment of the selected phase. In this step, we add a decisive split times between phases. This criterion is necessary in order that we can minimize non-productive times of the crossroad. To solve this criterion we can used Little algorithm. The outcome of this subtask is the fixation of the positions phases, including the greens, for various streams toward others. (Krejci, L., 2011)
The third subtask determines the optimal times of beginnings and ends of green in the cycle for all streams. Last subtask is solved using linear programming model with the selected optimization criterion. The model operates with two sets of variables, which can be integer or non-negative real values. Variables set start and end times for each of the green stream for the given streams. Another variable is selected according to the used criterion. It can be selected either the cycle length or a relative minimum reserve. If you choose the selected cycle lengths, you may choose the relative reserve that is maximalized by the model. Another possible criterion might be the sum of the length of waiting vehicles, which is minimized, and we can also select the length of the cycle. (Krejci, L., 2011)

5.2. Exact approach

The model contains two sets of variables for modeling the start and end times of greens for individual streams and variable depending on the selected optimization criteria. Mentioned step can be compared with the subtask three of the previous approach. The difference can be found in the fact that the model contains two more sets of bivalent variables. The first set is focused on the position of the beginnings and ends of green for individual streams. We evaluate whether the greens have a natural position. If the value of the beginning of the green is lower than the value of the green end, we mention that its position is one of the border of two cycles. A similar philosophy has set bivalent variables. The difference is in fact that there is no modeling of green positions, but the modeling of positions of the split times. Here various optimization criteria are possible. (Krejci, L., 2011)

6. EVOLUATION OF THE ANALYSIS IN A REAL ENVIRONMENT

Analysis of light signal device should be focused on the change between intervals. If there were some changes at various crossroads some light signals occur which create a risk of an accident. Traffic accidents are extraordinary events that affect not only the correct function of the critical infrastructure. For this reason, it is necessary to pursue this issue. On figure 3 it is shown a real case how the light-signaling device can be dangerous.

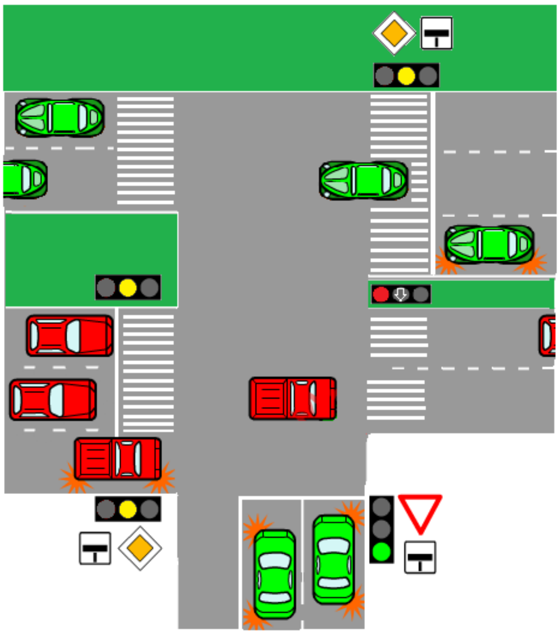

Figure 3 Illustrated real signals from case studies [author]

The picture shows the individual signals from each side of the crossroad. Each semaphore is shown according to the real analysis. From the picture, it is clear that in cases where we cannot safely stop and drive through the crossroad on a yellow light signal it could actually lead to a traffic accident.

Because of the fact that the individual crossroads are different, it is necessary to set the risky crossroads individually. When assessing the above-mentioned crossroads we concluded that our proposed measures are not too expensive and can be dispensed with and without structural modifications.

Corrective solution is aimed at complementing the programming language when it comes to its completion. We add condition that compares individual states of light signaling devices. Using the comparison, we prevent the situation shown in figure 3

7. CONCLUSION

S Lights signaling devices are classified among safety components on the roads. They ensure both safety and continuity on the land road. Taking into account today traffic density, we cannot avoid these devices. It would be chaos on the roads. Statistical data of the number of accidents would quickly increase.

At present, we can say that finding of a light signaling device is not a problem. From the safety perspective, we can permanently innovate something. It is a question if there is no need to start to build the safety from the ground.

The density of traffic is still growing. Traffic lights cannot be accelerated. The only one offered solution is to program the minimum spacing between switching of light signals. Consequently, we call such crossroads risky ones. Not only has that, in the event of a traffic accident the state had to pay money the participants. In the worst possible cases, fatal injuries occur here. At these events, we can also be a direct participant or a close person of one of the participants.

To increase safety we must implement conditions for the individual directions to avoid the shown risky situations. Case situation is shown in figure 3. To be able to minimize such situations, we have to individually assess each crossroad based on the statistics. Taking into account the statistical data of the given crossroad, we have to focus on offences like running on the red light so called disrespecting right of way. After picking up the data, we can analyze the obtained information and we can analyze other risky crossroads with lights. Gradually, we can apply our proposed solutions in terms of programming. The result will not only minimize the number of accidents at crossroads with light signaling devices but provide the greater safety as well.

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MODELING DRUG TRAFFICKING ROUTES USING POTENTIAL SURFACE ANALYSIS FOR THE SIMULATION OF MILITARY TRAINING SCENARIOS

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ABSTRACT

This research paper reports the methodology that adopted Potential Surface Analysis to model drug trafficking routes that led to social problems and public health deterioration in Thailand, the region and most parts of the world. With the final output aimed at creating military training scenarios to be included in a fire-arms training simulator of the Royal Thai Army, real world data from Geographic Information Systems (GIS) were prepared and used as Earth 'Surface' data upon which an Analytic Hierarchy Process (AHP) was performed. Before that process, roundtable discussions among expert of the filed were held to achieve factors and their ratings. Weightings and ratings were based on debate brought to the table from experiences, knowledge, expertise and judgments that ended up with mutual agreement. Physical, drug-aspect and Socio-demographic factors were identified as three main factors and their sub-factors were further separated to respond to drug-trafficking in reality. The factors seem literally diverse so that the Consistency Measure stepped in to ensure the consistency of each weighting and rating significance. Since the calculated Consistency Ratio (CR) was 0.0944, the significance of all the factors became less than 0.10, making the consistency reasonably acceptable. The Potential Surface Analysis (PSA) took form of suitability map that revealed the potential of GIS vector layers that suited drug-trafficking routes. Areas of most suitability were cross-checked to find that they corresponded with recorded drug-trafficking routes. It was securely concluded that the PSA was the proper method adopted to model a drug trafficking route given the studied factors. The project was carried on to simulate the real terrain of real events that passed more realism to military training scenarios in an army simulator.

Keywords: Modeling and Simulation, Drug Trafficking, Potential Surface Analysis, Military Simulation and Training

1. INTRODUCTION

1.1. Drug Situation: The World, The Region, and Thailand

Drug uses still generate social problems and public health deterioration in Thailand, the region and most parts of the world. According to World Drug Report (2015), it was estimated that almost a quarter of a billion people between the ages of 15 and 64 years used an illicit drug in 2013. Although opium poppy is cultivated in South-East Asia, individual drug seizures indicate that neither of the opium cultivating countries in the region, the Lao People's Democratic Republic and Myanmar, appears to be an important heroin trafficking departure hub (United Nations Office on Drugs and Crime, 2015). On the other hand, Windle (2016) found that while Thailand is no longer a major source of any illicit drug, it is an important transit point for drugs originating in other Southeast Asian states. The current trends in drug production, trafficking, and consumption say that Thailand is an important transit point for drugs destined for countries in Southeast Asia, East Asia, and Oceania because the country shares porous, remote, and poorly controlled borders with major drug producers. Therefore, we believe that virtual world simulation of training scenario is one of alternatives so that interception, monitoring and surveillance in drug trafficking can be enhanced.

1.2. AHP and PSA in Suitability Map

Jafari S. and Zaredar (2010) embraced the commonly used spatial AHP method for determining the most suitable areas for rangelands in Taleghan basin. Results indicated that the spatial analytical hierarchy process was a powerful support system resolving different uses of land suitability issues in the region. To deal within consistent judgments for complex decision analysis, Patil et al (2012) adopted AHP on land use suitability in conjunction with five different models and spatial PSA technique regarding highly suitable areas to find the highest potential candidates for residential construction purposes for Pimpri-Chinchwad-Municipal Corporation (PCMC) area, Maharashtra, India. However, debates to bring experiences, knowledge, expertise and judgments for mutual agreement for weightings and ratings were not mentioned.

Esmaelian et al (2015) proposed a Multicriteria Spatial Decision Support System (MC-DSS) to identify shelters and emergency service locations in urban evacuation planning to determine the zones most vulnerable to an earthquake. The final scores obtained were integrated into a mathematical programming model to calculate a GIS platform for the most suitable locations for emergency service stations. They suggested that MC-DSS be able to analyze spatial and space–time data so that the DMs could develop models that best represented reality. Taking a totally different approach, Chiranjeevi and Revathy (2015) provided a deeper understanding and assessment of the predictive accuracy with the assistance of information technology for knowledge discovery. They developed and implemented data mining framework to work with the geospatial plot of crime that helped to improve the productivity of the detectives and other law enforcement officers. The data source was the complete record of drugs such as cannabis, opioid, cocaine or amphetamine-type stimulant group leaving and returning to ports in the Airport region.

By thus far, AHP and PSA have been rarely applied to modeling drug trafficking routes. The closest study was when Dell (2011) examined how drug traffickers' economic objectives influenced the direct and spillover effects of Mexican policy towards the drug trade. The study predicted the diversion of drug traffic following close the Mexico's conservative National Action Party (PAN) victories by estimating a model of equilibrium routes for trafficking drugs across the Mexican road network to the U.S. When drug traffic was diverted to other municipalities, drug trade-related violence in these municipalities increased. Taken into account the room for AHP and PSA to play in drug trafficking route prediction, we identified physical, drug-aspect and socio-demographic factors and their respective sub-factors to respond to drug-trafficking in Thailand's northern borderline. PSA method resulted in suitability maps to reveal the potential of GIS vector layers calculated for drug-trafficking routes. The PSA-based real terrain was passed on to military training scenarios for incorporating into the army simulator.

1.3. The Royal Thai Army Fire-arms Training Simulator

The Royal Thai Army cooperates with Thai Government Agencies in Chiang Mai to intercept drug trafficking from entering the country and to suppress internal drug cartels. Nine fire-arms simulators worth of more than 2 million US dollars were installed in the army units across the country and one of them in Chiang Mai for task force and special force trainings. Officials from drug suppression and interception state agencies are welcome to recall their fire-arms aiming, shooting and frequently shoot-not-shoot decision skills. The Army Training Command needs to upgrade the simulators by incorporating a mission-based training scenario into the systems. Geo-specific and user-centered training scenarios were initiated by the authors to respond to the trained missions and drug-trafficking scenarios were realized to simulate real world mission of drug suppression and interception.

2. DATA AND METHODOLOGY

2.1. GIS Data Collection

The GIS data collection incorporated a combination of vector and raster GIS. One-meter resolution satellite image was used for GIS layer generation as shown on the Figure 1 right inset. Numerous and different work plans were carried out to cover the entire 20 km^2 study area. Urban survey was conducted and concluded to be the most time-consuming of the field survey tasks. The survey of land uses and plantation in agricultural areas was completed by the integration of remote sensing image processing and GIS heads-up digitization method. A forest inventory was divided into several plots to collect tree or shrub types and heights for later use in virtual world creation. Terrain contour lines were interpolated from GPS height point collection for terrain generation. The validation of spatial data accuracy was randomly ground-checked and reported to be insignificant for the terrain heights which were later cover-planted by three dimensional vegetation models.

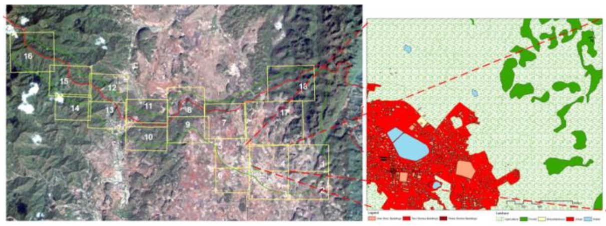

Figure 1: The studied areas and GIS data layers of an urban part

2.2. Methodology

Figure 2 illustrates the conceptual framework of the current study. The methods of this investigation are fourfold; (2.2.1) Defining factors and sub-factors related drug trafficking, (2.2.2) Analytic Hierarchy Process (2.2.3), Modeling drug trafficking routes using PSA, and (2.2.4) Virtual world creation, the details of which are as follows;

2.2.1. Defining factors and sub-factors related drug trafficking

Prior to applying Potential Surface Analysis to model drug trafficking routes, roundtable discussions were proceeded in order to retrieve which factors and sub-factors had comparatively more impact on drug trafficking. The group discussions were carried out among several military and police sectors that are involved with interception, monitoring and surveillance of drug trafficking. Particularly, homogeneity within those decision makers was necessary to impose. Since the factors and sub-factors were debated and defined (as seen in Table 6 and 7), the same group of decision makers needed to evaluate the significance of each criterion using AHP (Malczewski, 1999) as one of weighting and rating techniques to be described later in section 2.2.2. This methodology of multiple decision making executing variables related to drug trafficking demonstrates a substantially unique work compared to the results when Medel, Lu, and Chow (2014) merely defined variables of drug trafficking cost based on common knowledge.

Figure 2: Conceptual framework of study

2.2.2. Analytic Hierarchy Process

AHP is one important multi criteria decision analysis (MCDA) that researchers frequently used to explain the significance intensity of criteria quantitatively. So as to acquire the significance value of each factor, roundtable discussions were performed among the same group of officers (described in section 2.1). The pairwise comparison method developed by Saaty (1980) was applied to obtain relative weights for the output. The scale of pairwise comparison contains intensity of significance from 1 to 9. The method could be best described by an example of intensity scale of significance among physical and drug factors displayed in Table 1. Experts when considering that the type of road network to have more intensity of significance to drug trafficking would have a scale of 3 compared to that of the landuse. On the contrary, landuse would have the intensity of significance to drug trafficking of 0.33 compared to the type of road network. Pair by pair, all factors and sub-factors were scaled from a group of experts. Eventually, the single intensity of significance among factors was agreed at the end of each roundtable discussion so that the pair wise comparison method could be calculated as seen an example in Table 2. The pairwise comparison accomplished this way ensured the estimation of factors and sub-factors weights (Malczewski, 2015) to be further analyzed in PSA. Next step was to compute factor weights using normalized pairwise matrix (Malczewski, 1999). It comprised three steps including; (a) summing in each column of pairwise comparison matrix (Table 2); (b) dividing each component in the matrix by sum values acquired from step (a) bringing up normalized pair wise comparison matrix (Table 3); and (c) computing the average of components in each row of the normalized matrix. These averages gave the estimation of relative weights of criteria associated (Table 4).

Table 1: An Example of intensity scale of significance

Intensity of Significance	
Landuse	RD[a]
9 8 7 6 5 4 3 2 1	2 **3** 4 5 6 7 8 9
Landuse	TS[b]
9 8 7 6 5 4 3 2 1	2 3 **4** 5 6 7 8 9
Landuse	SM[c]
9 8 7 6 5 4 3 2 1	2 3 4 **5** 6 7 8 9
RD	TS
9 8 7 6 5 4 3 2 1	2 **3** 4 5 6 7 8 9
RD	SM
9 8 7 6 5 4 3 2 **1**	2 3 4 5 6 7 8 9
TS	SM
9 8 7 6 5 4 3 2 **1**	2 3 4 5 6 7 8 9

[a]Type of road network, , [b]Transit site, [c]Trafficking method

Table 2: An example of pairwise comparison

Pairwise comparison			
Criteria	RD	TS	SM
Landuse	0.33	0.25	0.20
RD	1.00	0.33	1.00
TS	3.00	1.00	1.00
SM	1.00	1.00	1.00
Sum	5.33	2.58	3.2

Table 3: An example of normalized pairwise comparison matrix

Criteria	RD	TS	SM
Landuse	0.06	0.10	0.06
RD	0.19	0.13	0.31
TS	0.56	0.39	0.31
SM	0.19	0.39	0.31

Table 4: An estimation of the relative weights

Criteria	TS	Weight
Landuse	(0.06+0.10+0.06)/3	0.07
RD	(0.19+0.13+0.31)/3	0.21
TS	(0.56+0.39+0.31)/3	0.42
SM	(0.19+0.39+0.31)/3	0.30

In our study, we implemented above mentioned steps (from Table 1 to 4) so as to retrieve the estimation of relative weights of factors and sub-factors defined by group of officers. The results are shown in section 3.2. To verify reasonably acceptable relative weights, Consistency Ratio (CR) was employed. If the CR was <1.0, the overall relative weights of factors and sub-factors were reasonable, otherwise, the intensity of significance among factors was reconsidered.

2.2.3. Modeling Drug Trafficking Routes using PSA

To the best of our knowledge, none research on drug trafficking in Thailand has been focused on geographical relations. Moreover, it has been confirmed that using the combination of AHP and PSA can enhance the understanding of decision making problems involving spatially referenced aspects (Pawattana, and Tripath 2008, Dell 2011; Alexakis, Hadjimitsis, and Agapio 2015, Mishra and Deep 2015). Prior to applying PSA, twelve GIS layers were extracted from orthophotos associated with field survey to create a defense geo-database. Those factors and sub-factors related to drug trafficking, which were imposed by a group of decision makers, were manipulated and transformed into a spatially referenced format even though a few of them was non-spatial including the number of information received per month, and trafficker's network (Table 6). PSA, based on equation 1, was applied to model drug trafficking routes. The relative weights of each criterion acquired from section 2.2.2 (An example as seen in Table 4) were included in this equation (W_i and X_i).

Potential drug trafficking routes = $\sum_{i=1}^{n} WiXi$ (1)

Where

W_i is relative weight of $factor_i$ related drug trafficking
X_i is relative weight of sub-factor of $factor_i$ related drug trafficking

The potential areas of drug trafficking were spatially analyzed using equation 1 and categorized into less, moderate and high potential. Most importantly, the validation of modeled drug trafficking routes was carried out using lessons learnt from the operational military units and the Thai Government Agencies in Chiang Mai. The results of model validation were further explained.

2.2.4. Virtual World Creation

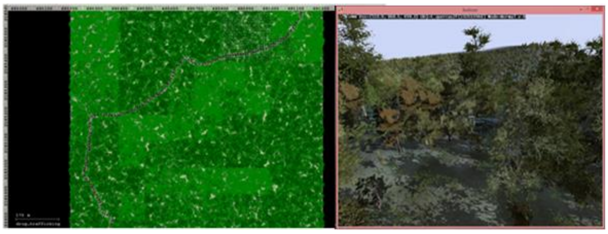

Figure 3: Terrain data prepared in Landbuilder® and the virtual world rendered by Buldozer®

3D virtual world creation started with selecting a region from GIS data in Section 2.1 that covered the result of the modeled drug-trafficking routes in Subsection 2.2.3. The necessary and prepared GIS data included interpolated heights, satellite images, GIS attributes data that defined position and boundary of natural and manmade objects, photos from the selected site for 3D model selection and 3D models to represent objects found on the selected site. Visitor4® terrain development tool that was part of Virtual Battle Space version 3 (VBS3®) was used to create the virtual world. The process encompassed inputting the .tif terrain height data, satellite images and GIS shapefile vector layers. Landbuilder® (Figure3 left) was used to plot 3D vegetation models bounded by a forest ESRI® shapefile. The virtual world was rendered by Buldozer® (Figure3 right). The processed virtual world was further used (Figure 4 left) for mission training scenarios (Figure 4 right) in VBS3®.

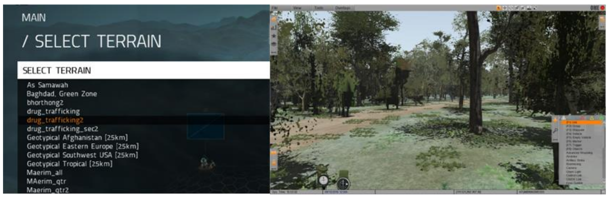

Figure 4: Terrain data prepared in Landbuilder® and the virtual world rendered by Buldozer®

2.2.5. Drug Trafficking Training Scenario

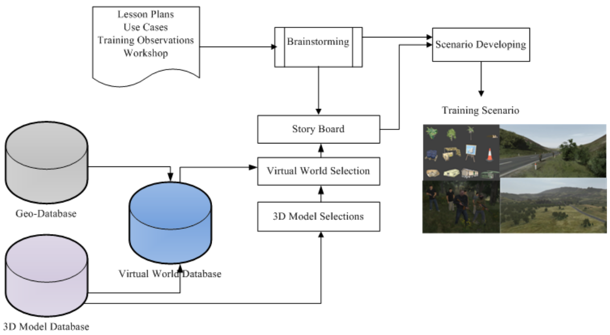

Figure 5: Steps of training scenario creation

Training Scenario requirements were gathered via activities in Figure 5. Such diparate data was from lesson plan, standard operating procedures, trainings or genuine field experience, and training observation. Workshops on Range3000® Video Branching at the

Chulachomklao Royal Military Academy during 9 - 10 July 2015 (Figure 6 upper left) and Workshop of Weighting and Rating Factors and Sub factors-related drug trafficking at one of the Army units in Chiang Mai on 14 May 1015 (Figure 6 upper right) were also incorporated into the VBS3® Engine scenario where appropriate weapons, backpack, avatar and vehicle (Figure 6 lower left) were selected and placed on the selected virtual world of (Figure 6 lower right).

Figure 6: Drug trafficking scenario creation on VBS3 Game Engine

3. RESULTS AND DISCUSSION

The GIS layers were prepared from the ortho-rectification of satellite image of high resolution and topographic map for field survey. Consequently, twelve GIS layers were compiled in the geo-database to support the PSA for drug trafficking routes and training scenarios. The literature review of related research was conducted to emphasize the application of PSA for drug trafficking routes by integrating geospatial technology. It was found that the results of this project provided new findings, which employed the PSA principle and theory to analyze potential areas for drug trafficking routes coupled with the MCDA. Additionally, using AHP to configure the weighting and rating of factors, could incorporate tactics into intercepting and suppressing the drug trafficking. The extended sub-factors, including the significance and level of factors related to the interception and suppression of drug trafficking routes, were achieved through the meetings and discussions between researchers and representatives from relevant sectors of the Thai Government Agencies. Accordingly, the results from the PSA were divided into three parts: (i) factors and level of factors involved in drug trafficking routes, (ii) the score of significance and level of factors involved in drug trafficking routes, and (iii) the potential of drug trafficking area.

3.1. Geo-database Creation

Satellite images were processed for relief displacement and the resultant ortho-rectified images showed significant accuracy where random point generation means was applied to obtain forest stands at the spatial accuracy of approximately 72%. Attribute of the forest stand was populated further by plotting for forest inventory data. An expert group was consulted before, during, and after the forest survey of the study to validate while surveying the area for a safety reason of the survey team (see Figure7). The forest inventory was carried out on the high potential area of drug trafficking resulted from subsection 2.2.3. A 20m x 20m plot was for tree, shrub and forest in general. A 20m x 10m plot was for forest profile and density. A 5m x 5m plot was for trees at sapling stage and ground cover. And a 2m x 2m plot was for seedling to sapling. The forest inventory of the studied areas as shown on the Figure 7 lower inset was conferred to the forest department in Chiang Mai province.

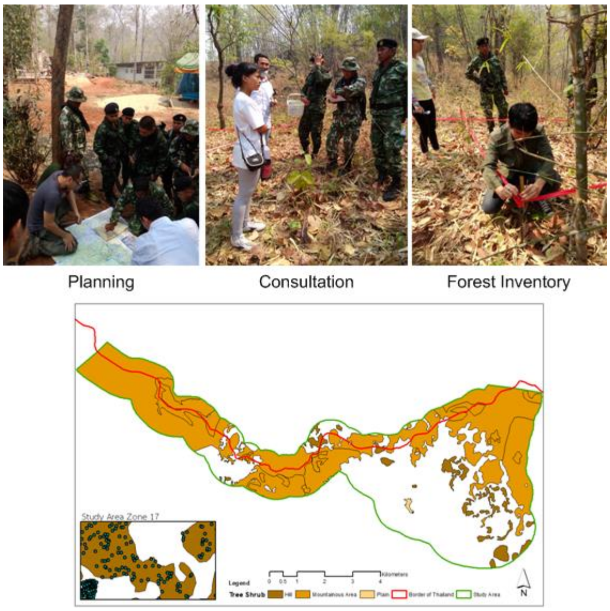

Figure 7: Planning, consultation and plotting for forest inventory data

3.2. Factors and sub-factors related drug trafficking

Fifteen experienced decision makers were designated both in command and field operation levels assigned from the Thai Government Agencies in Chiang Mai. There was an attentive issue found during the group discussions. Rank discrepancies among army officers suspected to have caused mute discussions were eliminated by allowing chances of writing documents to express relevant, straightforward and meaningful ideas. The factors and sub-factors categorized from the group discussion are shown in Table 6 and 7. Afterwards, the significance of each criterion and sub-criterion (scale of 1-9) was agreed from the decision makers mentioned above and pairwise comparison method was applied in order to acquire the relative weights of factors and sub-factors as seen in Table 6 and 7.

Table 6: Weights of factors related drug trafficking

Group of factor	Factor	Weight
1. Physical	Land use	2.37
	Road network	4.15
	Residential area	1.90
	Confidential	7.13
2. Drug	Drug production site[a]	4.72
	Transit site	6.63
	Drug SM	8.50
	Drug SR[b]	5.79
	Activities of MO[c]	10.86
	A number of information[d]	18.61
3.Socio-demographic	Trafficker's network	16.71
	Ethic group	12.62

[a]inneighboring country [b]Trafficking route [c]Military officers [d]received per month

Table 7: Weights of Sub-factors related drug trafficking

1. Physical Factors	Description	Weight
Land use	Field crop area	0.1521
	Horticultural crop area	0.2138
	Forest area	0.3641
	Urban area	0.1416
	Water area	0.0581
	Miscellaneous area	0.0703
Road network	Highway	0.1098
	Sub-pathway	0.3179
	Topographic pathway	0.5724
Residential area	Distance from urban area < 300 m	0.1667
	Distance from urban area > 300 m	0.8333
Confidential	Distance< 500 m from confidential	0.1667
	Distance > 500 m from confidential	0.8333
2. Drug Factors		
Drug production site[a]	Distance from drug production site <1 km	0.7500
	Distance from drug production site >1 km	0.2500
TS	Distance from transit site<1 km	0.8300
	Distance from transit site> 1km	0.1700
Drug SM	Motorbike	0.5500
	Pedestrian	0.3100
	Vehicle	0.1400
Drug SR	Outward border	0.1991
	Along border	0.6012
	Inward topographic pathway	0.1997

Table 7 (Cont'd)

Activities MO[c]	Reconnaissance	0.184
	Waylay	0.3327
	Check point	0.3938
	Blockade	0.0890
A number of information[d]	None	0.0355
	Less	0.0715
	Moderate	0.1367
	High	0.2425
	Very high	0.5138
3.Socio-demographic		
Trafficker's network	Distance	0.0807
	Nationality	0.2923
	Mutual interest	0.6270
Ethic group	Lahu	0.2475
	Lisu	0.1538
	Thai Yai (Shan)	0.1013
	Akha	0.0560
	Wa	0.2379
	Chin Haw	0.0684
	Kachin	0.0325
	Local Thai	0.0297
	Mixed group	0.0729

[a]in neighboring country [b]from border [c]from residential area [d]received per month

The relative weights of criteria and sub-criteria were confirmed reasonably as the CR value was lesser than 0.1.

3.3. PSA Modeling Drug Trafficking Routes

Drug trafficking routes were modeled and the results were explained regarding the physical and socio-demographic correlation of drug. In Figure 8, the high potential of drug trafficking routes was discovered on the eastern and central parts of the study area, referred to as route A and route B, respectively. The physical relation could be elaborated in that prior to crossing Thailand border, drug traffickers with distance from drug production site more than 1 km chose to use a pedestrian means to smuggle drug along a topographic pathway. Afterwards they smuggle drug toward and through Thailand border either by pedestrian or by motorbike along sub-pathway and the topographic pathway. These trafficking trips occurred at forest, field crop (rice and corn fields) and horticultural crop areas (mango, lychee, longan and rubber plantations) before transferring to designated transit sites with distance lesser than a kilometer. Furthermore, ethnic groups among trafficker's networks described socio-demographic aspects related to drug trafficking. Further explanation was that trafficker's network nationality outside Thailand of route A and B had no difference; on the other hand trafficker's network nationalities within the country were in two different ethnic groups. The distance of trafficker's network found in route A was shorter than in route B because in route A the distance

from production site outside Thailand to its ethnic group populated at transit site was short. In addition, the number of information that officers received per month showed insignificant impact on trafficking routes.
The predicted drug trafficking routes were validated using actual data of trafficking routes recorded in year 2015 by Thai Government Agencies in Chiang Mai. It was discovered that the study's predicted drug trafficking routes A and B were completely precise when trafficking routes were validated using actual data of trafficking routes. The high potential drug trafficking routes mentioned above were extracted from the GIS database and transferred into virtual world creation so as to create training scenarios of drug trafficking as explained in section 3.4.

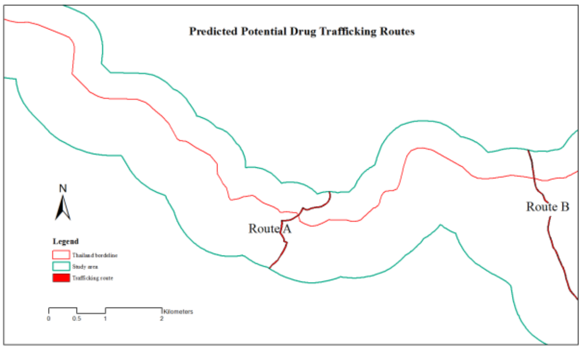

Figure 8: Potential Drug Trafficking Routes

3.4. Virtual World Creation

Figure 9: A visual comparison between a computer-generated image (left) and real photo (right)

Since the virtual world was created from GIS database used for modeling the terrain reality to the database with landscape features described in data attribute such as tree types and tree heights for 3D vegetation model selection, a comparable visualization on the computer-generated scene and photo taken from the landscape was visually validated in Figure 9. Slightly different viewpoints were selected for a comparison. Further studies and topics were discovered upon this comparison. Positional accuracy was achieved upon the placement of 3D models but attribute data representing the nature was difficult to resemble by a generic modeling tool. The study on specific modeling tool for tropical zone was urgently needed to fulfill the photorealistic weakness of the study.

3.5. Drug Trafficking Training Scenario

Figure 10: Workshop for VBS3-Milorange interface

Milorange® was the army simulator that played for test and host of the created drug trafficking training scenarios. A few workshops shown in Figure 10 were held to get the researchers accustomed to the interface whereby the basic shooting scenario was implemented and tested for technical validation when drug trafficking training scenarios were added on.

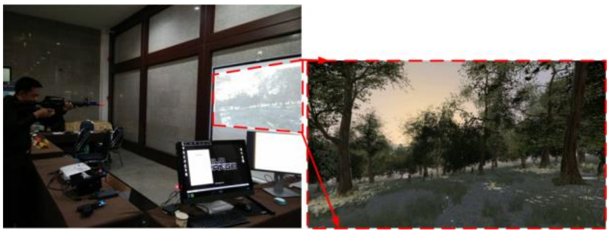

Figure 11: Technology demonstration for conceptual validation

One of the drug trafficking training scenarios was conceptually validated by the army officers in the annual Royal Thai Army Warrior indignity (see Figure 11). Several occasions were seen to have the research output demonstrated and high ranking commanders of the army were satisfied with the output. Various comments were received and promised to be present on further studies.

4. CONCLUSION AND FURTHER STUDIES

This article reports the original work of modeling drug trafficking using PSA to analyze the suitability map from the surveyed and collected GIS data layers. For GIS data collection, field survey was applied for the validation of the GIS layers digitized from the ortho-rectified image. AHP was the tool to calculate weights of factors and sub-factors related to the drug trafficking in order to rate the significance of the factors to one another. The Consistency Ratio (CR) of 0.0944 was achieved to confirm their acceptable consistency. Then, the GIS data layers were used to play host for PSA to find potential areas for the drug trafficking routes. The routes were adopted with relevant GIS data layers for creating the virtual world where the training scenario from direct experience was created for incorporating into the army simulator. It was concluded that the PSA was the right and profound method that was adopted to model the drug trafficking routes given the studied factors and sub-factors. Different steps either technical or conceptual validation were carried out in several formal events that comments were collected and input to the adopted methodology. The generated training scenarios for the purpose of incorporating into the existing simulator were widely and thoroughly accepted by the army. The project was such a success that it was further financially granted for its continuation.

By the time of this article's publication, the authors started to carry on with the project titled geo-database for military and security applications. With the widely accepted concept for GIS terrain modeling, unmanned aerial vehicles were embraced to help collect terrain data for the geo-database creation. Large scale geo-database was expected to help task force units in the northern part of Thailand on terrain analysis prior to mission execution. Training scenarios were extended to the Army Center of Aviation where photorealistic modeling of forested terrain was requested for its own version of helicopter simulator. Game Engine with extensive access to game builder community is currently under investigation to explore for a more open technology that the army can afford to employ and the research and development sectors can attain to the requirements.

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DTI'S MODELING AND SIMULATION INITIATIVE PROJECT TO STRIVE FOR THE HADR MISSION OF THAILAND'S MINISTRY OF DEFENSE

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ABSTRACT
Military operations other than war have been put ahead of missions in battlefield in time of resource scarcity and disaster crisis management. Defence Technology Institute or DTI was established to conduct large-scale and nation-wide research and development projects with great impact at national scale. This paper reports an initiative of research and development to prepare the nation for earthquakes, flooding and landslides that have effected Thailand and inevitably led the world economy to numb, taking the 2011 Thailand major floods as an example. An HADR simulation and simulator project was initiated to prepare a ready hand of Thailand's armed forces, non- and governmental organizations, academic institutes and even private sectors to cope with the crisis. Modeling and simulation are embraced as a tool to predict the disasters. Standard Operating Procedures of best practices from actual and frequent experiences are input for the method development and incorporation with Thai own SOPs in response to the eruption. Similarly, records, mistakes and success are analyzed in the modeling and simulation research that fits Thailand's situation and come up with Thailand's SOPs to recover victims or effected people from the disasters. Sharing resources and knowledge, involving indigenous academia, creating forum and bringing in foreign expertise are media that will place DTI in the middle of disparate stakeholders where project management takes control. Three years are a major constraint that the project needs project management for cooperation, collaboration and integration. High success has been expected so that feasibility study with the demonstration of one sample disaster scenario is minutely planned to acquire foreign outsourcing. Targets are set to ensure and secure budget in from of formal and promised user requirements. Deliverables are set at the end of three consecutive fiscal years.

Keywords: disaster crisis management, standard operation procedure, HADR simulation and simulator, project initiative

1. INTRODUCTION
The world's citizen has faced mighty natural disasters during the past few decades. According to list25.com (Josef, 2013), Mozambique Flood in 2000 made many people homeless as it affected 1,400 sq km of arable land, killing 800 people and 20,000 cattle. The Indian Ocean Earthquake on December 26, 2004 that lasted only 10 seconds caused a tsunami that killed 200,000 to 310,000 people along the shores of Indonesia, Sri Lanka, South India, and Thailand. Hurricane Katrina in 2005 was also one of the costliest with estimated property damages of US $81 billion. The Haiti Earthquake with a magnitude of 7.0 at the depth of 8.1 miles rocked Haiti on January 12, 2010, the strongest earthquake to hit the country since 1770 and it left over 200,000 deaths, 2 million homeless, and 3 million people in need of emergency aid. Tōhoku Earthquake and Tsunami (2011) recorded as the 7th largest earthquake in the world led to about 15 million dead or injured, and 2,814 people missing and caused a near nuclear disaster when there was a partial meltdown in 3 reactors of the Fukushima nuclear plant, which is the 2nd largest nuclear disaster after Chernobyl. The 2011 Christchurch earthquake with a magnitude of 6.3 severely damaged New Zealand's second-largest city, killed 185 people with 238 reported missing and 164 treated for injuries, with an estimated US $16 billion worth of damages incurred.

Figure 1: Delegates from 18 nations join the AM - HEx 2016 Final Planning Conference

Upon Thailand's perspective, the agriculture-based country was positioned to be the world's kitchen due entirely to its vast natural resources, various crop yields and agricultural products. According to the 2014 annual report of the Bang of Thailand, rice export brought a revenue of approximately 4,995.80 million US dollars (calculated at 35 Thai Baht/US dollar), with rubber export ranked second at 3,249.33 millions and sugarcane and sugar at 2,917.23 millions. That was not to include fruit and others. However, the national export revenues rarely came close to the estimated 41,142.86 million US dollar loss that the country underwent during the major flood of Thailand in 2011 that left the difficulties to 5,247,125 households, 16,224,302 people hugely effected and the death toll of 1,026 in 64 provinces across the country. Disaster information management for Thailand's human assistance and disaster relief that had been under great attention among relevant agencies or parties since the 2004 Indian Ocean tsunami was tested again at the national level with help from allied countries and international organizations. Given the military operation other than war, various military units were dispatched to flooded areas to provide immediate and responsive aid and relief to impacted people throughout the country. This eruptive task requires the task forces to expose to trainings that follow standard operating procedures so that on-site confusion and mistakes can be at best deducted or at least avoided.

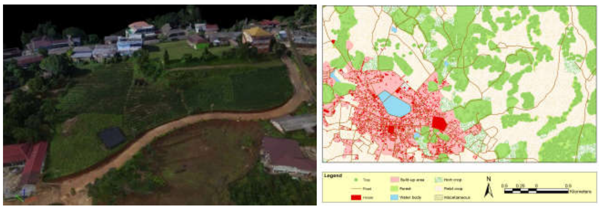
Figure 2: A FTX 3D Virtual Model DEMO (left) of terrain map (right) for flood training simulation

The Administration of the Ministry of Defence Act B.E. 2551 (2008), Section 8 which describes the authority of the Ministry of Defence as to "safeguard independence and security of the Kingdom from internal and external threats, protect the country and people from rebellion and disorder, safeguard and protect the institution of Monarchy as well as to support the mission of the institution of Monarchy, protect and safeguard the national interests and the democratic system of government with the King as Head of State, develop the country for security, support missions of the State in national development, protect and solve problems of disaster, provide humanitarian assistance. During the past years, Thailand deployed forces, both individuals and units, to support peacekeeping missions under the framework of the United Nations and regional cooperation, as well as operated a number of missions in sending relief assistance to disaster-affected foreign countries. The Administration of the Royal Thai Armed Forces Headquarters Royal Decree B.E. 2552 (2009) Article 12: says that the Armed Forces Development Command has the responsibility associated with, among others, prevention and solving disaster problems and humanitarian assistance. The development command units located in all over the country are front-liners following the 2015 National Disaster Prevention and Mitigation Plan. This line of engagement corresponds to The Administration of the Ministry of Defence Act B.E. 2551 (2008), Section 8 dealing with protecting and solving problems of disaster and providing humanitarian assistance.

2. RELATED WORKS

2.1. Disaster Simulation and Information Management System

Fujitsu Indonesia (2015) applied Disaster Management Capabilities to recent flooding in Indonesia based on the disaster management solution that Fujitsu offers in Japan and available at the DKI Jakarta disaster management command center from December 2013. The system was put into action during the recent flooding of January 2014, improving coordination and disaster response compared to previous years. NEC Corporation (2016), in collaboration with Thailand's National Disaster Warning Center (NDWC), had conducted a trial of its flood simulation system to predict the inundation areas in the event of flood and the trial conducted in Uttaradit Province in Northern Thailand. The effectiveness of the system was confirmed.

Assilzadeh and Mansor (2016) described the three main components namely Communication, Data Distribution and Data Management Systems as a solution for natural disaster data and information management to reduce the cost and time for contingency and decision-making in Malaysia. The scope of work needed to expand participation of wider range of stakeholders such as local government institutions to build up their capacities to meet the demands in disaster management.

The review and research imply that civilians have been incorporated into the disaster management system. Military sectors have been far removed from the disaster information management loop. The case in Thailand is totally different from neighboring countries since military resources and personnel are the first group to care for security, support missions, to protect and solve problems of disaster and to provide humanitarian assistance.

2.2. Disaster Management Simulator

Krzhizhanovskaya et al (2011) described a prototype of the UrbanFlood Early Warning System (EWS) that included an Artificial Intelligence module for sensor data anomaly detection, and a cascade of models for dike stability analysis, dike breaching and flood propagation with a developed Virtual Dike computational module. Krzhizhanovskaya et al (2013) reported the novelty of a coupled distributed simulation of surface and subsurface flows that predicted inundation of low-lying inland zones far from the submerged waterfront areas, as observed in St. Petersburg city during the floods. A look into an automated damage assessment was under investigation.

Advanced Disaster Management Simulator (ADMS) offers challenging, true-to-life virtual environments for training incident command and disaster management teams at all levels. With Incidence Command Post simulator, the system seems to come close to DTI's

HADR simulation and simulator except the fact that Thai military and civilian SOPs that are required to feed into the simulator is expected to take as lengthy the time as the currently proposed concept. Furthermore, intellectual property plays a vital and central role on what path DTI chooses to take.

2.3. Disaster Recovery Management

In recognition of the importance of computer modeling in disaster preparation, DeMeritt (2012) reported the Federal Emergency Management Agency (FEMA) created the Regional Catastrophic Preparedness Grant Program (RCPGP) to support state-of-the-art research into emergency response methods and tools. GIS-based Common Operating Picture (COP) showed inaccessible areas, polygonal barriers within the impacted areas and a flood inundation map, provided by the US Army Corps of Engineers and the West Virginia National Guard. The map provided the inclusion of the flood inundation map that allows users to identify which shelters and hospitals would be offline and thus should not be activated during the event.

Ardalan et al (2015) presented an experience about using virtual simulation methods to teach health professional on disaster medicine in Iran. They continued to call for support and extended collaboration within and outside Iran from all concerned to effectively incorporate virtual simulation with the ultimate goal of endowing disaster professionals with field-based and practical skills in Iran. The same call should also be made beyond Iran to other countries and regions known to be embroiled in devastating disasters.

3. DTI'S INITIAL INVOLVEMENT WITH HADR EXERCISE

Defence Technology Institute (Public Organization) or DTI was established almost a decade ago to conduct great-impact, large-scale and nation-wide research and development projects to serve the MoD. Military Simulation and Training is one of eight targeted technologies that DTI managed to get approved of by the Defense Ministry Council. The humanitarian assistance and disaster relief simulation and simulator project was included in the master plan to press interest on military operations other than war rather than missions in battlefield in time of resource scarcity and disaster crisis management. DTI was invited to join the 2016 ASEAN Military Medicine Humanitarian Assistance and Disaster Relief Exercise or AM - HEx 2016 where delegates from 10 ASEAN countries and 8 other dialogue partners gather to exchange dialogue on the issues. It is the joint exercise between Experts' Working Group on Military Medicine or EWG on MM and Experts' Working Group on Humanitarian Assistance and Disaster Relief or EWG on HADR, see the many participants for the AM - HEx 2016 Final Planning Conference. The event is in line with the three year plan of EWG on MM approved by ASEAN Defence Senior Officials' Meeting or ADSOM and the meeting among ADDOM EWG on HADR and EWG on MM. To join the exercise, DTI prepared technology demonstration that displays concept and ideas currently implemented in the three year plan of the DTI's HADR simulation and simulator research and development project.

Several demonstration and static displays are prepared to present technology and concept readiness of the planned project; 1) A workshop will be held during 1 - 5 August, 2016 in Hua Hin for DTI researchers to customize proprietary Disaster Information Management System (DIMS) software aimed to manage the congested flow of data and information during the crisis., 2) A Dynamic Disaster Risk Mapping (DDRM) system is proposed to keep simulation and simulator users current and regularly updated with disaster-related data and processed information from relevant agencies. Conducting research, holding data for access to incidents as they occur, public and private universities located in northern, north eastern, central and southern parts will be allocated with enough budget to produce the dynamic risk map of the region they are geographically familiar with and intellectually capable of., 3) A 3D Virtual Model of Field Training Exercise (FTX) site, see fig. 2, is to demonstrate a used platform and sensor, research capacity and related technologies that large-scale geographic data is incorporated with the DDRM for terrain analysis of the flood training simulation., 4) DTI HADR SS's project's partners prepare posters of research projects that dealt with result maps of flood, earthquake and landslide risk areas. the result of applying Geographic Information Systems or GIS to obtain damage assessment of flooded areas of northern Thailand was presented at the static display., 5) The oral presentation of the DTI HADR SS project that brings in collaboration, cooperation and coordination in the midst of an urgent need for a common platform to help the country stay prepared and ready for time of crisis will be delivered before high ranking commanders and delegates from allied countries to create widespread and international awareness. In the presentation content, some great help and contribution from an agreed foreign partner will be acknowledged to show appreciation for government-to-government collaboration on a CPX-based DTI HADR Simulator.

4. THREE MAJOR OBJECTIVES OF HADR SIMULATION AND SIMULATOR

4.1. Modeling and Simulation (M&S)

Through research coordination and collaboration, this objective is to conduct M&S research that results in the Dynamic Disaster Risk Mapping (DDRM) system with the outcomes to keep simulation and simulator users current and regularly updated with disaster-related data and processed information from relevant agencies.

4.2. Responsive Training Simulator

Based on best practices and well-proven CPX simulator, the objective is to develop training simulators that help trainees in various levels to respond to the simulated flood from the flood risk map. An SOP in the

Thai context will be run and tested with SOPs of best practices as a benchmark.

4.3. Recovery Training Simulator

This objective will be achieved via a similar form of the responsive simulator that inputs Thailand's SOPs to recover victims or effected people from the disaster. The SOPs will be studied with proof from standard blinded peer review journal papers with acceptable impact factor before incorporating into DTI DIMS HADR SS.

5. DTI HADR SS ARCHITECTURE

5.1. DDRM System

The DDRM System, top part of fig. 3, will produce, and continue to do so in years to follow, risk maps to floods and flood-related disaster of Thailand's regional parts. Public sectors as flood-related data guardians will be involved at this early stage to supply necessary data and comments in appropriately held workshops to the academic sectors for data analysis and flood forecasting. International organizations will provide certified and standardized disaster management trainings. Advanced hardware and equipment for the projects will be supplied by certified private sectors.

At the lowest level of the SS actors, onsite military units and town municipalities or sub-district administrative organizations as identified on the dynamic risk map report will be advised with activities that include disaster preparedness and resources management. Located in or nearby the town e, this group of academic institute players is accessible to the map, advise, necessary trainings at all time. Activities to follow the DDRM implementation will keep academia and local people close, the preparedness and resources management regularly monitored.

5.2. DTI DIMS for Updated Disaster Information

The Responsive Humanitarian Assistance Simulation and Simulator (purple box of fig. 3) includes DIMS capabilities to obtain updated disaster-related information from registered and reliable public via mobile devices, agreed public sectors, collaborated private sectors, region-based academic sectors, and international agencies and organizations. The output from the DIMS is fed into DTI HADR SS via CPX SS where practiced, shared, learned and experienced SOPs exist.

These decision making levels are responsive in threefold; 1) MoD players: Defense Minister commands and controls RTArF, RTA, RTN, RTA Operation Centers, 2) Interior Minister commands and controls relevant ministries, and 3) Prime Minister commands and controls ISOC, National DPM Center, National Security Council . This corresponds to the intertwined coherence of national entities to coordinate and cooperate in time of crisis management illustrated in the national disaster prevention and mitigation plan of 2015.

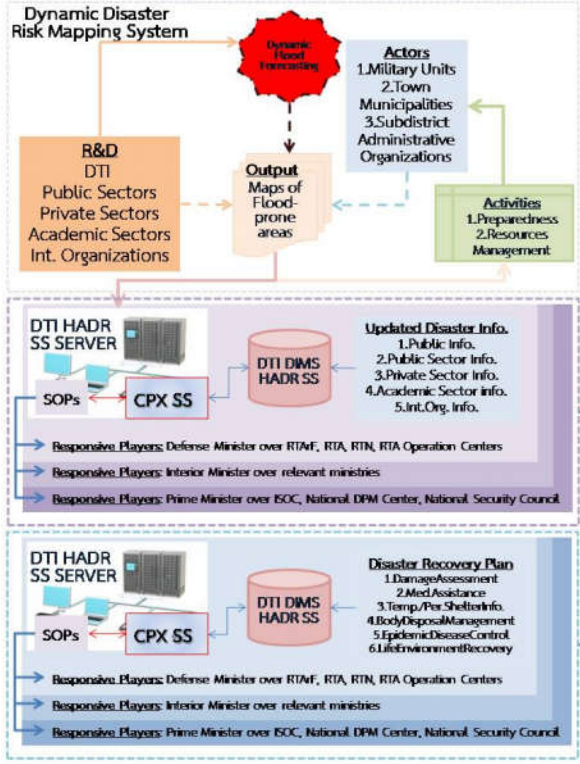

Figure 3: Three main components of DTI HADR SS Architecture

5.3. DTI CPX SS for Disaster Recovery Management

The blue box of fig. 3 is to set up a disaster relief simulation and simulator system where disaster recovery plan is supervised according to line of engagement from the defense minister up to the prime minister. The information input to DTI DIMS HADR SS is an academically sound and profound study of involving SOPs, the accreditation of which is from blinded review international journals with widely acceptable impact factor within their respective fields.

Those topics include, but not limited to, disaster damage assessment and resources management, medical assistance administration and public health management, temporary and permanent plan of shelter and evacuation, body disposal and management, epidemic quarantine and disease control, and human quality of life and environment recovery. The results are in form of report of standard and sustainable approaches to deal with the issues so that implementation is obtainable.

6. INVOLVEMENT IN DTI HADR SS PROJECT

Based on software system engineering management, the project will initiate involvement the management of software, equipment, data, personnel and facilities. How DTI coordinate, all research parties collaborate, and data guardians and agencies in charge of disaster prevention and mitigation cooperate is graphically illustrated in fig. 4. The three C's are an mechanism that facilitates the sharing of resources and knowledge, involving indigenous academia, creating forum and bringing in foreign expertise with DTI as the modeling and simulation research institute to drive disparate stakeholders when project management takes control.

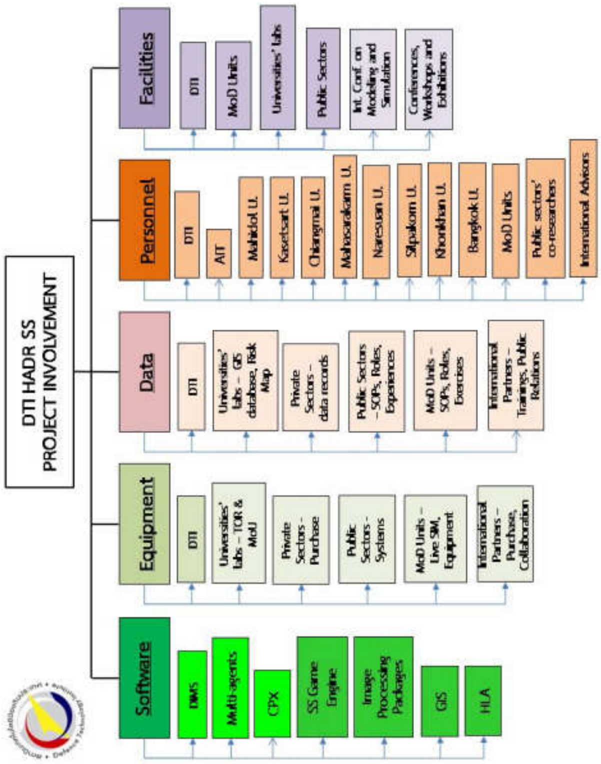

Figure 4: Collaboration, Coordination, and Cooperation for DTI HADR SS Project

6.1. Software Management
Seen as core development of the modeling and simulation component, two groups of software are identified with one in dark green box of fig. 4 already existing in DTI, public and academic sectors. The light green boxes are packages that DTI needs to purchase for later customization and tailor-made purposes. Multi-agent modeling and simulation are within the expertise of an academic sector that will participate through a memorandum of understanding mechanism.

6.2. Equipment Management and Collaboration
DTI was established such that an official interaction is short and runs through a short line of command provided that the roles and responsibilities are lawfully defined. The memorandum of understanding is an executive instruction that productive collaboration can be explored to get access to labs and excellence centers in universities. Where there is need of equipments and hardware, private sectors will be requested to join the bid in a manner that puts domestic products first in purchase priority, local distributors for exceptional import orders, and then direct government to government contract. For the MoD unit research counterpart, equipments for live training on disaster assistance and relief are source of data for regularly trained SOPs. When they are incorporated into those of relevant public sectors, the result will be central in the CPX system.

Figure 5: Collaboration with National Disaster Warning Center starts with an official visit

6.3. Data Exchange, Sharing and Interoperability
Personal interactions in the course of public-private-participation guarantee disaster awareness originated by exchanging data of people in similar fields as well as like roles and responsibilities. The M&S research component of the project will benefit the most from the coordination that leads to data exchange and sharing of producing disaster risk maps. Prospective partners will include, but not limited to, Hydro and Agro Informatics Institute (Public Organization), Geo-Informatics and Space Technology Development Agency (Public Organization), Department of Disaster Prevention and Mitigation of Ministry of Interior, National Disaster Warning Center of ICT Ministry, and Armed Forces Development Command (AFDM). The DTI project management body ensures that frequent meetings and workshops are held to facilitate the data exchange, sharing and interoperability. In addition, joint FTX's and CPX's are a great example of interoperability from disparate SOPs of different agencies. It is a matter of getting right parties involved at the right time that DTI has to play a central role.

6.4. Personnel Cooperation
Goal of DTI establishment following Article 7 of DTI Royal Decree B.E. 2551 (2008) is to coordinate with private, public and academic sectors inside and outside the country in fields of defense technologies. Researcher head count of the project can be exponentially multiplied by this intention. While an MoU that DTI has signed with a number of universities, public and private sectors gives guide to the cooperation between institutes, project contracts that define objectives in the term of reference, deliverables, due dates and human resources management of win bidder will drill down to individual responsibility.

6.5. Management of Research Facilities
For the project initiative leads the project management body to involving relevant organizations with direct roles and responsibilities, agencies established for disaster crisis management, institutes with hands-on knowledge and updated activities, it is plausible to manage existing research through facilities (fig. 5) of prospective partners as mentioned in 5.3 to their utmost use and invest in as less budget as possible. Instead, much more investment will be allocated to activities to run and operate the facilities ranging from MoD units'

training center, universities' labs, public sectors' infrastructure.
HADR is the global issue and world's citizen should be informed and best in an international conference on modeling and simulation, disaster management, crisis resources management, and disaster risk mapping from space technology. National conferences, workshops and exhibitions are a forum that participated research facilities are used to provide and support trainings of the project deliverables, to exchange comments, concepts and new ideas of research findings, and to nurture disaster management and related issues.

7. EXPECTED DTI HADR SS DELIVERABLES

Milestones over three years were marked so that there continues to have deliverables each consecutive year (fig. 6). Lab prototypes and knowledge regarding risk maps, DIMS and CPX are expected for first year output. On-site test and simulator-in-training-loop test are output for second and third year deliverables.

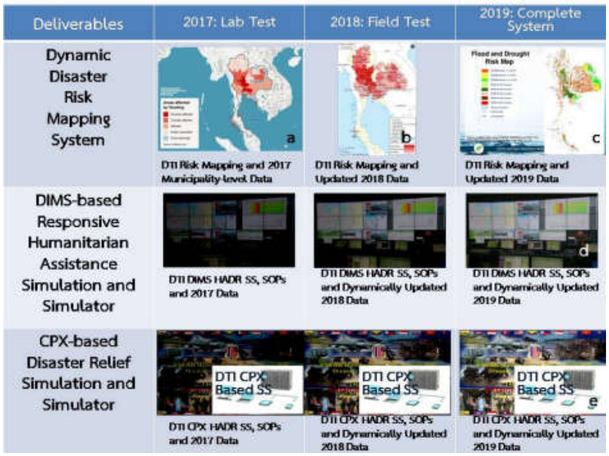

Figure 6: Deliverables of the three year plan project
(Sources: a from http://marcusrockar.blogspot.com/2011/10/bangkok-digs-in-as-floods-high-tides.html, b from http://www.mapsofworld.com/thailand/floods-2011.html, c from http://www.slideshare.net/VeerachaiTanpipat/thailand-flood-v1, d from slide presentation of Jun-ichi Hayashi, Defense Systems Unit, Japan's Fujitsu Limited at DTI on 11 July 2015, and e from slide presentation of AM – HEx 2016 Final Conference Planning)

7.1. 2017 Lab Prototype Deliverables

The disaster risk mapping system will be focused so that DTI will be able to deliver flood-risk mapping system at the 2017 Data with municipality-level accuracy. Five flood-risk mapping subsystems, spread all over the country and dynamically monitoring the situation, remotely bring in the report, maps and comments for disaster response to the central system. One DIMS-based responsive humanitarian assistance simulation and simulator with completely studied SOPs will be located and lab-tested in DTI for final report later in the year. Similarly, CPX-based disaster relief simulation and simulator with SOPs and 2017 Data will be included in the DTI lab. HLA-based system interface between the three systems will be tested for system compliance (Chieochan et al, 2015). Simulated situation will be run on the workshop attended by those identified in fig. 4 to test and evaluate the flow of information, SOPs and how DTI HADR SS fits the involving parties in flood crisis management.

7.2. 2018 Deliverables for Field Test

Following the test and evaluation results in 2017, the disaster risk mapping system will be upgraded to real-world trainings of armed forces development command in one of the flood-prone northern provinces of Thailand where the risk map indicates. The DTI DIMS will be FTX(Field Training Exercise)-tested by local people and military alike for SOP field tests. Results from blinded peer review academic papers will ensure standard and quality of the studies response and recovery SOPs. Contents from national conferences, workshops and exhibitions are enough for official discussion to host the international conference on disaster issues. Municipality-level data of all parties involved will be checked, updated and delivered to local authorities for preparedness and resources management. CPX-based disaster relief simulation and simulator response and recovery SOPs will be incorporated into the 2017 version system and delivered to the armed forces development command training center. Extended versions are expected to serve the Department of Disaster Prevention and Mitigation of Ministry of Interior where at least 18 different systems (see the potential on fig. 7) are possible, subject to official negotiation.

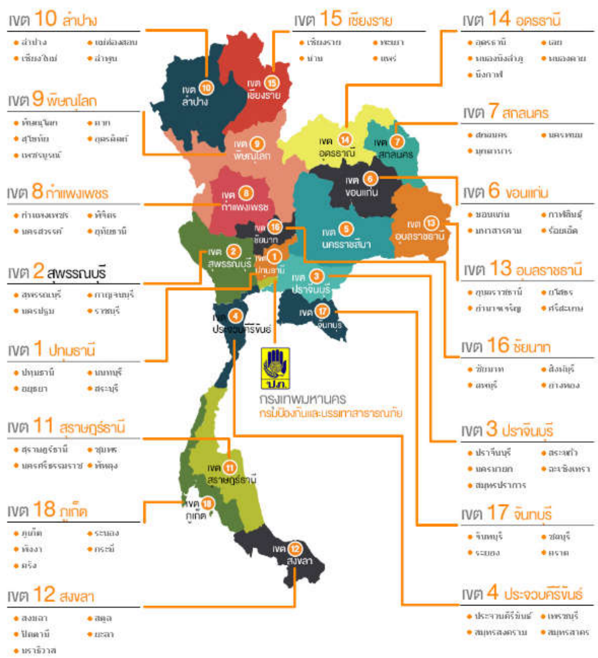

Figure 7: Total 18 areas under responsibility of Department of Disaster Prevention and Mitigation (source: http://122.155.1.143/th/about-about07)

7.3. 2019 Deliverables for AFDM Complete System

Two years of continued and updated research will complete the DTI HADR SS by the third year end. The full system will include DDRMS, DIMS HADR SS, DTI CPX HADR SS, updated data and well-proven SOPs for disaster response and recovery. Knowledge, experiences and insights gained along the first two years are enough to form a HADR training center of the region. The discussed international conference on disaster issues is matured enough to run in parallel with or as part of an event for ADDOM EWG on HADR and EWG on MM. An MoU between DTI and Department of Disaster Prevention, previously negotiated, takes form.

8. CONCLUDING REMARKS

Mighty natural disasters have turned several parts of the world into ruins and wreckage. Thailand was counted in by the 2004 Indian Ocean Earthquake and the 2011 Major flood. The MoD is to protect and solve problems of disaster, provide humanitarian assistance and has DTI established to conduct research and development projects to serve some of those missions. The HADR simulation and simulator project was included in the master plan to put interest on military operations other than war.

DTI joined the AM - HEx 2016 by preparing technology demonstration that displayed concept and ideas implemented in the three year plan of the DTI HADR SS project with three objectives, namely, to apply M&S research for the dynamic disaster risk maps, to develop the responsive training simulator based on the DIMS taken into account experienced and best practiced SOPs, and to input Thailand's SOPs to recover victims or effected people from the studied disaster SOPs with proof from standard journal papers before incorporating into DTI DIMS HADR SS.

DTI HADR SS Architecture has the first proposed component to produce dynamic flood-prone maps of Thailand's regional parts and fed into HADR SS via CPX SS where practiced, shared, learned and experienced SOPs exist. Decision makers are embraced for the response and recovery's SOPs. Involvement from others was deemed crucial, then, categorized in line with software system engineering including software, equipment, data, personnel and facilities. Overall, DTI DIMS HADR SS was initiated to reflect DTI' goal of coordinating others in fields of defense technology with private, public and academic sectors inside and outside the country.

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The authors are grateful to Thailand MoD's office of policy and planning for granting an opportunity to the authors and DTI researchers to attend the AM - HEx 2016 in September at the city of Pattaya. The Japan Defense Attaché in Bangkok is highly appreciated for such kindness and assistance that led to DTI - Thailand's Fujitsu agreement that originated the modeling and simulation architecture on which Thailand's MoD trainings regarding disaster crisis management is based. Armed Forces Development Command Officers are herein acknowledged for their input on user requirements. Researchers of the Geo-database for Military and Security project from Silpakorn University are of great help in providing data and content for this report.

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A MODEL TO DESCRIBE HYBRID CONFLICT ENVIRONMENTS

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ABSTRACT

This article focuses on the definition, implementation and testing of a model to describe Hybrid Conflict Environments. Without the need of citing specific cases or countries, it is clear that hybrid strategy and warfare are becoming more important. A hybrid strategy can affect policy makers, military operations, economics and financial trends, intelligence and legal activities as well as information and media. A conceptual model is introduced to define and to gain further insight into hybrid environments. The model is then implemented and tested by running experiments to provide evidence on its relevance. Finally, results are presented and discussed.

1 INTRODUCTION

Hybrid warfare is a new approach to warfare (Berzinš 2014)(Davis 2014) (Hoffman 2009a). It is described as the black version of comprehensive approach because it aims the destabilization of the targeted nation/community by exploiting it's weaknesses at the maximum extend. The most of the research in the field is for obtaining a better insight into it and hence for developing more effective techniques to counter the adversaries implementing a hybrid strategy. Hybrid warfare is also called as nonlinear warfare by some nations.

A hybrid strategy is based on a broad, complex, adaptive and often highly integrated combination of conventional and unconventional means, which include overt and covert activities by military, paramilitary, irregular and civilian actors (Berzinš 2014)(Davis 2014) (Hoffman 2009b) (Hoffman 2009c). The owner of the strategy, which is typically not known by the public, orchestrates all these means to destabilize the targeted nation or community for achieving (geo)political and strategic objectives. All the vulnerabilities are analyzed carefully and exploited at the maximum extend. A hybrid warfare is conducted across the full Diplomatic/Political, Information, Military, Economic, Financial, Intelligence, Legal (DIMEFIL) spectrum (Cayirci and Marincic 2009). Ambiguity is created, the denial is always possible especially for the creator of the strategy, and the decision making processes are overly complicated for the defendant. Hybrid strategies can be applied by both state and non-state actors, through different models of engagement, which may vary significantly in sophistication and complexity. Adversaries employing hybrid strategies will seek to remain ambiguous, claim pursuit of legitimate goals and aim to keep their activities below a threshold that results in a coordinated response from the international community. This includes avoiding direct military confrontation, and even maintaining economic and diplomatic relations if possible; although the use of overt military action as part of a hybrid strategy cannot be discounted.

Hybrid Warfare involves threats that can be categorized into four broad classes; traditional, irregular, catastrophic terrorism and disruptive. Asymmetric warfare, information warfare and cyber warfare (Cayirci and Ghergherehchi 2011) (Gunneriusson and Ottis 2013) are important domains for hybrid warfare that can be fought on three battlegrounds: within the conflict zone population, home front population and the international community.

As the definition implies, hybrid warfare requires modelling and simulation in various domains, such as, conventional, cyber and information warfare (Cayirci and Ghergherehchi 2011), social and human behaviour modelling (Bruzzone et.al. 2014) both with local and international perspectives, threat networks and asymmetric warfare. Although modelling and simulation requirements for many of these fields have been studied extensively, hybrid warfare as a domain has not been addressed holistically yet. Moreover, a model that describes hybrid environments and its dynamics is not available to understand better what to tackle with. Our research, conducted as an international exploratory study titled as "Exploratory Team 043 Modelling and Simulation for Hybrid Warfare" under NATO's Science and Technology Organization, aims to fill this gap. The preliminary results from our research are reported in this paper.

In Section 2, we explain our model called the conceptual model for hybrid environments (CMHE). The dependent parameters in the model are the objectives of the owner of a hybrid strategy. We relate these objectives to a set of independent parameters in the model. In Section 3, we analyze the dynamics between the independent and dependent parameters in our model through experimentation. We conclude our paper in Section 4.

2 THE CONCEPTUAL MODEL FOR HYBRID ENVIRONMENTS

The top level depiction of CMHE is in Figure 1. As it is clear in the Figure, a hybrid strategy is an offensive strategy. There are two key values related to the community/nation under attack, namely the willingness and the threshold. The willingness is the level of desire and stamina by the targeted community to engage with the offender. It also implies the support by the international community to the defendant. When the willingness is over the threshold, the targeted community approves tackling with the offender, even an armed conflict, after which the hybrid environment may become a theatre of operations unless the offender backs off. Of course, after this point, the offenders homeland may also become a theatre of operations, and hence, the conflict is not a proxy war for the offender anymore.

Therefore, the offender aims to keep the threshold as high as possible, while managing the willingness as low as possible. Vague environment, denial and all sort of perception management are the main tools for this (Bachmann and Gunneriusson 2015) (Bachmann and Gunneriusson 2015b). Strategic communications (STRATCOM) is a key both for the defence and the offence in hybrid environments. Apart from STRATCOM, the offender can take hybrid actions which can be denied, and may have to take also non-hybrid actions from time to time. Of course non hybrid actions increase the willingness and decrease the threshold.

The defendant aims completely the opposite, i.e., decrease the threshold and increase the willingness. The main reason for this is that the capacity of the offender depends on the difference between the threshold and the willingness. For this, the defendant needs to clarify and prove what the reality is. All the components of diplomatic, informational, military, economic, law enforcement and intelligence (DIME+LI) domains should be used to achieve that. The aim is to stabilize the community/the nation under hybrid attack and to gain the international and legitimate support for eliminating the hybrid threats. Therefore, comprehensive approach and STRATCOM are the main tools for the defendant.

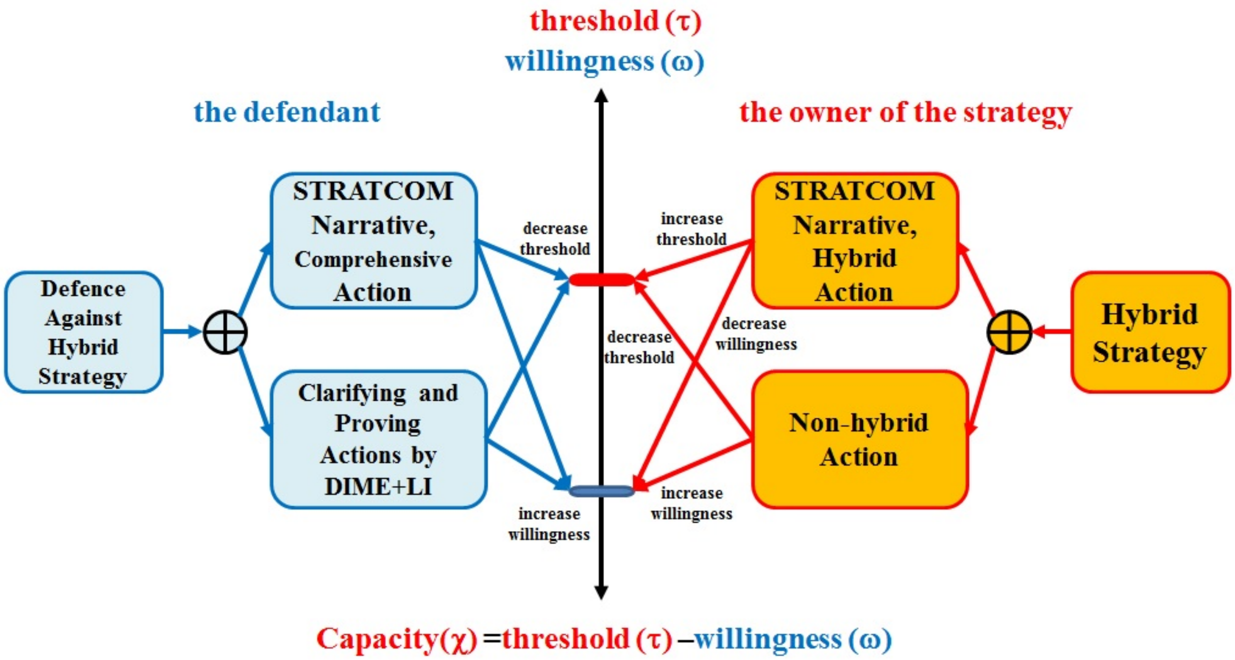

Figure 1: The top level depiction of the conceptual model for hybrid environments.

In Figure 1, the results of the actions are shown as "increase or decrease threshold/willingness". However, the passive case (i.e., no action is taken) has also a result which is complete opposite of the results shown in the Figure. For example, if the defendant is passive and taking no comprehensive action or does not have a proper STRATCOM narrative, the threshold increases and the willingness decreases.

2.1 Modelling the threshold for CMHE

As shown in Figure 1, the capacity χ of the opponent to continue with a hybrid strategy depends on the threshold τ and the willingness ω. This is given in Equation 1.

$$\chi = \tau - \omega \quad (1)$$

When $\chi \leq 0$, it is expected that the offender backs off or an armed conflict starts. The offender tries to keep the capacity χ over zero (i.e., $\chi > 0$) until completely destabilizing the targeted nation/community and creating the environment to reach its geo(political) and strategic objectives.

The threshold depends on four parameters, the normalization ν of the current level of instability (i.e., the defendant is getting used to the situation), STRATCOM by the opponent s_o, STRATCOM by the defendant s_d and the power p_Σ of the defendant in all DIME+LI domains p_δ (diplomatic), p_ι (informational), p_ϕ (military), p_ε (economic), p_λ (law enforcement), p_σ (intelligence) as given in Equations 2 and 3. Please note that the weight μ of each DIME+LI domains in overall power p_Σ of the defendant may be different from each other. In these equations, s_o, s_d and p_Σ are real numbers between 0 and 1 (i.e., $s_o \in \Re$, $s_d \in \Re$, $p_\Sigma \in \Re$ and $0 \leq s_o \leq 1$, $0 \leq s_d \leq 1$, $0 \leq p_\Sigma \leq 1$)

$$p_\Sigma = \mu_\delta p_\delta + \mu_\iota p_\iota + \mu_\phi p_\phi + \mu_\varepsilon p_\varepsilon + \mu_\lambda p_\lambda + \mu_\sigma p_\sigma \quad (2)$$

where $\mu_\delta + \mu_\iota + \mu_\phi + \mu_\varepsilon + \mu_\lambda + \mu_\sigma = 1$

$$\tau = (\nu s_o) - (p_\Sigma s_d) \quad (3)$$

Please note that STRATCOM is not only public affairs. Everything that can pass the messages according to the narrative counts. This includes not only verbal or written messages but also all actions taken. Please note also that social computing is a critical media to disseminate the STRATCOM narrative by the defendant, as well as the disinformation by the opponent.

In Equation 4 and 5, the normalization parameter ν depends on the history, the types of the opponent's actions and their frequencies. It may change from community to community how well and how long the history is remembered. We call this parameter as the memory parameter ρ. The number of events (i.e., hybrid and non-hybrid actions taken by the opponent) n in the last period i that the normalization parameter is evaluated for, and the length t_i of the time interval between the last normalization evaluation and current time give the frequency (n/t) of events. Please note that the unit (i.e., months, weeks or days) for time intervals does not make an impact on the model. However, there is at least one event in every time interval and therefore the length of time intervals is not a fixed value.

It is also an important parameter how disturbing α an action is. We call this parameter as the difficulty, which needs categorization of events in space and character. In our model, the number of categories m is not a fixed value and may change in every evaluation period i as the length of time intervals do.

The frequency (n/t) is typically controlled by the designer of the hybrid strategy. On the other hand, the memory parameter ρ and the degree of difficulty α change from community to community, and there is an uncertainty associated with them. It is not easy to treat this uncertainty in aleatory domain at least for the time being. Still we refer them as random variables, i.e., $\rho:\Omega\rightarrow\Re^+$ and $\alpha:\Omega\rightarrow\Re^+$, where $R_\rho(\Omega, \Im_\rho, P_\rho)$ and $R_\alpha(\Omega, \Im_\alpha, P_\alpha)$ are the related random processes, Ω is the set of positive real numbers between 0 and 1 and including 0 and 1 (i.e., $0 \leq \Omega \leq 1$), $\Im_\rho$ is the set of values for how much the past influences the perception about the current situation (i.e., the weight of the past on the current perception), $\Im_\alpha$ is the set of values for how difficult to normalize an event, P_ρ and P_α are the probability density functions and statistics that fits best to the defendant.

The other important parameters for calculating the normalization factor ν are ethnical and religious divisions d (i.e., the number of ethnical and religious groups) and how much these divisions discriminate or tolerate (or even to support the opponent) h each other. The division parameter d is a positive integer greater or equal to one (i.e., $d\in Z$ and $d \geq 1$). The discrimination parameter h is a real number greater than zero and less than or equal to two ($h\in\Re$ and $0<h\leq 2$).

$$v = \sqrt[d^h]{\prod_{c=1}^{m_i}\left(\prod_{k=1}^{n}(1-R_{ck\alpha})\right)^{t_i/n}} \quad (4)$$

$$v_i = \frac{R_\rho}{t} v_{i-1} + \left(1 - \frac{R_\rho}{t}\right) v \quad (5)$$

Please note that there is at least one event in each category c (i.e., for $\forall$c, $m_i \geq 1$). Otherwise the category does not exist. Therefore, ν is a real numbers between 0 and 1 (i.e., $\nu\in\Re$ and $0\leq\nu\leq 1$).

2.2 Modelling the Willingness for CMHE

The following parameters affect the willingness: STRATCOM by the opponent s_o, STRATCOM by the defendant s_d, the power p_Σ of the defendant in all DIME+LI to clarify and communicate the facts, the effectiveness of the comprehensive actions a_d by the defendant, hybrid a_{on} and non-hybrid a_{ol} actions by the opponent as shown in Equations 6-8, where a_d, a_{ol} and a_{on} are real numbers between 0 and 1 (i.e., $a_d\in\Re$, $a_{ol}\in\Re$, $a_{on}\in\Re$ and $0\leq a_d \leq 1$, $0\leq a_{ol} \leq 1$, $0\leq a_{on} \leq 1$). The division d and discrimination h parameters already explained in the previous subsection. A part n_l of the number of events n are non hybrid, and the other part n_n are hybrid actions. Therefore, $n=n_l+n_n$.

$$a_i = \prod_{c=1}^{m_i}\left(\prod_{k=1}^{n_l}(a_{ol})_{ck}{}^{1/1+(a_d)_{ck}}\right)^{t_i/n} \quad (6)$$

$$a_r = \prod_{c=1}^{m_i}\left(\prod_{k=1}^{n_n}(a_{on})_{ck}{}^{1+(a_d)_{ck}}\right)^{n/t_i} \quad (7)$$

$$\omega = \frac{p_\Sigma s_d\, a_i - (1 - p_\Sigma)\, s_o\, a_r}{d^h} \quad (8)$$

Since a_d, a_{ol} and a_{on} are real numbers between 0 and 1, the willingness ω is also a real value between 0 and 1, and therefore the capacity χ from Equation 1 will be a real value between -2 and 2 (i.e., $\chi \in \Re$, and $-2 \leq \chi \leq 2$).

3 EXPERIMENTAL RESULTS

Through Monte Carlo Simulation, we experiment with our model and observe how it behaves as we change the independent parameters. In our experiments, random numbers are generated for the memory parameter ρ and the degree of difficulty α according to normal distribution with various mean values. The sensitivity of the threshold τ, the willingness ω and the capacity χ against the changes in the other parameters of the CMHE is examined. The preliminary results from our experiments are provided and analysed in this section.

In Figure 2, the sensitivity against the changes in frequency (*n/t*) of the actions by the opponent is depicted. The values assigned to the other parameters during these tests are given in the caption of Figure 2. As expected, the community gets used to the hybrid environment as the frequency of events increase, and therefore the threshold increases, which also means better capacity for the opponent. As the frequency gets higher, its effect on the threshold gets lower. The sensitivity of the willingness is less against the frequency comparing to the threshold.

In Figures 3 and 4, the relations between the capacity and STRATCOM are shown. Both the threshold and the willingness are affected by the effectiveness of the STRATCOM by the defendant. Better defendant STRATCOM results in an increase in the willingness and a decrease in the threshold and the capacity. An opposite relation is observed between the threshold and the STRATCOM by the opponent as expected. There is another difference between the effects of STRATCOM by the opponent and the defendant, which is the sensitivity of the willingness against the changes in STRATCOM by the opponent is much less comparing to the STRATCOM by the defendant.

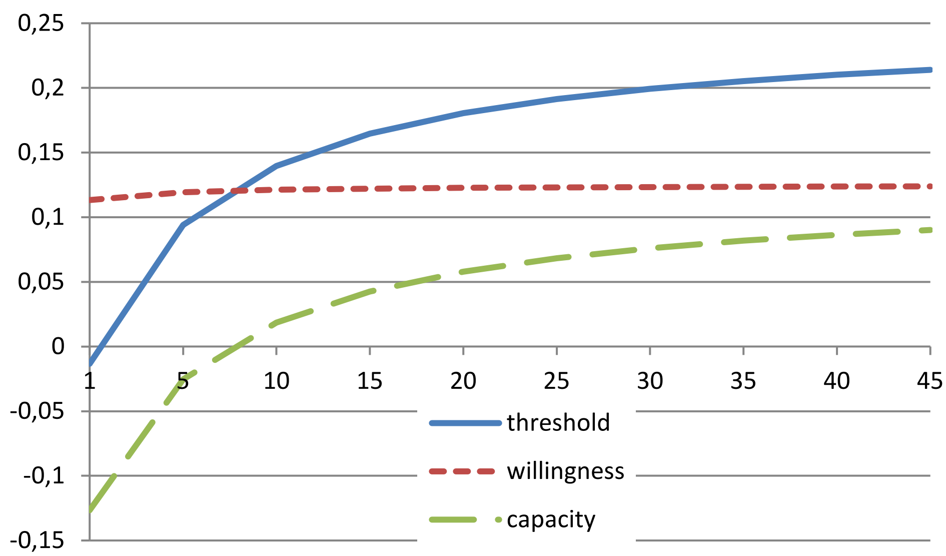

Figure 2: The sensitivity against frequency (*n/t*) when $\alpha=0.5$, $P_\Sigma=0.5$, $s_o=0.5$, $s_d=0.5$, $a_d=0.5$, $a_{ol}=0.5$, $a_{on}=0.5$, $d=2$, $h=1$.

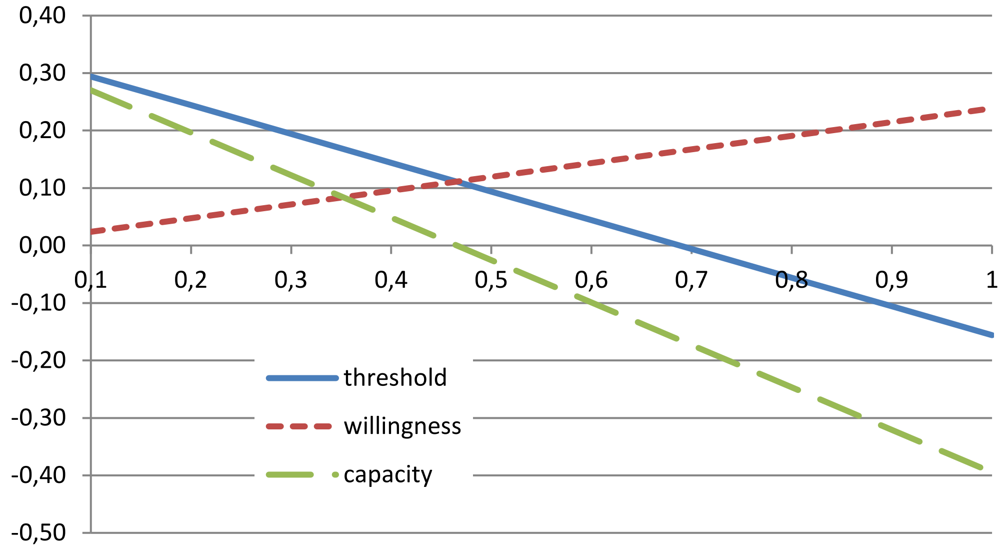

Figure 3: The sensitivity against STRATCOM by the defendant (s_d) when α=0.5, P_Σ=0.5, n/t=10, s_o=0.5, a_d=0.5, a_{ol}=0.5, a_{on}=0.5, d=2, h=1.

In Figure 5, the results from the tests for the discrimination parameter *h* are illustrated. How much the divisions in a community discriminate each other is an important weakness that can be exploited easily by the opponent. This is clearly observable in Figure 5. When the discrimination is higher, the willingness of the community to tackle with the opponent is lower. On the other hand, the higher the discrimination is, the higher the threshold and the higher the capacity of the opponent become.

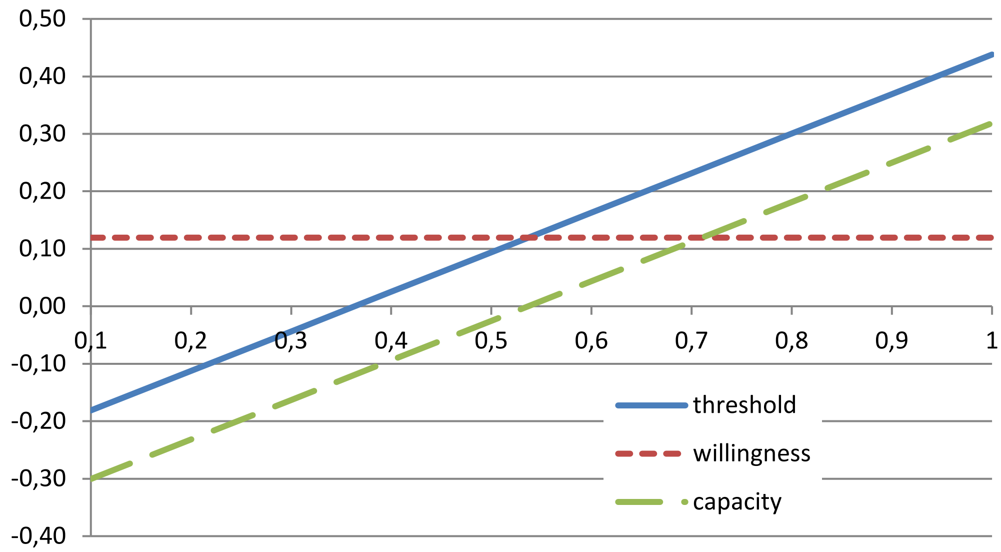

Figure 4: The sensitivity against STRATCOM by the opponent (s_o) when α=0.5, P_Σ=0.5, n/t=10, s_d=0.5, a_d=0.5, a_{ol}=0.5, a_{on}=0.5, d=2, h=1.

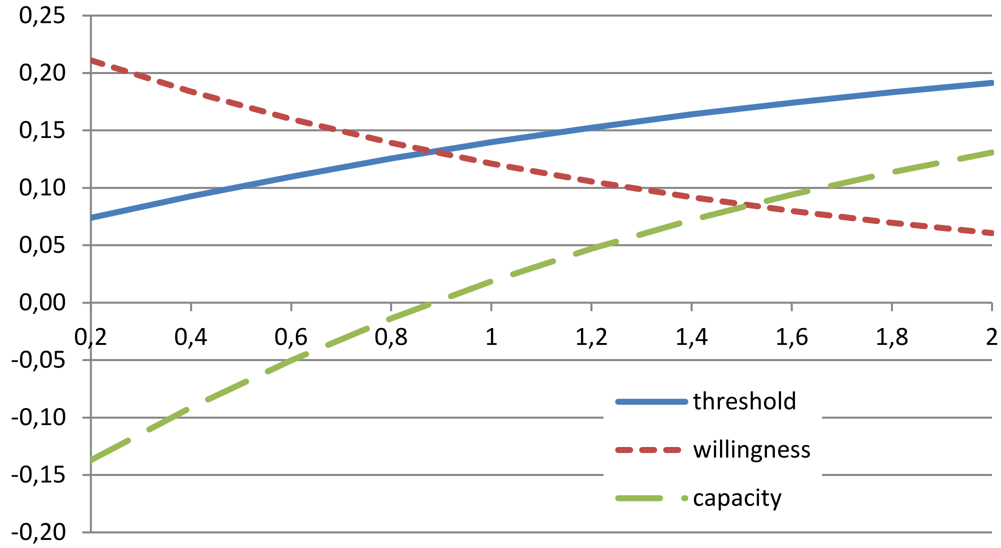

Figure 5: The sensitivity against discrimination (h) when $\alpha=0.5$, $P_{\Sigma}=0.5$, $n/t=15$, $s_o=0.5$, $s_d=0.5$, $a_d=0.5$, $a_{ol}=0.5$, $a_{on}=0.5$, $d=2$.

As shown in Figure 6, as the actions by the opponent gets more difficult (i.e., more disturbing) for the defendant, the threshold decreases, because those events are more difficult to be normalized (i.e., more difficult to get used to). The willingness of the community changes in positive direction but much less comparing to the threshold.

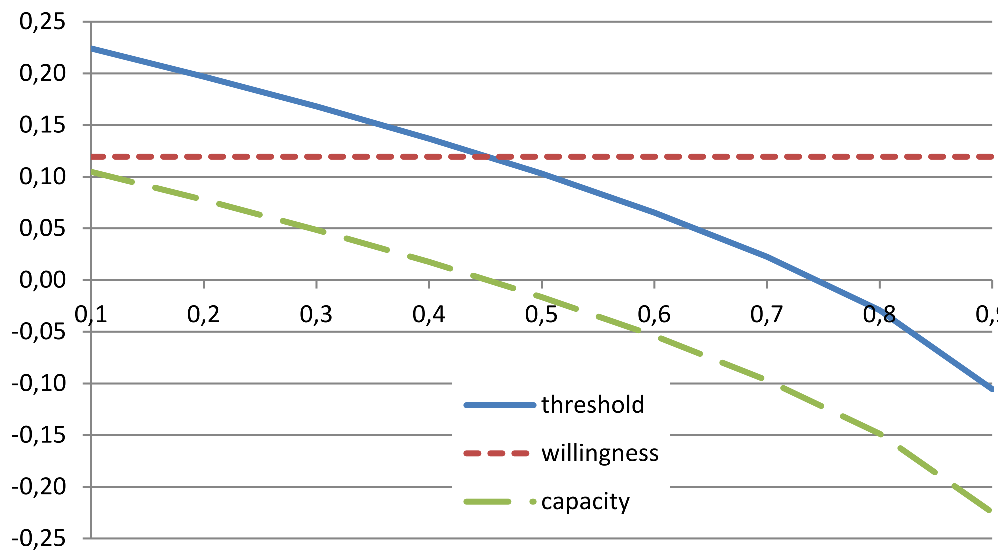

Figure 6: The sensitivity against the difficulty (α) of the opponent actions when $P_{\Sigma}=0.5$, $n/t=10$, $s_o=0.5$, $s_d=0.5$, $a_d=0.5$, $a_{ol}=0.5$, $a_{on}=0.5$, $d=2$, $h=1$.

Our final experiment is about the effectiveness of the comprehensive actions by the defendant. They do not change the threshold but the willingness, which gets better as the comprehensive actions by the defendant becomes more effective. However, the effectiveness of the comprehensive actions is not much if they are not supported by a consistent STRATCOM narrative.

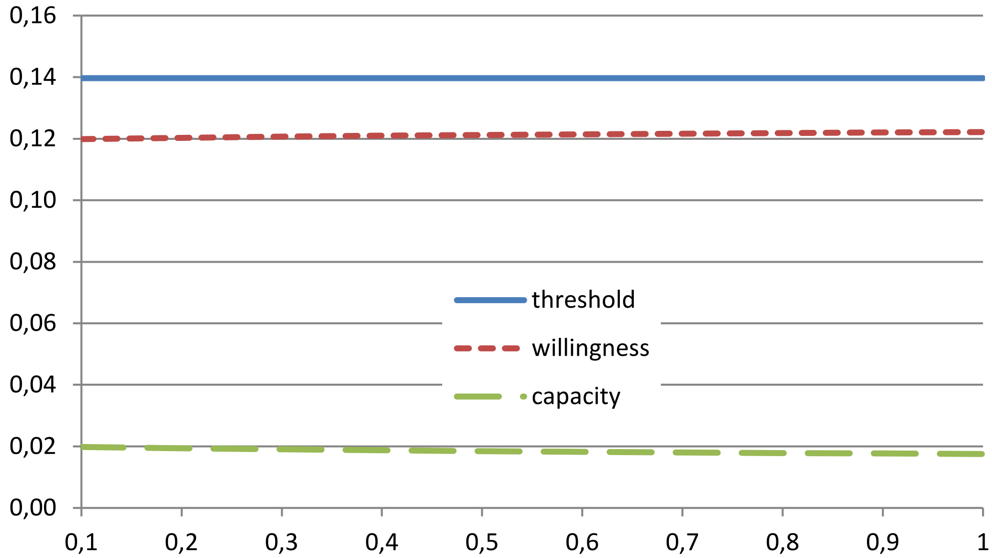

Figure 7: The sensitivity against comprehensive actions (a_d) of the opponent actions when α=0.5, P_Σ=0.5, n/t=10, s_o=0.5, s_d=0.5, a_{ol}=0.5, a_{on}=0.5, d=2, h=1.

4 CONCLUSIONS

In a hybrid warfare, the adversary uses all available means, very often from the black side, to exploit the vulnerabilities of the defendant and to destabilize it. Creating ambiguity, the denial and disabling the defendant in decision making are aimed in every action. The adversary tries to meet its objectives without an armed conflict even without a major change in its diplomatic and economic relations. It manages two parameters related to the defendant, namely the threshold and the willingness. It tries to keep the willingness of the defendant to clarify the adversary's intention and to engage in an armed conflict at the minimum possible level. The willingness also strongly related to the international community's desire to support the defendant. When the willingness is over the threshold, the hybrid warfare is over one way or the other, i.e., either the adversary backs off or has to face an armed conflict with the defendant supported by the international community. Therefore, the adversary does it's best to raise the threshold as much as possible without losing the control on the willingness.

In this paper, we introduce the CMHE that captures all these relations. The CMHE is developed within the NATO exploratory study called ET-043. We also run experiments with the CMHE. The preliminary results are consistent with the theory about the hybrid environments.

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A COMBINED APPROACH FOR EMERGENCY MANAGEMENT USING AHP AND SYSTEM DYNAMICS

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ABSTRACT
Emergency management plays a critical role in industrial plants design and management. The investigation of all the entities involved and the possible factors, which intervene during an emergency, can determine the safety of human life and the security of assets. In this article, the authors use the AHP method to derive a ranking of factors which affect both the development of the emergency events and the various entities involved in the disaster. The AHP ranking is then used by a system dynamics model that reproduces an emergency scenario that takes into account all the variables and the entities involved. By performing several experiments, the system dynamics model shows that the emergency management is strongly affected by the parameters considered by AHP. Therefore, having identified the key factors, it's possible to act on them to achieve better management of resources, the least number of victims and the best assets protection.

Keywords: Industrial Plants, System Dynamics, AHP, Emergency management.

1. INTRODUCTION

The security and emergency management is a critical aspect of every activity or process. This is even more important in industrial plants, where security and emergency management has gained an increasingly importance in time. An industrial plant manages technological resources but also human resources and the main target is to secure their safety and integrity (Kuwata et al. 2004). The security management aims to prevent any incidents which may result in undesirable effects on people inside or outside the site, the environment or on company resources. If despite all prevention efforts, an emergency happens then an effective emergency management is the only way to tackle successfully the problem.

In industrial plants, a high level of security grants a correct management of assets during their life cycle. Indeed, security already starts during the assets design phase, by applying the technical and precautionary standards, then different types of maintenance and control assure the assets security over the time (Longo et al. 2012). Furthermore, emergency plans aim at planning one or more sequences of actions to minimize the consequences in case of accidents.

Research & Development activities in the area of emergency management usually involve:

- the identification and assessment of possible accident scenarios and their effects through the use of complex mathematical models;
- planning and emergency management (operational procedures, suitable tools and dedicated infrastructure);
- solutions for training and exercises.

In the end, emergency management in industrial plants is definitely a complex issue, characterized by many stochastic variables (eg. response time, availability of resources, evolution of the disaster scenario, etc.). These variables interact with each other and increase, as the time goes by, the complexity of the system (Bruzzone et al. 2014). Often, the use of analytical models to support the proper management of emergencies does not guarantee reliable results. In fact, the analytical methods require simplifying assumptions that may affect the trustworthiness of the results themselves (Banks 1998). Consider as an example the transportation of the injured people from the disaster site to the hospitals and the nearest first aid facilities. A number of variable including the type of road, traffic and weather conditions, type of vehicles, etc., should be properly considered (Bruzzone et al., 2006) both to support the emergency management and, in an early phase, the road network design and facilities locations. In that context, it is therefore essential to be able to recreate the complexity of the real-world system

(Bruzzone et al., 2007). System Dynamics is surely a reliable method and also a possible way to study the problem, especially if we are dealing with very complex situations or have many processes, many stochastic variables and questions that are difficult to give an answer (Taboada, 2011). Furthermore, the Analytic Hierarchy Process (AHP) proposed by Saaty (1980) is a widely used method and has been applied in a large variety of areas including planning, selecting a best alternative, resource allocation and conflicts resolution (Nachiappan et al., 2012). For example these are some application of AHP in specific fields: research and development (R&D) projects selection, marketing (Wind et al. 1980, Mark 2001), medical and healthcare decision making (Liberatore et al. 2008), resources allocation (Heidenberger 1999), energy (Pohekar 2004) and process safety (Arslan 2009). AHP has also been integrated with other techniques, e.g. SWOT, meta-heuristics, etc., (Ho 2008). This article proposes the application of AHP and system dynamics for supporting the understanding of emergency management in industrial plants. The proposed approach combines AHP and System Dynamics for organizing and analyzing complex decisions and understanding the nonlinear behavior of complex systems over time. Indeed, the System Dynamics model intends to test various configurations of emergency management for different scenarios while taking into account the AHP output.

The article is organized as follows: section 2 presents the emergency scenario; section 3 describes the System Dynamic model; section 4 explains the AHP model. Sections 5 and 6 summarize main results and conclusions.

2. EMERGENCY SCENARIO DESCRIPTION

This section presents a general disaster scenario which will be duly declined on a specific case (as described later in the paper) through a system dynamics model.
In particular, it has been hypothesized an explosion in an industrial plant devoted to store petrochemical products. The event affects a certain percentage of the industrial plant area and it is assumed the presence of a certain number of not evacuated employees.
Preliminary information on injured people in the disaster are also available according to a triage approach based on green, yellow, red and black codes.
Some of the evacuated employees are part of the internal emergency team. The internal emergency team usually intervenes with proper devices (according to the received training) helping in evacuation procedures, operative procedure (e.g. release valves and electrical systems, etc.) and recognition (with external aid).
In this general scenario, we also hypothesize the presence of an hospital (close to the industrial plant); in particular it is known the distance between the hospital and the place of the disaster, the type of connection roads and the number of available resources (e.g. ambulances).
Additional scenario information regard the number of tanker trucks, the number of firefighters and where the barracks of the fire brigade is located.

3. THE SYSTEM DYNAMICS MODEL

Systems Dynamics (SD) is an approach for modeling complex and dynamic systems. SD captures an essential feature of many systems: the capability of self-regulating over time (Collins el al. 2013). This means that feedbacks among the system components incrementally adjust the state of the system.

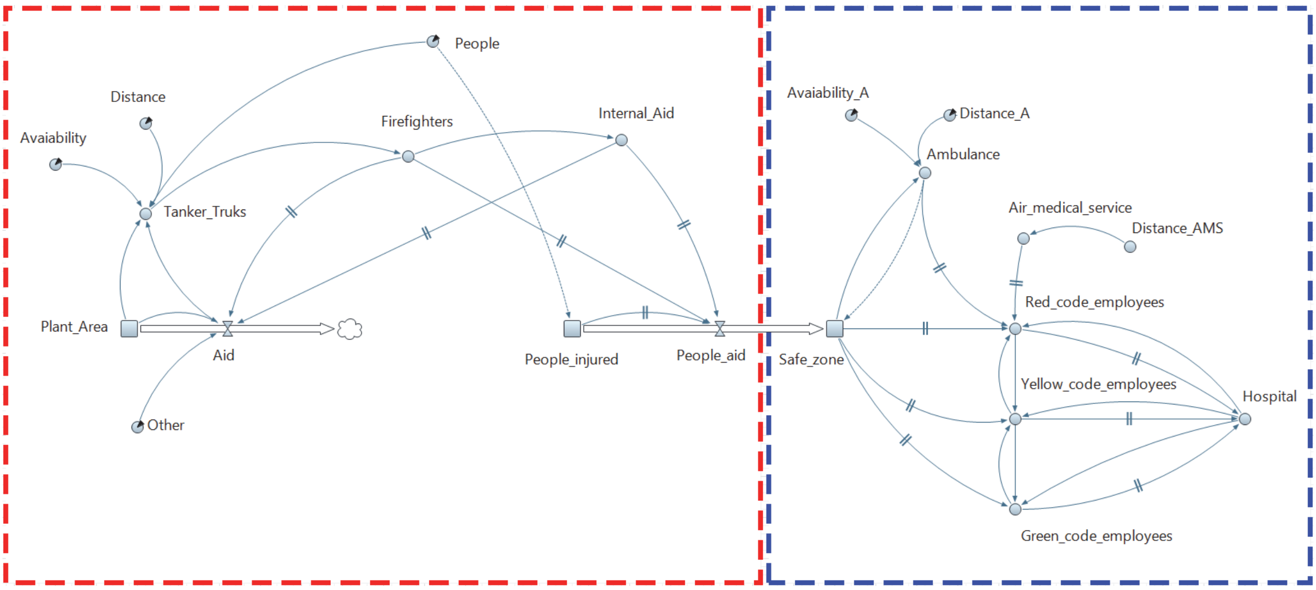

Figure 1 – Causal loop diagram of an emergency management system. The diagram discerns the complexity of the system into the major variables and feedback loops of emergency management.

A change in one part of the system affects another part that, in turn, may affect others with some delay, some of these changes will eventually feedback to amplify or dampen the effect of the original change.
In short, an SD model recognizes that changes do not occur in isolation and furthermore that many systems do not respond instantaneously to these changes. SD represents the interactions between the elements of the system through causal loops (see figure 1). SD takes an approach to analyze the impacts of complex dynamic interactions in a system. (Forrester, 1961).

3.1. Fire management model

Figure 1 is a casual loop diagram that represents the dynamics impacting an industrial fire management system.
The box on the left part of the figure represents the fire itself, the factors that affect its expansion and how this is handled. The right box represents how the assistance of the ambulance is managed. Starting from the left box, we identify the fire level that, together with rescue operations are the key variables that connect the fire department and the internal emergency team to the one that is the ultimate goal of the model: extinguish the fire.
The distance of the fire department from the emergency area and the number of tanker trucks can be included in the model as well but they do not affect directly on the fire evolution. Indeed, the performance indicators taken into account in this study are not the time to extinguish the fire or the time needed to transport the victims to the nearest hospitals (according to the types of injuries) but, more appropriately, the percentage change of these times in correspondence of the variation of the main parameters.
The parameters that can be modified in the SD model are the same that have been taken into account in the AHP and are those that affect the final output. Behavioral and operational procedures that mark the various moments of the emergency cover different aspects as briefly explained below.

3.2. Fire parameters

The first aid role is given to the internal emergency team. The team has the following duties:

- Immediate intervention after the fire explosion;
- deal with the timely rescue of potential victims by implementing, if necessary, preparation maneuvers to make it accessible to rescuers;
- inform the firefighters.

Once received the alarm, the Fire Department will intervene with operational teams whose number, in terms of tanker trucks and firefighters, will depend on the severity of the fire. The influence that firefighters may have on the fire depends on the following parameters:

- distance of the fire department from the place of emergency;
- time between the request for assistance and the arrival of the rescue teams;
- number of units sent by the command.

The Firefighters are responsible for:

- fire extinguishing
- ensure the conditions for a quick and safe rescue of the workers from the fire area to the safe zone.

3.3. Rescue parameters

As it can be seen from the right box in figure 1, the emergency management, starting from the safe zone, depends by:

- the number of people involved in the fire;
- the arrival time of ambulances;
- the number of available ambulances;
- the hospital distance from the place of emergency;
- the presence of the air medical service and its distance from the fire location;
- the transfer time to the hospital of people injured.

The ambulances arrival in the safe zone will determine the division of the injured people according to the gravity of their situation: red code, yellow code and green code.
The dwelling time of the injured in the safe zone depends on their code. As far as the hospital transportation is concerned, priority will be given to the red codes, to be followed by the yellow and finally to the green codes.
Starting from the original scenario there are several decisions to be taken as well as there are different factors that will affect the fire extinguishing time and the time required to perform injured people transportation to the nearest hospitals. Obviously, based on these decisions it is possible to act in a more or less significant way trying to manage as well as possible the entire emergency.

4. THE AHP MODEL

The AHP is a decision-making procedure originally developed by Saaty in the 1970s. First of all, it is important to know the environment in which the industrial plant operates. This basically means the understanding of the the external environment and of the internal company organization. The analysis is undertaken with the aim of

- establishing the strategic, organizational and risk management;
- identifying the constraints and opportunities of the operating environment.

In this paper the AHP methodology is used to rank alternatives factors that influence in different way the emergency management evolution through the use of different criteria.
In an emergency management, the factors that come into play are countless and each one influence in different ways the various phases and the different

entities involved in it. Considering the scenario described in the previous section, we found the following entities part of the emergency management:

- Ambulance;
- Non-transporting EMS Vehicle;
- Air Medical Service;
- Doctor;
- Tanker Truck;
- Fire Fighters;
- Patrol.

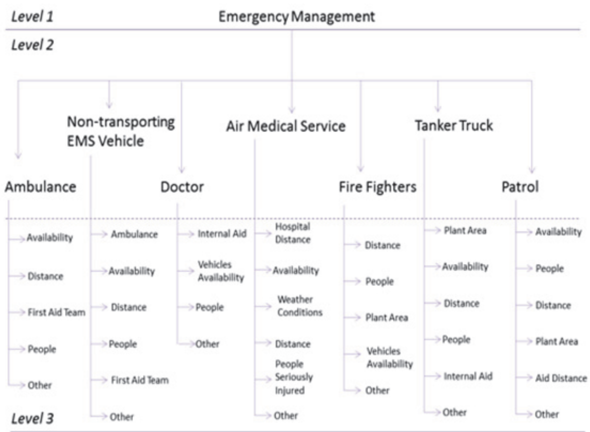

Figure 2 – AHP network

For each entity the following criteria have been found (see also figure 2):

- *Availability* (A) – entities number available nearby the disaster;
- *Distance* (D) – the distance between the disaster site and the entities ;
- *People* (P) – number of people involved in the disaster;
- *Plant Area* (PA) – area (in m^2) concerned in the disaster ;
- *First Aid Team* (FA) – tells if the first aid team could intervene before the external aid arrivals on the disaster site;
- *Other* (O) – other criteria not much relevant on the entity are expressed here.

Once defined the criteria, seven related matrices and the resulting weight vectors have been generated. In order to streamline the text, only the matrices related to Tanker Truck and Ambulance are shown in the following tables.

Table 1- AHP Tanker Truck

	P	A	PA	IE	D	O	W
P	1	0.5	0.5	2	0.33	3	*12.42%*
A	2	1	1	3	2	5	*27.40%*
PA	2	1	1	3	1	5	*23.95%*
IE	0.5	0.33	0.33	1	0.25	2	*7.63%*
D	3	0.5	1	4	1	4	*23.88%*
O	0.33	0.2	0.2	0.5	0.25	1	*4.71%*

According to AHP method, a Consistency Ratio CR is calculated for each matrices:

$$CR_{amb} = 9\% \quad (1)$$

$$CR_{tt} = 2\% \quad (2)$$

Table 2- AHP Ambulance

	A	D	P	O	FA	W
A	1	0.33	0.2	6	1	*13.09%*
D	3	1	0.33	5	3	*23.41%*
P	5	3	1	5	7	*49.23%*
O	0.17	0.2	0.2	1	0.33	*4.83%*
FA	1	0.33	0.14	3	1	*9.44%*

The CR tells the decision maker how consistent he has been when making the pair-wise comparisons. It is necessary that the CR is less than 10% to consider the decision maker consistent. Consequently, using as reference the AHP Ambulance table, the weight vector (W) ranks the criteria according to their importance:

1. People;
2. Distance;
3. Availability;
4. First Aid Team;
5. Other.

That means the People parameter is the most influent so its variation creates a notable change in the entity. Obviously, a variation in the Distance parameter will be more influencing than a variation of the Availability and less influencing than the People parameter.
Similar rankings have been found for the Tanker Truck as well as for the Non-transporting EMS Vehicle, the Air Medical Service, etc.

5. EXPERIMENTS AND RESULTS

This section reports some preliminary experiments that have been carried out by using the system dynamics model according to the AHP rankings. Such experiments allows to:

- deepen the relationship between the fundamental variables involved in the management of the entire emergency (namely the methods used in extinguishing the fire and the resources used for injured people transportation to hospitals) and the factors associated with these variables that, with different weights, will influence the results in terms of emergency management;
- testing and validate, for each variable, the hierarchy of values resulting from the AHP analysis.

The results in terms of emergency management are calculated according to two performance measures:

- Time taken to extinguish the fire;
- Time needed to transport the injured to hospitals.

As case study, it has been assumed to properly decline the scenario defined in section 2. The factors were chosen to ensure e a certain plausibility in the overall management of the disaster. The parameters values are shown in figure 3 as they appear in the System Dynamics model interface. To this end, please note the System Dynamics model has been opportunely equipped with a Graphic Interface that allows the user declining the general disaster "picture" described in section 2 and therefore carrying out a experiments on a number of different scenarios.

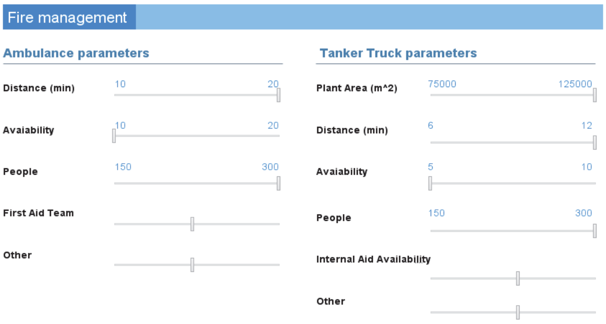

Figure 3 – Starting Scenario

It is worth saying that the time to extinguish the fire is directly connected to the tanker truck variable, while the time required to transport the injured people to the hospitals is connected to the ambulance variable. In particular, as noted in section 3, it is important to understand to which extent a variation of a specific factor may influence the performance measures.
Furthermore, to check the validity of the ranking given by the AHP four different configurations were tested (for the scenario depicted in figure 3) and the results are reported in table 3.

Table 3- Scenarios analyzed

Ambulance	Scenario	Scenario1	Scenario2	Scenario3	Scenario4
Distance	20min	-	10min	-	-
Availability	10	20	-	-	-
People	300	-	-	150	-
First Aid Team	-	-	-	-	-
Other	-	-	-	-	-
Transportation Time		49%	50%	51%	1%
Tanker Truck					
Plant Area	125000m^2	-	-	-	75000m^2
Availability	5	10	-	-	-
Distance	12min	-	6min	-	-
Internal Aid Availability	-	-	-	-	-
People	300	-	-	150	-
Other	-	-	-	-	-
Fire Extinguishing Time		49%	9%	1%	44%

The analysis of the results reported in table 3 establishes that the variation of a factor significantly affects (with a certain weight) the performance measures. Taking into account the ambulance variable it can observed for example how, in Scenario 3, the factor "people involved" may strongly affect the time required to transport people to the hospitals (51% reduction). Similarly, the Ambulance availability and distance may tremendously impact the time needed to transport injured people to the nearest hospitals. The analysis of the lower part of table 3 reveals that tuck tankers availability and the extension of the industrial plant area may significantly affect the time fire extinguishing time. Similar results have been obtained by considering other variables; furthermore, the results shown in table 3 confirm the rankings obtained by the AHP model where the factors people, distance and availability are the most critical to tackle correctly the emergency management.

6. CONCLUSIONS

Over the years, the accidents occurred in industrial plants have led to disastrous consequences both for the number of victims, the damage to assets and for the surrounding environment, so correct approaches to emergency management are needed. The approach proposed in this paper shows that the integration between two different methodologies (namely AHP and System Dynamics) may produce significant advantages in understanding how the different factors involved in the emergency management may influence some critical performance measure. In particular, the outputs obtained from the AHP model can be validated by suing the System Dynamics model. Furthermore, the System Dynamics model provides the user with the possibility to analyze a large set of potential disaster scenarios. To this end, the model itself is based on a general disaster "picture" that can be declined (or customized) by the user according to the specific need. The system dynamics model can be used to investigate scenarios where multiple people are involved and few resources are available or scenarios where large industrial plants are located in external city areas and therefore far from firefighters and hospitals, etc.
Understanding the key factors of a disaster can provide several hints to identify the best place to locate resources as well as industrial facilities (above all in areas considered at risk) as well as to define new rules and procedures to improve emergency management.

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HUMAN BEHAVIOR MODELING: A STATE OF THE ART

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ABSTRACT
Over the last years, the study of Human Behavior Modeling was marked by a tremendous growth of interest from academics in several fields of application. Given the abundance of HBM techniques today applicable to model different human aspects, a review of the current state of the art has become essential. This work has as primary goal the investigation of the most common approaches – agent-based modeling, artificial neural networks, fuzzy logic, genetic algorithms, knowledge-based approaches, Markov chains and so on – as well as the newly applied techniques. Furthermore, the main advantages and limitations associated with implementing each analyzed methodology have been framed in order to provide some basic sparks in the identification of the most promising approach to model human behavior in different contexts.

Keywords: Human Behavior, State of the Art Analysis, Human Modeling, Human Centered Systems

1. INTRODUCTION

Human Behavior Modeling (HBM) is a disciplie with a great potential. In fact, HBM finds applications in numerous fields, such as disaster management (Agresta et al., 2015; Ardalan et al., 2015), military sciences (Mavor et al., 1998; Cordar et al., 2017) and manufacturing (Baines et al., 2004; Bocca et al., 2007).
Recent advances (in terms of research and technologies) permit scholars to publish innovative and new works on this topic. It is clear that modeling human behavior (HB) is very complex, not only for the uncertainty that affects human actions, but also for its strict dependence upon exogenous variables (weather, interactions with other people, etc.).
The key strength of the HBM is the opportunity to mitigate people's errors, satisfying and anticipating their needs, helping them in their daily actions (Cacciabue, 1998). Although such a scenario could be appear fantascientific, HBM practices are already used today to foresee HB during an evacuation, control human reactions while driving, reproduce people's social interactions and so forth. In addition, it is common opinion that HBM could be used to predict the future behavior of an individual (Liu and Pentland, 1999).

The ultimate goal of this article is to provide general knowledge about HBM issues, describing the state of the art and the major approaches to HBM. This paper explores, in the first section, the major approaches in HBM, which are identified and described, by underlining their possible advantages and disadvantages and providing some possible applications. In the second section, a brief reference to the recently approaches designed to overcome the limitations arising from the use of traditional methodologies is made. Finally, in the concluding section, after a careful and thorough analysis of all the studied approaches, remarks and future directions of this research field are outlined.

2. TRADITIONAL APPROACHES FOR HUMAN BEHAVIOR MODELING

Between the mid '50s and mid '90s, scholars designed several approaches to model HB. Seven approaches developed during this period have been identified and described in their main aspects in this section. At the end of section 2, a summary of the relevant advantages, limitations and solution to overcome limits is reported in table 1.

2.1. Knowledge-based

An important HBM approach is knowledge-based approach (KBA). The application of KBA consists nothing more than a "simple" IF-THEN algorithm. Applying this idea to HBM, this means that KBA models the behavior of people tha face with a limited number of situations and, whenever any of these happens (model using "IF condition"), they always respond with a preset action (specify in "THEN operation").
The ideal application field of KBA is in contexts characterized by a high degree of standardization; where an operator executes default actions as, for example, an assembly line (Embrey, 2005).
Numerous opportunities arise using the knowledge-based approach:

1. KBAs can be used as a training aid to increase the expertise of staff;
2. KBAs represent and efficient way of getting answers as it does not involve additional support staff: KBS are implemented by automated systems;

3. KBA model can be updated and extended easily: adding new lines in computer algorithm;

On the other hand, the KBA presents significant disadvantages. They depends by the static nature of a knowledge-based system (KBS).

1. KBSs does not learn from mistakes unless user feedback and human maintenance is part of its ongoing development;
3. KBSs not consider emotional aspects of HB;
4. KBSs not model path dependence;
6. Human-Decision Making (HDM) is very complex and hence it is impossible to describe it accurately by using a simple and static IF-THEN algorithms.

In general, the KBA is not suitable for HBM applications according with its numerous limitations: as already said, it is adapt manly for limited contexts. For this reason, following, some approaches less elementary are described.

2.2. Agent-based modeling

The Agent-Based Modeling (ABM) approach can be described with one word: interaction. Interactions with other people are the roots of human life. AMB becomes necessary when the system that we have to study is complex in terms of interdependence of its components. The ABM approach is based on the concept of agent. For Macal and North (2005), there is no universal definition of the term "agent", though a number of features is identifiable and common to every definition as listed in Castle and Crooks (2006). These represents the main characteristic of an agent:

1. Autonomy: Agents are autonomous units, and they do not depend by other entities;
2. Heterogeneity: agents are different from each other;
3. Active: agents exert independent influence in a model;
4. Goal-directed: agents have a goal to pursue;
5. Reactive/Perceptive: agents are conscious of the existence of other agents, obstacles and surrounded environment;
6. Bounded Rationality: agents act solely on the basis of the information in their possession;
7. Interactive/Communicative: Agents have the ability to communicate with other agents and/or the environment within a neighborhood;
8. Mobility: Agents can move in the surrounding environment;
9. Adaptation/Learning: Agents can be designed to alter their state depending on their current state, permitting them to adapt with a form of memory or learning.

ABM is most natural method for describing a system composed of behavioral entities (Bonabeau, 2001). As Deljoo et al. (2012) said, it is flexible and it represents the canonical in disaster management. In this context, Bazghandi (2012) has written an work where he has explained the possible applications of ABM to manage emergences caused by a traffic jam, where he underling common point between agents' characteristic and HB in this context; or Castle and Crooks (2006) that propose a model to reproduce HB when people have to interface with hurricanes or sand dunes. Usually, in this application, agents modelled have to save themselves from dangerous event modeled.

Obviously, ABM has some limitations. People's actions and choices are often driven by irrationality that complicates the implementation and the development of a HB model. In adding, using ABM is impossible model human emotional aspects: fundamental for HBM (Elkosantini, 2016).

A number of application example in which some of the limitations have been solved above in terms of mathematical definition and simulation by ABM of human emotional aspects (e.g. fear, fatigue, stress, etc.) can be found in Bruzzone et al. (2011), Bruzzone et al. (2012), Bruzzone et al., (2014). Example of applications in non-typical contexts for ABM (cultural heritage fruition) can be found in Longo et al. (2014) and Longo et a. (2015).

2.3. Artificial Neural Networks

A good definition of Artificial Neural Networks (ANNs) is given in Holger and Mark (2008). In this work, the authors define an ANN as "a form of artificial intelligence which attempt to mimic the function of the human brain and nervous system".

ANNs have a well-defined structure. Fausett (1994) has described it as a set of elementary elements called neurons, units, cells or nodes. Each neuron is connected to other neurons by directed communication weighted links. The weights (a scalar number) determine the strength of the connections between the interconnected neurons and represent information used by the ANN to solve the problem studied.

ANNs are strictly connected with HBM problematics. In fact, they imitate human brain functioning: receiving from environment percepts in input and producing an action in output (Schmidhuber J., 2015). This is very important because brain represents the engine of human actions, and the knowledge of their hidden processes could be useful to understand the principles behind HDM. Unfortunately, the reproduction of neural processes in people is very complex: it represent a neuroscience problem − a modern discipline, where scholars have still much to discover .

In adding, making a comparison with ABM, we can observe that ANNs implementation is more complex and it requires a longer running time (ABM is described by linear laws, ANNs are described using non-linear laws). The propriety of non-linearity of ANNs permits the use of them in different application as the prediction of human motions (Abdel-Malek et al., 2016) or in smart environments (a set of software and hardware elements that support an intelligent interaction between environment and users) as in Dev (2001).

In conclusion of ANNs approach analysis, we try to explain them advantages/limitations. The advantages of ANNs use is, in Xu's opinion (2011):

1. An ANN can perform tasks that a linear program cannot: linear programs are less reliable than non-linear (such as ANNs);
2. When an element of the neural network fails, the network can continue working without any problem due to its parallel nature;
3. ANNs often exhibit patterns similar to those exhibited by humans;
4. An ANN learns and does not need to be reprogrammed.

On the other hand, ANNs' disadvantages are:

1. Handling of time series data in ANNs is a very complicated topic;
2. Once a network has been structured for a particular application, that network is ready to be trained. A possible way to do this is resort to the use of genetic algorithms (GAs);
3. ANNs foresee complex operation and, for this, the run of relative program is very expensive in terms of processing time.

2.4. Fuzzy logic

Fuzzy logic has been employed to handle the concept of partial truth, where the truth value may range between completely true and completely false by using decimal numbers. It is possible consider fuzzy logic as an evolution of traditional binary approach (also called crisp approach), where a specific model state is associated to variables that can assume only two values (0 or 1). The use fuzzy logic is recommended to model phenomena with a high grade of uncertainty: characterized by imprecise information and uncertain situations (Calvo-Florese et al., 2014). HBM is an example of this context, inasmuch HDM almost always are distinguished by a great number of possible action executable. In HBM, fuzzy logic is used as tool to HDM processes in mathematical formulas: for Kril and Yuan (1995) it provides us with meaningful and powerful representation of measurement uncertainties and also with meaningful representation of vague concepts expressed in natural language.

Some of most important opportunities arising from fuzzy logic use are describe below:

1. Enam et al. (2011) have proposed fuzzy logic to solve complex problems in neurosciences as it resembles human reasoning and decision-making;
2. In De Reus's opinion (1994) the application of fuzzy logic is very easy compared to computationally precise systems;
3. De Reus (1994) observed during an experiment that fuzzy logic models are not very sensitive to changing environments;
4. Fuzzy logic has proved to be suitable formalisms to handle imprecise/vague and uncertain knowledge (Cannon and Sied, 2004).

In the article by Cannon and Sied (2004), they also identify some disadvantages such as:

1. Fuzzy outputs can be interpreted in a number of ways, making the analysis difficult;
2. Fuzzy requires lot of data and expertise to develop a fuzzy system (Baines et al., 2004);
3. The use of fuzzy logic may often be sensible when computing power restrictions are too severe.

In addition, some other authors identified other important limitations, such as:

1. Fuzzy approach is based on stochastic assumptions (Sugeno and Yasukawa, 1993);
2. Differently to others approaches like ABM, fuzzy logic does not permit interaction between the different entities that populate the model (De Pedro et al., 2007).

It is important underline that, the previous limitations could be exceed joining ANNs characteristic at fuzzy logic propriety: recusing at the neuro-fuzzy logic approach.

2.5. Neuro-fuzzy logic

Neuro-fuzzy logic approach represents a "trait d'union" between ANNs and fuzzy logic. This approach captures the essential aspects of the two methods. Neuro-fuzzy logic uses fuzzy logic theory to describe the uncertainties associated with HB, such as thinking and reasoning, while the use ANNs permit to model important human characteristics as learning, adaptation, fault tolerance, parallelism and generalization.

Neuro-fuzzy logic is used in HBM to overcome limits of fuzzy logic and ANNs. Acampora (2015) used it to limit uncertainty and vagueness that characterize HBM fuzzy logic applications, proposing a model that reproduce the dependence of HB to the external context's modification (including learning propriety of ANNs). Neuro-fuzzy logic have some interesting characteristics (Acampora, 2015):

1. Easy to implement fuzzy natural languages so that the structure of knowledge is very clear and efficient;
2. Any changes in the task and environment can be easily taken care of by adapting the neural weights;
3. Since a fuzzy system is one kind of interpolation, drastic reduction of data and software/hardware overheads can be achieved.

It is important say that, neuro-fuzzy logic approach is a much discussed method in the academic field. In fact, some scholars have doubts about the quality of the system (Acampora, 2012). In particular, scholars are investigating about the compatibility between ANNs and fuzzy logic (Acampora, 2012).

2.6. Genetic Algorithms

Often, people have to reach different objectives in the same time. This situation is not expected by previous described approaches and, to overcome this limit it is possible use GAs approach.

GAs are inspired by Charles Darwin's evolutionary theory. The basic techniques of GAs are designed to emulate evolutionary processes in real world. In a GA, a population of candidate solutions to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (called chromosomes) which can be altered. GAs represent a good method to model HB. Indeed, they allow to model situations where the entities implemented in the model studied must pursue different objectives simultaneously (multi-objectives problems). For this reason, GAs could be a good way to model human-decision making (HDM) processes, for their greater adherence with reality. Numerous opportunities arise using the GAs approach. Below, we have tried to explain the most important:

1. GAs have the ability to avoid being trapped in local optimal solutions, unlike traditional methods, which search from a single point (Deepa, 2007);
2. GAs permit solving optimization problems where we have to maximize/minimize more than one parameter (Tabassum, 2014);
3. Noisy/stochastic objective functions are handled very well (Deepa, 2007);
4. A large number of parameters can be a problem for derivative based methods (Deepa, 2007).

On the other hand, GAs also have some limitations:

1. GAs resolve multi-objective problems. In this type of models sometimes reaching an optimal solution is impossible: optimizing an variable value could damage another parameter;
2. GAs usually need a decent sized population and many generations before you see good results.
3. GAs' solutions strictly depend from a fitness function: a poorly designed fitness function could be make ambiguous results.

A possible application of GAs is in knowledge management field. Kosorukos (2001) has defined a GA applied to this purpose Human Based Genetic Algorithm (HBGA), that is possible use in different contexts as brainstorming and innovation management to find the best solution during a discussion or a better marketing strategy of a new product.

2.7 Markov Chains

A possible application of Markov chains is in HBM fields, in particular to predict HB with an high accuracy. A formal definition of Markov chain is provided by Luenberger (1979): "An n^{th}-order Markov chain process is determined by a set of n states $\{x_1, x_2, \ldots, x_n\}$ and a set of transition probabilities pij, i =1,2, ..., n, j=1, 2, ..., n. The process can be in only one state at any time instant. If at time k the process is m state s_i, then at time k+1 it will be in state x_j with probability p_{ij}"

HB is amenable to them imagining that, at a precise moment, an individual (α) is located in an initial state xo associated with a specific behavior. In this situation, α may carry a limited range of actions $\{x_1, x_2, ..., x_n\}$. The approach of the Markov chain consists of assigning a probability that quantifies the possibility that α has to move from x_o to a generic state xi, executing a particular operation, as Liu and Pentland (1999). The same structure is presented by Dongyue et al. (2016), where the authors predict interarrival time of visitors in a library using Markov chains. From reading many studies about the use of Markov chains, it is possible identify the main benefits that they generate in HBM applications:

1. Markov models are relatively easy to derive (or infer) from successional data;
2. Markov chains approach has high reliability. For instance, the model proposed by Pentland and Liu (1999) has a reliability of 95%);
3. Results of the analysis of Markov models are readily adaptable to graphical presentation;

On the other hand, the Markov approach also has some limitations. For instance, Markov chains is based on uncertainty and approximated data; it is impossible using them model human interactions and they do not integrate learning. In addition, considering that Markov chains have a prediction interval limited to a few seconds (Liu and Pentland, 1999), it is possible make from this limitation an opportunity: this HBM approach could be used to model hasty decision for it capacity to reproduce in a faithfully way the operations of an individual in a very short period. Before analyzing some recently proposed approach, table 1 reports a useful summary of the methods described in section 2.

3. MODERN APPROACHES FOR HUMAN BEHAVIOR MODELING

Since 2013 various scholars have been developing new and interesting methodologies that break with the past. This section will analyze five new approaches:

1. Ambient Intelligence (AmI) (Botìa, 2014): Ambient Intelligence (AmI) is an emerging discipline in information technology, in which people are empowered through a digital environment mainly consisting of complex software and devices (sensors and actuators) connected through a network;
2. Data-driven (Oliver, 2015): The Data-drive approach consists in the modeling of HB using data collected from mobile phones. The use of data driven approach investigates the personality of individuals, something that other HBM methods do not;
3. Dynamic factors (Abebe, 2016): This approach offers a better model of evacuee behavior than traditional methods, which do not adequately account for the numerous dynamic factors that would notably influence evacuation decisions of individuals. It is important underline that Dynamic Factors approach was applied only for evacuations, and needs improvement that makes it applicable in other contexts;
4. Human-Centred System (HCS) (Elkosantini, 2016): the main advantage of HCS is that it considers psychological, individual, and social factors, in contrast to others traditional approaches, but the method is not yet validated;

Table 1. Traditional HBM approaches – a synthetic description

APPROACH	CONTEXT WHERE USE IT	RELEVANT ADVANTAGES	RELEVANT LIMITATIONS	SOLUTIONS TO OVERCOME LIMITS
AGENT-BASED MODELING	**CONTEXTS WHERE THERE ARE PEOPLE WITH A HIGH GRADE OF INTERACTION AND HETEROGENEITY.**	Capture emergent phenomena [17], [9]. Provide a natural description of a system [12]. **FLEXIBILITY [21].**	It is very difficult to model human psychology, when it is train by irrationality [17]. **ABM USES MATHEMATICAL RELATIONS RARELY USED IN THE REAL WORLD [17].**	**MODERN APPROACHES**
ARTIFICIAL NEURAL NETWORKS	Contexts where it is not possible to identify some relations between input and output **CONTEXT WHERE WE HAVE TO MIMIC THE HUMAN DECISION- MAKING PROCESS.**	ANNs preforms better than linear program [45], [44]. ANNs is a black box like human brain [1], [44]. **ANNS LEARN AND DOES NOT NEED TO BE REPROGRAMMED [44]**	The non-linear quality of ANN makes it difficult to apply this approach [44]. ANNs need to train [39]. **ANNS FEEDS ITS OUTPUTS BACK INTO ITS OWN INPUTS [37].**	Genetic Algorithms Neuro-fuzzy Logic **MODERN APPROACHES**
CRISP APPROACH	**CONTEXTS WHERE PEOPLE HAVE TO CHOOSE BETWEEN ONLY TWO ALTERNATIVES.**	Simple application [16]	**POSSIBILITY TO MODEL ONLY TWO ALTERNATIVES [16].**	Fuzzy Logic Neuro-fuzzy Logic **MODERN APPROACHES**
FUZZY LOGIC	Contexts where people have to choose between more than two alternatives. **SITUATION CHARACTERIZED BY UNCERTAINTY.**	Fuzzy logic resolve complex problems [26]. Simple application [24]. Fuzzy algorithms are robust [24] **LIMITS AMBIGUITIES [15].**	It is tedious to develop fuzzy rules and membership functions [15]. Performances of fuzzy model are straightly connected with calculator specifics [15]. **FUZZY LOGIC IS BASED ON STOCHASTIC ASSUMPTIONS [15].**	Agent-Based Modeling Dynamic Factors Neuro-fuzzy Logic **MODERN APPROACHES**
GENETIC ALGORITHMS	Contexts where there are more than one objective to pursue. **CONTEXTS WHERE WE HAVE TO TRAIN ANNS.**	It is possible to use GAs to model multi-objective problems [20], [43]. **A LARGE NUMBER OF PARAMETERS CAN BE A PROBLEM FOR DERIVATIVE BASED METHODS [17]**	No guarantee of finding a global maxima. **SOLUTIONS OF GAS DEPEND ON THE FITNESS FUNCTION.**	Neuro-fuzzy Logic **MODERN APPROACHES**
KNOWLEDGE-BASED	Contexts where we can easily code facts and rules. Contexts describable by standardized procedure. Context sufficiently restricted. **CONTEXT WHERE WE DO NOT FIND AN EXCESSIVE NUMBER OF EXCEPTIONS.**	Easy to traduce in computer languages. The knowledge base can be updated and extended easily. **KNOWLEDGE BASE CAN BE UPDATED AND EXTENDED EASILY.**	Does not learn from mistakes unless user feedback and human maintenance is part of its ongoing development. Unlikely to come up with creative solutions. Not able to learn from mistakes. **CANNOT CREATIVELY COME UP WITH NEW SOLUTIONS FOR ISSUES.**	Agent-Based Modeling Artificial Neural Networks Fuzzy logic Neuro-fuzzy Logic **MODERN APPROACHES**
MARKOV CHAINS	Contexts where there are heterogeneous agents. **CONTEXTS WHERE WE HAVE TO MODEL HIDDEN ASPECTS THAT WE CANNOT OBSERVE DIRECTLY.**	High reliability (95%). [33] **RESULTS OF THE ANALYSIS OF MARKOV MODELS ARE READILY ADAPTABLE TO GRAPHICAL PRESENTATION.**	Impossible to model interactions. Based on stochastic laws. **MARKOV CHAINS HAVE A PREDICTION INTERVAL LIMITED TO A FEW SECONDS [33]. MARKOV CHAINS DO NOT INCLUDE LEARNING PROPRIETY [10]**	Agent-Based Modeling Dynamic Factors **MODERN APPROACHES**
NEURO-FUZZY LOGIC	**CONTEXTS WHERE FUZZY LOGIC AND NEURAL NETWORK ARE NOT SUFFICIENT TO DESCRIBE SITUATION.**	High scalability. [3] Detection human behavior in a complex scene [3]. **DRASTIC REDUCTION OF DATA AND SOFTWARE/HARDWARE OVERHEADS CAN BE ACHIEVED [3].**	Limitation of Fuzzy Logic and ANNs approaches [3]. Doubts about quality of approach. [3] **COMPATIBLY BETWEEN FUZZY LOGIC AND ANNS. [39]**	Agent-Based Modeling Genetic Algorithms Modern approaches

5. Video Analysis: Video analysis or, for Asafar et al. (2015), Automatic visual detection approach, is the analysis of HB using systems of video capture such as video surveillance. It is possible used video analysis as tool to collect information to build models.

As a result of the analysis conducted in this article, some conclusions can be drawn about the current status questions of HBM: first, there is a substantial number of HBM approaches, and all have their advantages and limitations. From this it is clear that it is impossible to define an optimal approach to HBM. However, it is possible to define a target for which the application of a specific approach can be particularly recommended. Table 1 presents a scheme with this information, with an indication of possible solutions to surpass the limitations of the various approaches. An analysis of these reveals that the ABM approach solves the majority of other HBM methodologies' limits. This is endorsed by the fact that ABM is a flexible approach that is widely used in many different contexts.

4. CONCLUSIONS

This paper is an attempt to provide the reader with useful state of the art information about the past and current research activities in the area of Human Modeling Behavior. After surveying the most known traditional methods the article reports a brief summary about the modern approaches, where Agent Based Modeling seems to present the major advantages because:

1. It allows the modeling of interactions among the various entities that make up the model;
2. The agents have the characteristic of being able to learn;
3. All actions of agents are aimed at a specific purpose.

Obviously, there is no denying the presence of handicaps also in modeling agents. Such restrictions can only be reduced by using recently developed methods, but they are still at an early stage. Further research activities are therefore needed to carry out VV&A (Verification, Validation and Accreditation) with the aim of solving current flaws and increasing the reliability of the proposed approaches.

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AN AGENT-BASED MODELING AND SIMULATION TOOL FOR ESTIMATION OF FORCED POPULATION DISPLACEMENT FLOWS IN IRAQ

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ABSTRACT

Forced displacement and migration is on the rise globally. As a result of wars, insurgencies, political persecution, complex emergencies, and climate change, more than 65 million people worldwide are considered as forcibly displaced. This rising number has created significant challenges for humanitarian agencies. Therefore, understanding the causes, movement patterns, and migration flows of displaced populations has attracted researchers. While traditional migration models can be used, more sophisticated and advanced models are required to capture various factors influencing the displacement process and the complex interactions and behaviour of various agents that force people to make displacement decisions. Agent-based modeling (ABM) has emerged as a preferred modeling method for complex social and environmental problems including forced displacement and migration. ABM in the context of forced migration allows for a more accurate and detailed simulation by including dynamic interactions of migrants and humanitarian actors. This paper presents an agent-based model developed to understand the nature of forced displacement in Iraq caused by recent conflicts.

Keywords: Agent-based modeling, displacement tracking, forced displacement, internal migration

1. STATE OF THE ART

Since the end of World War II, global conflicts have generated an increasing number of refugees and internally displaced persons (IDPs), resulting principally from conflicts or persecution within states (Anderson, Chartuvedi and Cibulskis 2007). According to the UN Refugee Agency (UNHCR), formerly known as the United Nations High Commission for Refugees, the total number of people forcibly displaced worldwide in 2015 reached a total of 65.3 million (UNHCR 2015). An estimated 12.4 million of these were newly displaced in 2015 as a result of conflict or persecution. After Syrians who constitute the largest number of displaced persons (11.7 million), Afghans, Colombians, Congolese, Iraqis, Nigerians, Somalis, Sudanese, South Sudanese, and Yemenis, each with more than 2 million displaced people, are the next largest groups (UNHCR 2015).

Various factors contribute to forced displacement. Threats to personal safety and security are of primary importance in leading people to abandon their homes (Davenport, Moore, and Poe 2003). Besides violence and culture, other relevant factors like domestic economic situation at home and abroad may influence internal displacement (e.g. flow path selection). Previous studies have found that networks and cultural communities provide people with information about migration possibilities (Shellman and Stewart 2007).

The displacement of large numbers of people in times of crises represents a challenge for humanitarian agencies (Hailegiorgis and Crooks 2012). Provision of basic needs and services for displaced people, delivering critical aid such as shelter, food, and medical health in dynamically changing environments (i.e. unpredictable number of people, in scattered locations) are very difficult undertakings.

Until recently, forced displacement has been primarily considered a political phenomenon; therefore, it has been ignored in migration literature (Schmeidl 1997).

Computational studies investigating the refugees' movements are scarce in the academic literature. However, extensive research has been done both on evacuation, which focuses on smaller space and time scales, and migration modeling, which focuses on much larger space and time scales (Groen 2016; Uno and Kashiyama 2008; Smith and Brokaw 2008).

Nowadays, ABM is intensively applied in several domains, such as engineering, biology and social science. In the last ten years, several researchers have been demonstrating its potential to advance our understanding of complex systems (Andersson, Chartuvedi, and Cibulskis 2007; Collier and North 2012; Asakaura, Aoyama, and Watanabe 2011). However, ABM has only fairly recently been applied in humanitarian research. Therefore, there are very few references in the literature compared to more classical methods such as Linear Programming, System Dynamics or Discrete Event Simulation (Menth 2016). Sokolowski, Banks, and Hayes (2014) introduced a methodology for crafting the environment and agents to

represent the Syrian city of Aleppo and the displacement of its citizens due to the Syrian conflict. The model replicates the refugee behavior taking place within Aleppo by capturing the dynamic interaction taking place between rebels and government troops.
However, existing research shows that ABM can capture interactions among individuals, and, therefore, is well-suited for modeling sociological and psychological behavior and interactions of humans (Johnson, Lampe, and Seichter 2009). Interactions between individuals often produce nonlinear effects at the population level (Klabumde and Willekens 2016). The ABM simulation approach is capable of capturing these interactions. In fact, the major advantage of ABM for the analysis of social systems is the capability for modeling both explicit and implicit social interactions. In the case of forced migration events as a result of these interactions, individual decisions and behaviour may change, since these interactions are very dynamic (i.e., in time and space). This represents a huge advantage for modeling by means of ABM technology to produce simulations and shape the resulting networks, which expands its applicability and effectiveness with the integration of geographic information systems (GIS) technology (Crooks and Wise 2013).
The model presented in the current work integrates in a single platform individual decision making by the civilian population, as influenced by insurgent and military actions as well as resources provided by the humanitarian agencies. Moreover, the level of influence on population behavior (displacement flows) is estimated in accordance with real data (gathered from extensive field records) as a function of the risk level perceived and considering the observed destination preferences. Agent-based modeling of these dynamic interactions in a GIS environment allows a better simulation of the system. Thus, the model proposed herein differs from previous work, and could be a more effective tool for analysis and decision making required for humanitarian logistics planning and deployment.

2. CASE STUDY

Violence and conflict have caused unprecedented displacement in recent years, particularly in the Middle East. A large number of Iraqis have been affected. The UN Refugee Agency reported that 203,700 new asylum applications were filed in 2015 by people who have fled from Iraq (UNHCR 2015). However, the greater numbers of affected Iraqis have been internally displaced, forced to relocate to other regions within Iraq. For instance, from January to July 2014, there were an estimated 1.2 million internally displaces persons (IDPs) in Iraq (ECHO 2014). Presence of armed groups performing intimidation and terror acts at specific regions, still forcing individuals and entire families to find safer areas where their ethno-religious group constitutes the majority. Armed clashes between the multinational Forces and Iraqi Security Forces on the one hand, and ISIS insurgents on the other, have also produced population displacements (Couldrey and Morris 2007). The movement occurred predominantly in and between urban areas – with more than 70% fleeing Baghdad. At least 10 of the 18 Iraqi provinces have now tried to place entry restrictions on their internal borders to Iraqis displaced from elsewhere in the country (Margesson, Bruno, and Sharp 2009).
Within many areas in Iraq, conditions are deteriorating and are leading to more permanent problems. Seven out of the eighteen Iraqi provinces host more than 80% of the total identified IDPs (IOM 2016): Baghdad (16%), Anbar (16%), Dahuk (15%), Kirkuk (13%), Erbil (8%), Ninewa (6%) and Sulaymaniyah (6%). Figure 1 is a slide prepared by European Commission – Humanitarian Aid & Civil Protection (ECHO) showing the movement of people displaced in Iraq in January-July 2014 (ECHO 2014).

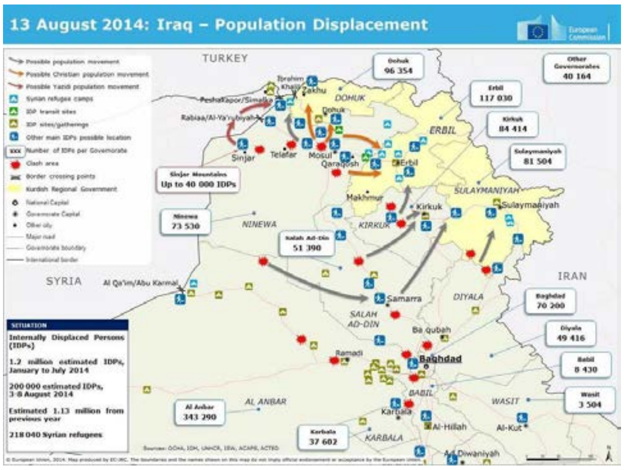

Figure 1: Movement of People Displaced in Iraq from January to July 2014

Based on the availability of data and on the fact that violence and conflict continue to take place in Iraq, the present work seeks to produce a broadly applicable computer simulation that will be used to capture the behaviour of civil populations, military forces, and humanitarian agencies.
The model can be used to analyze the forces that are driving refugee flows and conditions. The impacts of government policies can be examined and used to conduct policy experiments to see how refugee communities might respond to alternative courses of action.
By executing the computer model with different initial values for its parameters and inputs, patterns and regularities can be discerned from the results (Andersson, Chartuvedi, and Cibulskis 2007).
The approach used to reach this objective consists of the following:

- Extracting real data from the Displacement Tracking Matrix (DTM), an information management tool used by the International Organization for Migration (IOM).
- Identifying and analyzing events that cause forced migration.

- Developing an agent-based simulation tool to capture the behaviour of displaced people, insurgents, and military forces.

3. DESCRIPTION OF THE MODEL

ABM has been chosen because in addition to the above mentioned advantages, their application avoids unrealistic restrictions and assumptions, imposed on the system if being modeled under other approaches as system dynamics, where aggregate data is used. ABM can be used to conduct policy experiments to see how refugee communities might respond to alternative courses of action (Anderson, Chartuvedi, and Cibulskis 2007).
ABM has been chosen as it allows:

1. Virtual simulation of the consequences of decisions,
2. Integration of multiple theories regarding the phenomena under analysis,
3. Representation of agents with multiple decision strategies,
4. Modeling of heterogeneous actors who can modify their behavior over time.

We have used AnyLogic simulation software 7.3 (AnyLogic 2016), which allows GIS environment to be embedded and used in the simulation and proves to be very important in large scale forced displacement simulation. Implementing ABM in the GIS environment, it is possible to model the emergence of phenomena through agent interactions over time and space (Crooks and Wise 2013). Based on this approach, the overarching objective of our project is to simulate the flows of displaced people and calibrating the model using empirical data from the Displacement Tracking Matrix (DTM), which represents one of the contributions of the current work.
The simulation model's components are:

1. Agents,
2. Input section,
3. Map and visualization,
4. Output section.

The agents include:

- Governorates,
- Insurgents,
- Families displaced,
- Iraqi security forces,
- Foreign peacekeeping forces,
- Iraqi commanders.

The Governorate is the environment in which agents act and interact. In the specific case of Iraq, 18 different governorates have been considered, even if the focus is on the eight most significant, in terms of people displaced.
insurgents respresent a minority group who are forcing political change by means of a mixture of subversion, propaganda and military pressure, aiming to intimidate the broad mass of people to accept such a change. They seek to destroy the state by violent action designed to disrupt the normal functions of control (UK Army Field Manual, 2007).
In the model, insurgents goal is to capture major cities and therefore their destinations could be several.
The families are the civil population of the Governorates. Families,based on the movement of insurgents, decide if staying in their place or moving toward other governorates where they feel safer. Figure 2 shows the decision tree for the families.

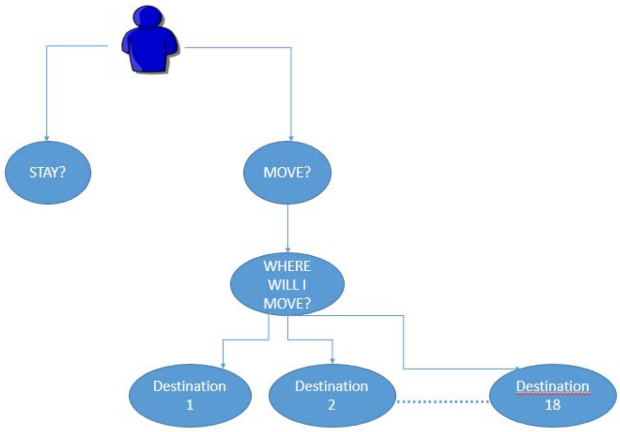

Figure 2: Decision Tree for the Families

The initial decision of the families is dependent upon the value of a Risk Index which has been calculated for each governorate. The Risk Index is a function of a number of dynamic variables (e.g., push and pull factors of displacement). These variables are:

- Presence of national military,
- Presence of international forces,
- Presence of insurgents,
- Number of civilian casualties,
- Access to transportation infrastructure,
- Local behaviour,
- Presence of humanitarian organizations,
- Level of poverty,
- Presence of relatives.

As the values of push/pull factors change, the overall index will fluctuate and the number of families displaced for each governorate will change. The higher the value of Risk Index, the higher the population displaced. Figure 3 shows the number of displaced people as a function of the Risk Index (as implemented in the model).
Iraqi Security Forces are the existing military forces in Iraq who battle against the insurgents. The main Iraqi Security Forces organizations belong to the Ministry of Interior (MOI) and the Ministry of Defense (MOD), although other ministries control smaller, specialized security forces (The Washington Institute 2004). Based on the actions of the insurgents, Iraqi Security Forces

may undertake several possible actions (which may be chosen by the users).

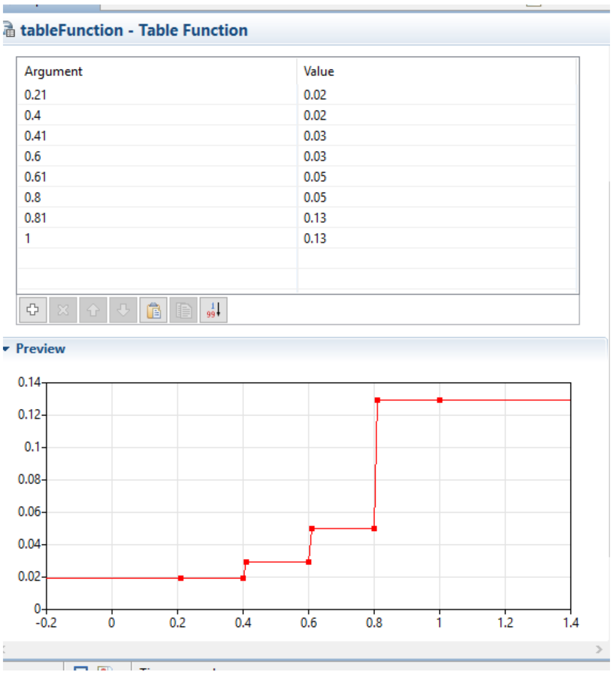

Figure 3: Displaced Population Function

Foreign Peacekeeping Forces are the U.S.-led coalition forces who battle against insurgents in Iraq. The coalition forces in the model are from USA, UK, Canada, Australia, Italy, Denmark, and Germany. Based on the rules of engagement (Rules of Engagement 2007), four categories of strikes against insurgents have been implemented in the simulation model:

- Troops into contact,
- Pre-planned strike,
- Fleeting target,
- Time-sensitive targets.

For each strike, U.S. military forces can use several resources:

- Aircraft,
- Any organic direct fire weapons,
- Mines.

In this simulation, the B-1 Lancer bomber aircraft, bombs of 1kiloton, and Claymore mines have been used. The US strike authorities remain subject to the expected level of collateral damage (Rules of Engagement 2007). If the insurgent (target) is in a High Collateral Damage Zone, which means that there are more than 30 families within a 1 kilometer radius, a strike requires the approval of the Secretary of Defense. If the target is in a Low Collateral Damage Zone, it requires the approval of the Commander of Iraqi Multi-National Forces, while if the target is in a No Collateral Damage Zone it requires only the approval of the Division Commander. This is the behaviour of the Agent 'Commander' in the model.

The map section shows the evolution of the flow of displaced people over time. The input section allows the user to set up a number of different parameters, such us the initial population, different types of agents, and the value of Risk Index for each Governorate. Finally, the output section reports the main simulation results, including the number of people displaced from each governorate and the final destination of these displaced people. Figure 4 shows a partial view of the interface for the Input Section, with sliders to input the Security Risk Index for each governorate (values shown are for demonstration only).

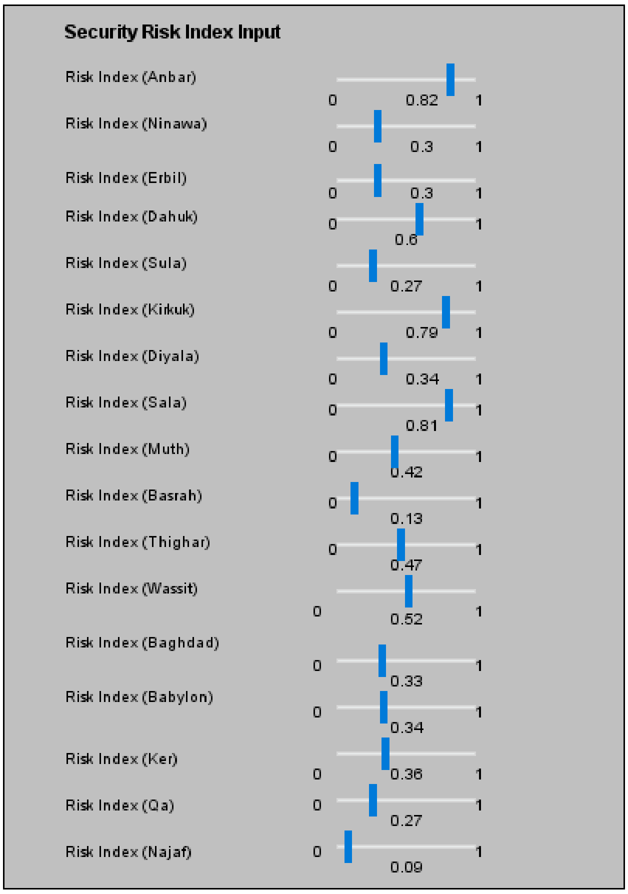

Figure 4: Graphical Interface for Input Section

Figure 5 shows the simulation model visual and map section that includes the eight principal governorates (Al Anbar, Ninewa, Kirkuk, Diyala, Saladin, Baghdad, Babil, Erbil) with their real population (Joint Analysis and Policy Unit 2015), and the flow of people displaced for each governorate. Furthermore, this figure also shows the movement of insurgents, the principal basis of foreign military forces (Ninewa, Saladin, Diyala, Baghdad, and Kirkuk) and the pre-planned attack with aircraft made by U.S. military forces against the insurgents. In the Model Setup section, the user can add different agents to the simulation model, and, based on the movement of the insurgents, could choose, through several buttons, which kind of military strike could be undertaken.
Figure 6 shows the most important results of the simulation that could be accessed at run—time. The

main results are also saved in a database file that can be accessed at the end of the simulation.

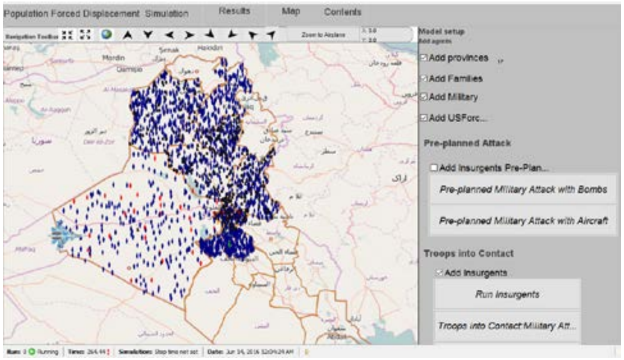

Figure 5: Simulation Model Animation Graphical Interface

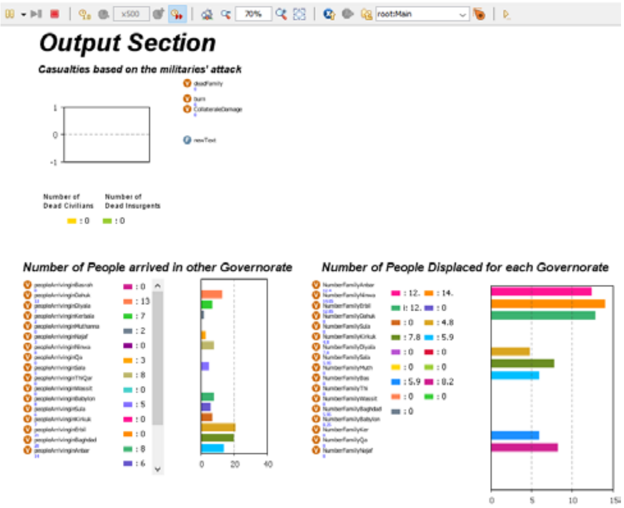

Figure 6: Graphical interface for the Output Section

4. SIMULATION RESULTS

The simulation model introduced in section 3 has been used to model the flow of IDPs. Multiple simulation runs have been executed for each governorate and the results are summarized below.

These experiments have been performed for eight governorates. In this work, results are reported for the Governorates of Al Anbar and Erbil only. The simulations results correspond to the values for 4 weeks of simulated time.

Selection of these two cases is based on the fact that, according to the DTM dataset, Al Anbar is the worst affected governorate in terms of people displaced, while Erbil is the least affected Governorate.

The governorate of Al Anbar is situated in western Iraq. With a total population of close to 1.5 million, it is the largest governorate in the country in terms of land area.

Over the past decade, Al Anbar saw multiple waves of displacement due to the offensive of insurgents. The experiment about Al Anbar has been done with a Risk Index value of 0.81. Table 1 reports the results of simulation with the number of people displaced in the Governorate of Anbar.

Table 2 reports the probabilities of choosing different destinations for the displacement from Al Anbar. In this specific period, 39.4% of the families displaced from Al Anbar choose another district in Al Anbar as destination, while 27.3% of the families displaced from Al Anbar move to Baghdad and 12.1% to Erbil.

Table1: Number of Families Displaced from Al Anbar based on the Highest Value of Risk Index

Risk Index Value	% Displaced	Number of Individuals Displaced	Number of Families Displaced
0.81	13.0%	193,440	32,240

Table 2: Probability of Destination for Families Displaced from Al Anbar

Destination Governorate	Probability (%)
Al Anbar	39.4%
Baghdad	27.3%
Erbil	12.1%
Kirkuk	9.1%
Sulaymaniyah	6.1%
Babylon	1.0%

Situated in northwest Iraq, with a total population of just over 1.5 million, Erbil hosts the capital of the region of Kurdistan which is administrated by the Kurdistan Regional Government (KRG). As the economy and security of Erbil are generally better than many other areas of Iraq, this governorate continues to be a common destination for displaced populations. Erbil is the least affected governorate in terms of people displaced.

The Erbil experiment has been done with a Risk Index value of 0.21. Table 3 reports the simulation results with the number of people displaced in the Governorate of Erbil. Table 4 reports the probability of destination for the displacement from Erbil. In this specific period, 98.9% of the families displaced from Erbil choose another district in Erbil as destination, while 1% of the displaced families move to Salah al-Din.

Table 3: Number of Families Displaced from Erbil based on the Lowest Value of Risk Index

Risk Index Value	% Displaced	Number of Individuals Displaced	Number of Families Displaced
0.21	2.0%	30,840	5,140

Table 4: Probability of Destination for Families Displaced from Erbil

Destination Governorate	Probability (%)
Erbil	98.9%
Salah al-Din	1.0%

The model is able to estimate these results for all the Iraqi Governorates. During the simulation, the model updates the situation in each Iraqi Governorate based on the evolution of the Risk Index. Based on the different strike of US coalition forces against insurgents, during the simulation is computed the total amount of casualties (i.e., killed civilian and insurgents).

5. CONCLUSION

The main goal of this study was to extract real data from the displacement tracking matrix (DTM), an information management tool used by the International Organization for Migration (IOM); to identify and analyze events that cause forced migration and develop an ABM Simulation tool to capture and reproduce the behaviour of displaced people and military forces.
To this end, a specific agent-based simulation model has been proposed: the simulation model is characterized by the most relevant actors in Iraq (Insurgents, Families, Iraqi Security Forces, US coalition forces). The agents of the simulation model are characterized by variables, parameters and statecharts that define their behaviour. The simulation model implemented, is able to generate an animation to show the behaviour of the agents during the simulation, the different experiments can be defined using the input interface for seting up the parameters and the results can be obtained from the output interface.
Based on the real data, the proposed model is able to recreate the situation in Iraq, focusing on the simulation of the behaviour of families/individuals inside each governorate of Iraq.
In order to identify the causes of displacement, a Risk Index has been developed, which take into consideration the most important push factors of displacement.
In the last section of the paper, a scenario has been simulated and some of the main indicators and results are presented, showing the usefulness of the simulation outputs to be used to estimate the flow of people displaced from each iraqi governorate.
The model can also be used as a tool for training the commanders of Military Forces and to support their decisions, for the evaluation of the impact of these in terms of estimation impact on the civil population.

ACKNOWLEDGMENT

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SIMULATION OF MANNED & AUTONOMOUS SYSTEMS FOR CRITICAL INFRASTRUCTURE PROTECTION

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ABSTRACT
Critical Infrastructure Protection is a rising issues in today world; considering that most of the population live on coastal area it is not surprising the fact that several of these infrastructures are located within marine scenario. Ports, piping, cables, off-shore and coastal on shore plants are being more and more targeted by asymmetric threats. Employing Autonomous Assets allows to drastically reduce the protection costs but requires to design new solutions. This paper addresses this issues with special attention to off-shore platforms respect the opportunity to improve threat assessment by innovative solutions. Indeed the paper proposes an Agent Driven stochastic simulation for reproducing a combined used of autonomous and traditional assets devoted to identify threats as well as the possibility to use it for training Unmanned Aerial Vehicles (UAV) pilots. The authors present the results of the experimental campaign obtained on a test population of unskilled operators to evaluate the possibility to diffuse the use of such approach without requiring very highly qualified expertise.

Keywords: Simulation, Critical Infrastructures, Autonomous Systems, Training, UAV, Off Shore Platforms, Asymmetric Threats

INTRODUCTION
Nowadays the geopolitical situation and the technological evolution is emphasizing the impact of critical infrastructure. This is due to several reasons: general presence of heavy threats in terms of security related to terrorist organizations, vulnerability of existing critical infrastructures to easily accessible technologies operating on different layers, such as IED (Improvised Explosive Device) cyber-attacks, autonomous systems (Abrahams et al. 2005). The technology evolution is even further emphasizing this elements because is becoming more and more common to have critical infrastructures that are remotely operated, such as happens in energy sector, with many renewable energy solutions geographically widespread and lightly supervised and protected (e.g. wind farms). Another fact is the great need of energy for human societies (McKercher et al. 2004, Mastrangelo 2005) that promotes the growth of natural gas consumption and resulting risks connected with these facilities that are sensitive to terrorist attacks (e.g. NLG terminals). All these considerations highlight the problem of critical infrastructures protection (Bruzzone et al. 2013a) and their resilience also when connected along the supply chain (Longo and Oren, 2008). One factor that is strongly affecting countermeasures effectiveness is the sustainability in terms of reliability, operational costs, efficiency etc. For these reasons, it is evident that autonomous systems represent on one hand a potential threat and on the other an interesting resource for protecting critical infrastructures (Hill 1996, Hudson 1999, Mevassvik et al. 2001, Bruzzone et al. 2011a). It is worth to mention that actually, the autonomous solutions do not cover completely the mission spectrum; often protection, patrolling, block operations are expected to be carried out by traditional assets or at least in co-operation with them. This means that it is necessary to integrate these systems to evaluate the best configuration and even to identify how to cover the different spaces domains: cyber space, space, air, land, sea surface and underwater (Bruzzone 2013, Bruzzone et al. 2013b). An interesting observation is that many critical infrastructures are located in coastal areas due to the fact that ocean traffic supports most of logistics and connection and that the majority of the population live on urbanized coastal town.

1. OFF SHORE CRITICAL INFRASTRUCTURES
So many on-shore and off-shore installations are operating in this framework and need to be addressed; it is even important to outline that off-shore installation are even more complex to be protected with reasonable costs due to their configurations as happen with off-shore platforms, off-shore wind farms, underwater pipelines and cables. From this point of view, protective

solutions should be activated to cover different domains. It is evident the complexity of this framework and the necessity to integrate different domains, approaches, platforms, systems and procedures within a highly stochastic environment; so the use of simulation represents a very good opportunity to face these challenges and to model this context (McLeod 1982, Banks1998, Bossomaier 2000, Waite 2001).

The authors have investigated since long time the protection of critical infrastructures in marine domain and in energy sector as well as there are a number of research works that show the potentials of Modeling & Simulation based approaches in this area, not only for protection but even for performances improvement (Longo et al. 2013). In this paper, the authors propose a systemic approach devoted to integrate innovative technologies over different kind of platforms to guarantee high level of protection with low costs based on the integration of autonomous systems and AI (Artificial Intelligence).

The paper proposes a case related to the protection of off-shore platforms by using autonomous systems able to identify threats through innovative procedures; for instance the use of specific algorithms and sensors on these platforms could allow to conduct face recognition of the crew of suspected boats at large distance reducing the risk of false alarms and extending protective area. In this context the use of non-lethal weapon is crucial and this approach represent a very good example to improve the protection and improve safety and reliability.

Indeed the drones could be employed to extend the range where it is possible to identify the threats, to anticipate them and to increase the time available to adopt countermeasures (Ören & Longo 2008, Bruzzone et al 2011c). As anticipated this approach is beneficial also to reduce the false alarms, furthermore increasing the capacity to discriminate between real and false alarms improve protection system credibility.

Therefore the innovative drone technology is often not completely autonomous, but needs to be integrated other traditional assets (e.g. equipment devoted to be used to intercept, discourage or engage threaths) often operated by humans; in addition the drones require usually operators and the procedures are driven by the decision makers (Longo et al. 2014). In this paper the authors adopt the MS2G (Modelling and interoperable Simulation Serious Game) for addressing these aspects in order to create a framework that could be used in multiple ways: evaluator of capability assessment for these innovative solutions, training equipment for drone operators and simulator for the definition of policies and procedures (Mosca et al 1996, Kuhl et al. 1999, Massei & Tremori 2010, Guo et al. 2011, Bruzzone et al. 2012). Indeed the authors decided to carry out an experimentation to evaluate the potential to easily train not very skilled operator in conducting such scanning procedures; the experimentation carried out with drone users allowed to evaluate the effectiveness of the MS2G solution proposed to train the operators as well as to evaluate the benefits provided by augmented reality aid and other specific algorithms (i.e. face recognition) for what the authors name wide range detection (Raybourn 2012, Bruzzone et al. 2014).

2. CURRENT SITUATION AND RELATED R&D

Among critical infrastructures that ones related to energy industry are very important and it is interesting to note that while technological accidents in the energy industry have been deeply investigated over the last decades, the issue of attacks on energy infrastructures is gaining increasing importance as production and transit areas are evolving into politically unstable and unreliable frameworks. It is necessary to consider energy domain under the security perspective for risk assessment (Burgherr et al. 2015). Indeed the discussion arises on how to optimize security of critical infrastructure facing budget constraints, technological innovation and new competitive threats. The fields of investigation include Patrolling, Sensor Coverage and Interference, Domain Protection and Blocking (Bruzzone et al. 2009, Megherbi & Xu 2011, Kranakis & Kriznac 2015). To this end, many actors (e.g. EC, US DoD, NATO and Academic Institutions) are investigating innovative options (e.g. Autonomous Systems, Manned Patrolling Assets) for protecting critical infrastructures against asymmetric threats in the maritime environment using multi-agent simulation and interoperable simulation (Enters et al. 2002, Smith 2002, Lucas et al. 2007, Matusitz 2013, Massei et al. 2014, Bruzzone et al. 2015a). Ongoing researches are even oriented to the definition of multi-layered architectures for reconfigurable autonomous assets (Brdys 2014), as well as models to support decision making process based on innovative techniques such as Artificial Neural Network and Genetic Algorithms (Bruzzone et al 2015a) and Game Theory (Ordónez et al. 2013, Vorobeychik & Letchford 2015). The diffuse employment of drones in new operative scenarios implies the necessity to design innovative training sessions for operators through LVC Simulation (Live-Virtual-Constructive) (Vince et al. 2000, Ratliff et al. 2010, Bruzzone & Longo 2013c) capable of providing rapid and efficient knowledge and skill development for drones operators (Rowe et al. 2015). This necessity is even underlined by the availability of new technological contents, such as Augmented Reality, with which operators need to interface (Miller et al. 2014). Indeed one issue is to manually pilot the unmanned aircrafts remotely by using camera image streaming and sensors information (Yang et al. 2010) in particular for complex operations such as docking or low altitude flight. Over the years, in order to avoid catastrophic damages to assets and increase missions success rate, simulation-based procedures have been designed for training operators on mission specific operational scenarios in advance (Javaid et al. 2013). Often simulation for adaptive learning is adopted to improve time-critical decision making skills (Abhyankar et al. 2014). So the development of common standard in military training and computer game simulators domains to simplify development of new concepts and to increase capability to achieve common goals reducing negative crossover (Kuhl et al. 1999; Svane & Karisson 2003).

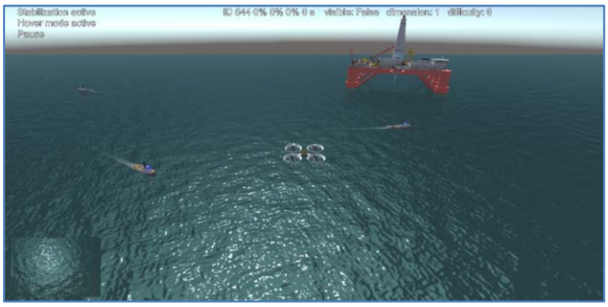

Figure 1 Scenario

3. PURPOSE OF THE SIMULATION

The authors are proposing an approach that integrates AI algorithms for face recognitions with sensors mounted on rotary wings as support for protecting offshore platforms. In this case the simulation is devoted both to understand the operative advantage of a rotary wing drone employed on off-shore platform for the decision maker and to provide a test-bed to train drones operator performing recognition activities in a hostile environment facing unconventional targets.

The simulator proposed for this case is titled SO2UCI (Simulation for Off Shore, On Shore & Underwater Critical Infrastructure) and it has been developed by the authors within the Simulation Team; SO2UCI is a simulation able to support training on protecting Off-Shore Platforms (e.g. oil rig, gas rig), On-Shore Critical Infrastructures (e.g. ports, power plants, refineries, desalinators) and Underwater Critical Infrastructures (e.g. cables, pipelines) from Asymmetric Threats using conventional assets and autonomous systems (e.g. RHIB, Helicopters, Sensors, UAV, USV, AUV, Gliders, etc.). The simulator is interoperable by using HLA (High Level Architecture) and support integration with real equipment as well as with other simulators and solutions as the SPIDER. SO2UCI integrates scenarios for training the use of specific sensors on rotary wing UAV to discriminate suspect boats invading the perimeter of Oil Rig (e.g. face recognition, thermal camera, etc.). The models have been verified by applying VV&A Procedures (Blaci et al. 1996).

In the proposed experimentation the user of the simulator is the Drone Operator. The control system of the drone is very basic and adopts simple on game interface; indeed this is due to the experimental nature of the project, but also to the consideration that most of future operators could be more familiar with this solution. Further development might possibly include the setting of a more specific control system and integrated framework with other protection systems.

The user main goal is to pilot the rotary wing drone close enough to the boats in order to activate recognition sensors, entering their range and within a specific relative position to catch the crew face. The user has to remain within the sensor range until sensors data acquisition process is over; the process is supported by information and alert provided by speakers to the boat from the drone; it is evident that for many reasons non cooperative behaviour could be expected and could lead to alert just based on additional evidence of suspect behaviours. The purpose of the experimental campaign, on the other hand, is both the evaluation of the impact of simulation for training purposes and the influence of augmented information provided by the simulation to pilots such as enabling the visibility of sensors range and of the required profile to successfully approach a suspect boat.

4. SCENARIO AND MODEL DESCRIPTION

The authors propose a scenario for training operators in controlling a remotely operated patrolling asset for an off-shore critical infrastructure protection. The scenario is set in deep water and the entities involved are:

- A Semi-Submersible platform
- Piping Infrastructures
- Small-Medium Size Boats
- Rotary Wing UAV (Umanned Autonomous Vehicle) and its Sensors
- Autonomous Underwater Vehicles

In facts the use of AUV in this testing is limited, but in other cases this allowed to cover also submerged threats and it is maintained; the simulation adopts High Level Architecture to support interoperability and could be connected with other simulators.

The simulator reproduces the physics of the entities and their control and actions. Sophisticated Intelligent Agents developed by Simulation Team are devoted to drive the entities and to reproduce behavioural model of small-medium size boats controlling their routing and speed (Bruzzone et al. 2011b).

The models of the sensors embedded in the Drone are devoted to perform crew face recognition and overall boat identification and classification in order to finalize the threat assessment based on these aspects and the boat behaviour analysis.

During the Simulation it is possible to present an augment reality where the sensors range and boat approach profile are proposed by a 3D visible volume, displayed around the fore part of the boats to help the UAV operator (Figure 2). Furthermore the simulator gives the user the possibility to visualize, at run-time, the percentage of completion of the sensors acquiring process computed as in Eq. 1

$$Completion\ \% = \frac{Time\ inside\ Working\ Range}{Nominal\ Working\ Time} \cdot 100$$

The Acquisition Process is cancelled in case the pilot exits the sensor range or adopt improper flight profiles before acquisition completion and restarts when entering the range again; the computation is referred to the single specific boat in the vicinity of the drone. Once face recognition is completed the Simulator provide a report about the time spent in performing the activity and an overall evaluation. In general the test iis considered failed when the drone impact the water or is damaged due to a crash.

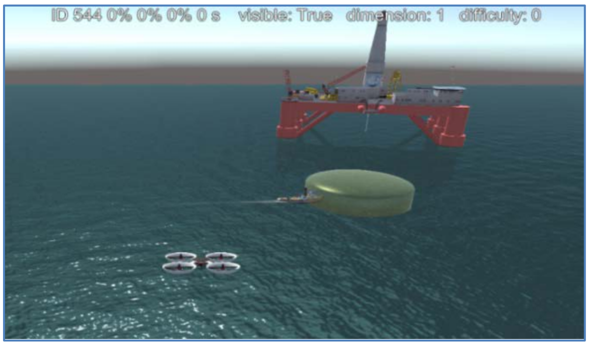

Figure 2 Simulation settings on screen top

Through the User Interface it is possible to act on the following settings:

- Augmented Reality for Sensor Range and Profile:
  - Non-Visible
  - Visible Range
- Dimension of the Sensor Range:
  - Small Range
  - Medium Range
- Difficulty Level:
  - Boats keep almost constant heading and adopt cooperative behaviour
  - Boats manoeuvre to evade the drone and adopt not cooperative behaviour

5. EXPERIMENTAL CAMPAIGN

The experimental campaign has been performed on a test population of 12 operators. The operator used were unskilled people and students, with limited or no experience in operating UAV; this approach was devoted to investigate the possibility to quickly train this kind of user to operate such procedures; it is evident that the sampling is very reduced and the results are limited and specific of the proposed case, so no general considerations could be finalized, therefore the study provide an overview about interesting consideration that actually the authors are using to conduct further development and testing. In the experimentation the operators performed 6 attempts each with constant difficulty and Sensor Range. The experimental campaign is designed to evaluate the influence of two target functions: Number of Successful Recognitions and Time to Accomplish Recognition respect the following independent variable:

- Sensor Range
- Augmented Evidence of Sensor Range
- Difficulty level

In the following each target function is analysed.

Number of Successful Recognition

From the analysis of experimental simulation data it is interesting to notice a higher number of successful recognitions for smaller Sensor Ranges. The reason behind this trend is the increased operator accuracy during the experimental tests.

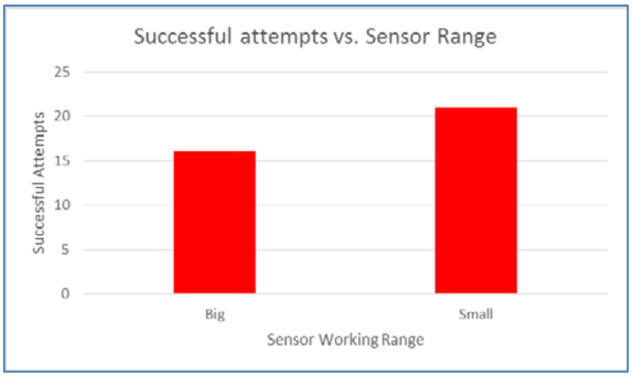

Figure 3 Successful Attempts vs. Sensor Range

Figure 4 Successful Attempts vs. Difficulty Level

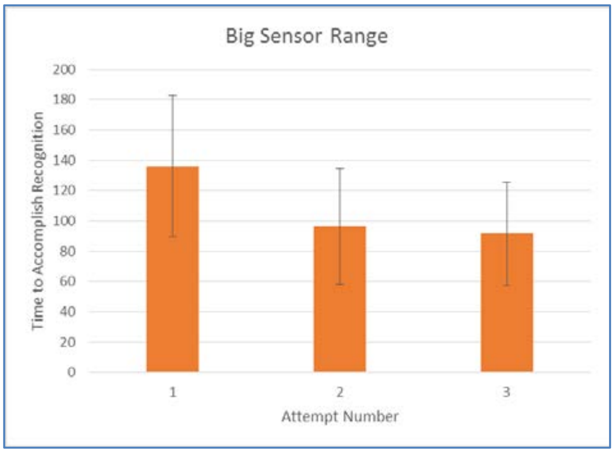

Figure 5 Time to Accomplish Recognition vs. Attempts

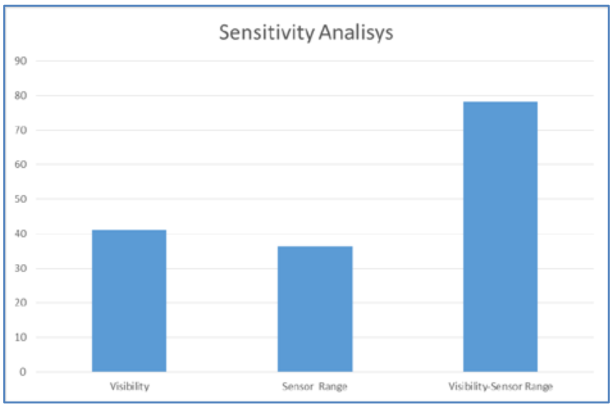

Figure 6 Influence of Visibility and Sensor Range dimension on Time to accomplish the mission

The Difficulty Level is another important aspect; in deed as expected, by increasing the not cooperative attitude of the boat to evade drone controls, the success rate of the UAV operator decreases.

Average Time to Accomplish Recognition

UAV operator performance has been evaluated in terms of time required to accomplish the first successful recognition in the scenario. The analysis of the experimental simulation data shows a positive reduction of the average time required to recognize the target over the different attempts. This result is significant even though the relative confidence band is pretty wide; the reason behind the amplitude of the confidence band is to be found in the heterogeneous nature of the UAV operator population involved in the testing campaign, indeed some of them were more keen on using serious games and were better experienced with the HMI (Human Machine Interface) than others.

The Sensitivity analysis on Time to Accomplish Recognitions, shown in the figure 6, highlights the positive influence of the Augmented Evidence of Sensor Range; indeed the average time required to perform recognitions improves when the Evidence of the Sensor Range is visible to the UAV operator through an augmented representation while flying.

The same considerations apply to Sensor Range size, in other words the higher the sensor range, the lower the average time to accomplish recognition. From the same figure it is possible to notice the influence of the combination of the two parameters, so to say, users provided with visible sensor range, needs less time to complete the mission if drone sensor range is high.

The experimental campaign has been performed using SPIDER (Simulation Practical Immersive Dynamic Environment for Reengineering) Interactive CAVE (Cave Automatic Virtual Environment) developed by Simulation Team. The SPIDER intended use is to support Live Virtual Constructive Simulations and even Augmented and Virtual Reality for single users or for multiple users for immersive and collaborative use of simulators (Figure 7).

6. CONCLUSIONS

The experimental campaign obtained on the test population shows the effectiveness of simulation both for training drones operators in using such unconventional asset to perform strategic tasks such as critical infrastructure patrolling and to evaluate the impact of additional information provided to operators during flights.

It is worth to notice, from experimental data, how the size of the sensor range have a negative impact on the number of success while it has a positive impact on the time to accomplish recognition; the operator of the drone with smaller sensor range configuration results often more careful, paying more attention to accomplish recognition, successfully completing more missions, but spending quite some time; on the other hand, the operator flying with large range configuration is often more proactive, failing more attempts, but resulting faster (in average) when succeeding.

The positives results obtained during the testing campaign show the potential use of this simulation as training tool as well as means of evaluating the effectiveness of employing an autonomous system in such a complex scenario.

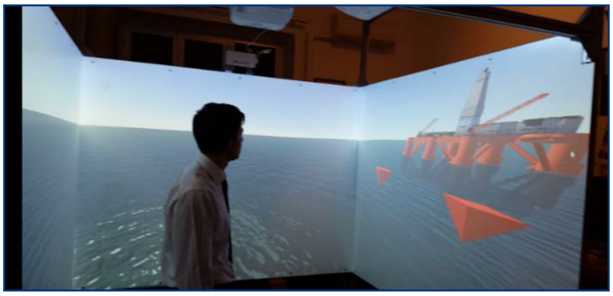

Figure 7 Testing facility, the SPIDER

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MODELING, INTEROPERABLE SIMULATION AND SERIOUS GAMES AS AN INNOVATIVE APPROACH FOR DISASTER RELIEF

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ABSTRACT

This paper presents the use of Human Behavior Modeling for Disaster Relief and Emergency Management. The authors propose an innovative MS2G (Modeling, Interoperable Simulation and Serious Game) using Intelligent Agents to reproduce a complex scenario used for Verification, Validation and Accreditation of the approach. The case study is inspired to South Sudan situation and to the necessity to provide accommodations, food, health care services, security and administrative support to a large number of IDPs (Internally Displaced Persons) over a wide area. The simulator includes camp preparation and installation, air drops, logistics network creation while the model includes populations, entities and units as well as different equipment (e.g. cargo planes, helicopters, ground units, etc.).

Keywords: Disaster Relief, Emergency Management, Human Behavior Modeling, Interoperable Simulation, Serious Games, Training

1. INTRODUCTION

Nowadays the geopolitical and economic situation is leading to a large number of critical events where a huge number of people is forced to move and needs to be supported. These conditions are generating large amount of refugees and IDPs with huge humanitarian emergencies and even critical logistic situation. Indeed the term IDP (Internally Displaced Person) is introduced in reference to someone forced to abandon his home without leaving his own country; these people are often referred as refugees even if they are not corresponding legally to this current definition (Weiss 1955). In facts a refugee is a person forced to leave his own nation and unable to return home safely (Bouchet-Saulnier et al. 2002). Obviously there are legal definitions for the terms that have been approved by United Nations along the years. Therefore the current number of refugees is estimated around 15 million while IDPs overpass 37 millions worldwide; this corresponds to a total of over 50 million people that need support on global scale (UNHCR 2015a). In table I it is proposed a synthesis of the situation as summarized in recent years and, even if the quantities are just estimations and often controversial, it is evident the complexity to address these issues (Wiki 2016).

Table 1: Overview of Global IDPs

Country	*Cause*	*IDPs*
Azerbaijan	Nagorno-Karabakh War	600,000
Afghanistan	NATO vs. Talibans Fighting	166,000
Myanmar	Internal Conflicts and Natural Disasters (Cyclones)	503,000
CAR	Civil War	197,000
Chad	Proximity to Darfur and Civil War	178,000
Colombia	War among Government, FARC, AUC & other Groups	4,000,000
DR Congo	Second Congo War	1,500,000
Cote d'Ivoire	Civil War,	709,000
Cyprus	Cyprus and Turkey Tensions	208,000
Ethiopia	Natural Disasters, Ethiopian-Eritrean War, Ogaden Conflict	200,000
Georgia	Displacement of Ethnic Georgian Population from Abkhazia and South Ossetia	260,000
Haiti	Haiti Earthquake and the resulting 575 camps for IDPs	390,000
Iraq	Wars since Saddam's Regime Fall including ISIS fighting	4,000,000
India	Kashmiri Pandits from Jammu and Kashmir fighting with Separatist Movement and Fighting between the Naxals and the Indian State	150,000
Indonesia	Fighting Government vs. Secessionist Rebels	275,000
Israel	Bedouins	10,000
Kenya	Riots and Violence after the Elections (2007)	325,000
Kosovo	Effects during Kosovo War.	590,000
Kurdistan	Kurdish-Turkish Conflict	3,500,000
Mexico	War on Drugs	925,000
Palestinian Territories	Internally Displaced Palestinians	320,000
Pakistan	Conflicts in different Regions (e.g. KP province)	400,000
The Philippines	Fighting between the Government and Communist and Islamic Rebels.	300,000
Serbia	Results of Kosovo War	220,000
Somalia	Civil War	260,000
Sudan	Civil War (South) and Darfur Conflict (West)	5,500,000
Syria	Syrian Civil War	7,600,000
Uganda	insurgency of the Lord's Resistance Army	869,000
Ukraine	War in Donbass	1,300,000
Zimbabwe	Political Violence, Major Land Reforms and the Economic Collapse	760,000

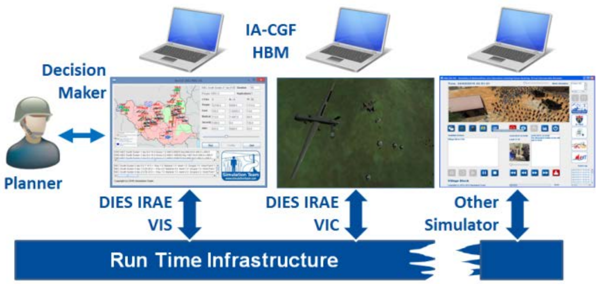

Figure 1: DIES IRAE Architecture

It is evident that these situations includes also natural disasters that have a huge impact such as Haiti Earthquake (January 2010) resulting in over 1.5 million IDPs (Billiam 2010) during the event and over 300'000 people that are still homeless after 6 years. These phenomena affect also developed countries as confirmed from recent disasters in Italy that generated, respectively, over 50'000 (April 2009) and 4'500 (August 2016) homeless in central part of the Nation (Povoledo & Mele 2016).

2. MODELING DISASTER RELIEF

In disaster relief is crucial to develop methodologies and techniques to support planning of operations and to evaluate impact of decisions even considering the case of emerging situations that may bring to particular behaviors of the entities involved (Oren and Longo, 2008).. The areas to be addressed, in most of the cases, in the above mentioned examples are related to several aspects including among others:

- Logistics
- Health Care
- Food Distribution
- Engineering
- Services Activation
- Infrastructure & Equipment Deployment
- Security & Defense

Therefore in these contexts the situation is usually very complex due to infrastructure collapse (e.g. economic, transportations, food chains, etc) and to the presence of multiple actors (e.g. refugees/IDPs, local population, conflict actors, supporting coalitions, NGO). Often these actors have conflicting interests, sometime they are even fighting at level of organizations (e.g. war or civil war) or socially (e.g. ethnic tensions, social tensions). It is evident that due to these reasons the scenarios are very complex and require the use of simulation to be properly studied and to support the decision making process (Anderson et al. 2007; Werker 2007; Bruzzone & Sokolowski 2012; Latek 2013).

The complexity of these scenarios is further reinforced by the heavy impact of human factors affecting social, ethnics, tribal, religious and political issues. These elements are often the main factors to be considered such as in recent conflicts ongoing in Africa and Asia (Johnson & Mason 2008, Bellamy et al. 2011; Dewachi et al. 2014). In facts the HBMs (Human Behavior Modifiers) include psychological factors (e.g. fear, stress, aggressiveness, etc.) as well as primary needs (e.g. food, security, health care) based on the local hierarchical priorities (Maslow 1943; Møller & Schlemmer 1983; Saati et al. 2011).

In general it emerged that the use of Human Behavior Models could be pretty effective to reproduce the people reactions and to measure the effectiveness of the disaster relief actions (Uno & Kashiyama 2008; Bruzzone et al 2014a). These elements strongly affect the behavior of conflict actors, humanitarian supports and population as well as local and domestic public opinion (Gartner & Segura 2008; Kreps 2010). The authors acquired good expertise in modelling critical situations such as country reconstructions, disasters and emergencies (Bruzzone &Massei 2010). Several experimental cases have been conducted by Simulation Team in this sector including Haiti Simulation based on use of interoperable IA-CGF (Intelligent Agents Computer Generated Forces) and CAPRICORN Project (CIMIC And Planning Research In Complex Operational Realistic Network) on CIMIC (Civil Military Cooperation) carried out in Afghanistan. These are a valuable base to further develop innovative models (Bruzzone 2013).

In the current paper, it is proposed the use of IA-CGF NCF (Non Conventional Framework) simulator named *DIES IRAE* (Disasters, Incidents and Emergencies Simulation Interoperable Relief Advanced Evaluator) composed by two simulators. The general architecture is similar to SIMCJOH structure (Simulation of Multi Coalition Joint Operations Involving Human Modeling) as presented in Figure I (Bruzzone et al. 2015). Indeed *DIES IRAE* adopts MS2G (Modeling, Interoperable Simulation and Serious Game) Paradigm (Raybourn 2012; Bruzzone et al.2014b) and it is composed by two main simulators federated by using HLA (High Level Architecture):

- **DIES IRAE VIS** (Virtual Interoperable Simulator): is a stochastic discrete event agent driven simulation using the IA-CGF for reproducing HBM; it simulates the actions of components, equipment, units and population. This module supports operation planning, commander training, policy analysis and review of procedures and processes.
- **DIES IRAE VIC** (Virtual Interoperable Commander) is a Virtual Simulator using Serious Game approach that provide the Synthetic Environment to reproduce the events and takes care of the detailed dynamics (e.g. air drops, landing, etc) such module allows to provide support for tactical training and education.

Indeed the solution guarantees maximal flexibility by adopting interoperable HLA: in this way it becomes possible to combine the proposed simulators also with other models. This approach enables the stand-alone use of *DIES IRAE VIS* without Virtual representation or to combine it with *DIES IRAE VIC* and other models addressing specific aspects (e.g. economics, war gaming, CIMIC, etc.) in a distributed simulation. In addition, this simulation might be combined with other ones in order to be active part of a complex CAX (Computer Assisted Exercise).

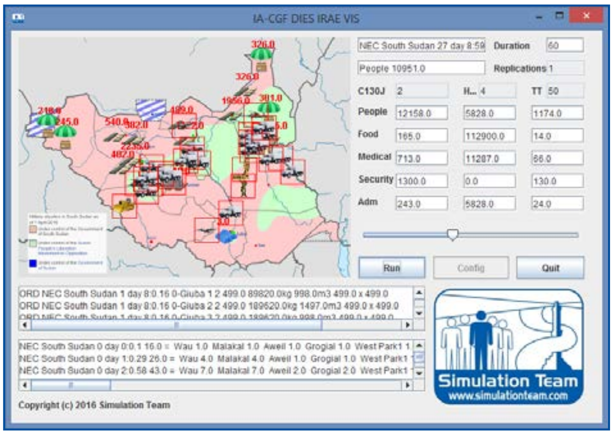

Figure 2: DIES IRAE VIS: The Discrete Event Stochastic Simulator

DIES IRAE VIS (see fig. 2) allows to simulate the operations and phenomena evolution in order to evaluate efficiency and effectiveness of the disaster relief plan. In facts, the Discrete Event Stochastic Simulator provides estimation of times, costs and availability of resources respect the demand. The model reproduce the flow of IDPs and refugees and their needs in terms of:

- Accommodation
- Food & Water
- Health Care
- Security
- Administrative Procedures

Each of these issues requires, potentially, to establish infrastructures to be deployed on site (e.g. camps, airstrips), consumables to support the operation (e.g. food packages) and resources (e.g. soldiers and medical doctors). The simulator reproduces the logistics of the operations from major hubs, to local Hub and HQs establishment, force deployment, transportations and material handling. The simulator considers to use both naval cargos, aerial solutions including helicopters and planes as well as ground vehicles (Bruzzone et al. 2002). The delivery and deployment could be carried out by conventional deliveries and/or air drops. Entities simulated include military unitis, NGO, paramilitary, civilians, IDPs, Refugees, Local Authorities, etc.
The Intelligent Agents drive the entities and the people on the scenario based on their perception and considering human factors (e.g. stress, fatigue, fear, hunger, etc)
In *DIES IRAE VIC* the IA are in charge of applying the disaster relief plan based on logic sequence, available resources and dynamic evolution of the boundary conditions (e.g. security, weather, availability of resources). The population model consider the *Interest Groups* and *People Objects* (Bruzzone 2013). Indeed the *Interest Groups* represent the different entities on the area and are interconnected by relationships identifying the intensity and type of their mutual attitude through multiple parameters.

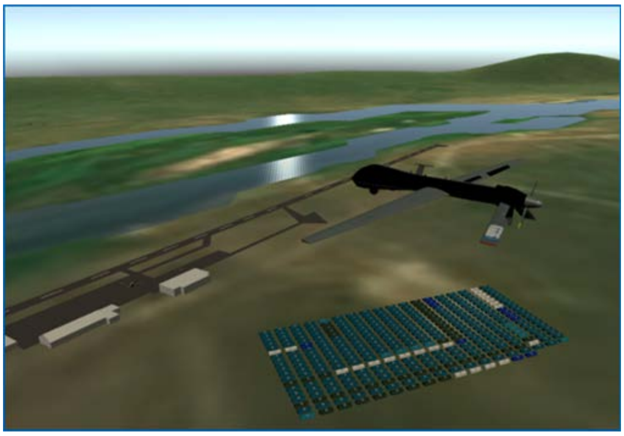

Figure 3: DIES IRAE VIC: Synthetic Environment and Virtual Simulation

Vice versa, each *People Object* reproduces a small group and its basic characterization including, among others:

- Gender
- Age
- Health Status
- Education
- Social Status
- Religion
- Ethnics
- Tribe
- Political Orientation
- Stress
- Fear
- Fatigue
- Aggressiveness
- Resilience
- Trustiness

The *People Objects* are interconnected by their social network through compatibility algorithms and are connected with the *Interest Groups* as well. They are also associated with the terrain, if appropriate, respecting geosocial characteristics of the area.
The *DIES IRAE VIS* allows to virtually reproduce these operations both in terms of observation of scenario evolution within the virtual simulator or interactive control of specific equipment as a Serious Game (e.g. conducting an Air Drop, Delivery on an Air Strip, Reorganizing a Camp). An example of the interface is proposed in figure 3.

3. SCENARIO: SOUTH SUDAN

In order to evaluate the capabilities of DIES IRAE Simulation the authors decided to identify a scenario that could be used for the VV&A (Verification, Validation and Accreditation),
Based on a preliminary analysis of the existing situation, it resulted that the current South Sudan situation could be an inspiring scenario. Indeed this reality represent a good example of modern crisis of the African continent after colonialism (Chatterjee 1993).

Figure 4: South Sudan Localization

3.1. The Context and the Scenario

All African countries became independent in the second half of the 20th century. Although some countries became independent in the 1950s, most of Africa was decolonized during the 1960s.

However, after independence, some of these states found themselves powerless against armed conflicts requiring trained, combat seasoned forces and quality equipment (Ciekawy 1998).

Some turned to UN requesting intervention to support local forces in internal or inter-state conflicts to ensure regional stability. In this context, International Coalitions started to conduct overseas operations (Murphy 1996).

During the 2000s, the European Union became a full-scale actor for peace and security in Africa, developing the African component of the European security and defense policy from 2005 (Smith 2015).

Humanitarian assistance provided in recent years by non-governmental organizations (NGOs) in Africa has saved hundreds thousands of lives; moreover, NGOs now collaborate with military forces in the delivery of humanitarian supplies.

3.2. Disaster Relief Planning in Humanitarian Operations and Commanding Officers

The above mentioned elements raise questions about the diverse range of operations and their capacity to address various needs (Pettit et al 2005).

Indeed the use of military forces to support humanitarian operations has grown along last decades to be almost commonplace in today's world.

A key objective must be to define workable doctrines for this involvement and to make commanding officers aware of the social, political and economic impact they may have with different modalities of commitment (Caunhye et al.2012).

Some of the questions to be addressed are proposed hereafter:

- How are military forces and their assets deployed in humanitarian operations?
- Which deployment models are commonly used and which doctrines need to be developed for each?
- Are the current roles effective and, if not, which roles are effective?
- How can military units be committed to peacekeeping or humanitarian operations without violating their neutrality?
- How can foreign military commanders best coordinate with civil relief authorities?

3.3. Scenario Definition

Based on the previous consideration, the proposed scenario proposed is South Sudan and its currently acute humanitarian crisis. In this country, emergency level of food insecurity is evident due to the on-going conflict (Pantuliano et al. 2008; Rai et al. 2012; Johnson 2014; UNHR 2015b; Kegley et al. 2015; Zambakari 2015).

Despite progress in the political situation following the formation of the Transitional Government of National Unity, the economic decline, depreciation of the South Sudanese pound and the sporadic violence continue to have a significant impact on the humanitarian needs within the country.

Clashes between government forces and an armed group are reported all around the country. The rapid decline in the food security situation and distribution raises fears an escalation of the crisis.

In this chaotic situation United Nations Security Council is:

1. Expressing its deep concern about the ongoing escalation of insecurity and the continued rise in violence in South Sudan as well as the persisting political impasse in the country,
2. Condemning strongly the increased cases of human rights violations and abuses and underscoring its deep concerns on further decline in the food security and nutritional status of the population,
3. Welcoming the decision of the Secretary-General to deploy a military contingent in Western Bahr el Ghazal (WBeG) region to support population and NGOs in the area.

3.4. Area Overview

Whit a surface area of 93,900 square km is one of the largest among the other South Sudan regions; according to the last population census has an estimated 333,431 inhabitants, with Christians and Muslims being the largest groups.

The source of livelihood for its inhabitants was subsistence farming, supplemented by small-scale cattle rearing and petty trading.

There was tensions triggered by boundary disputes now escalated into conflict due to rivalries over grazing land and ethnic/religious reasons. The situation is presently evolved in a humanitarian crisis, in particularly in Wau and Jur River counties refugees continue to arrive spontaneously.

3.5. Contingent Integrated Structure

The Contingent planned for testing the simulator is based on the organization proposed in figure 5 and requires the deployment of 1,450 people.

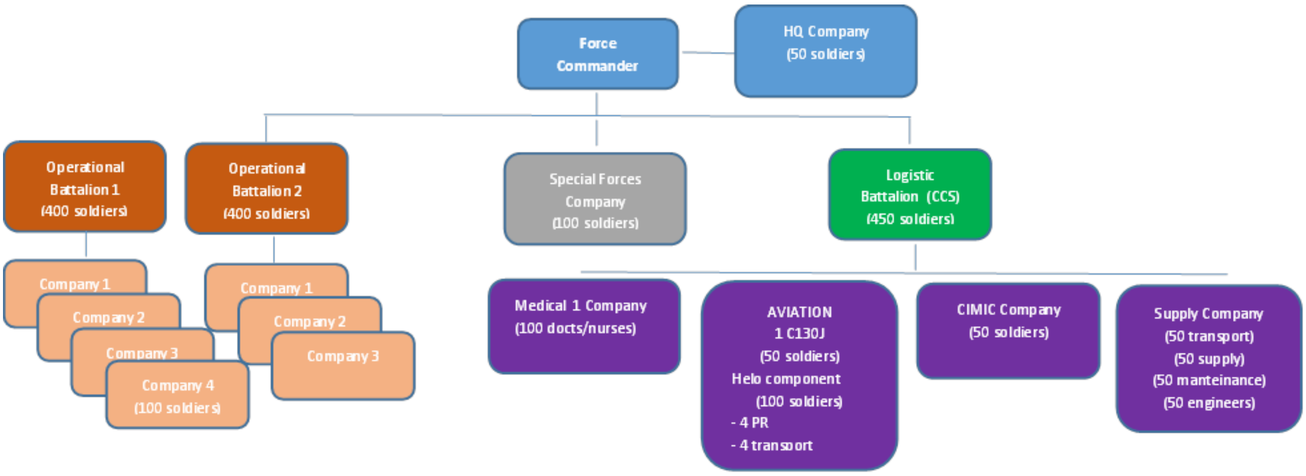

Figure 5: Contingency Structure

The organization includes C130J Planes and UH-60 Helicopters as well as UAV (Unmanned Aerial Vehicle) and ground vehicles.

3.6. Mission Mandate

With the population suffering from a humanitarian crisis that caused several thousand and to support the U.N.'s Food and Agriculture Organization (FAO), a multinational military contingent is planned to be deployed under UN mandate aims in a humanitarian operation to establish protected zones in south Sudan. The aim is also to interpose between two warring parties and to control areas.

The mission core: stability operation to restore a peaceful situation in order to supply, maintenance operations, deployment and distribution, health service support (HSS), engineering and logistic services.

3.7. Simulated Phases

The following phases have been planned

1. **Deployment**: Port Operations is Djibouti, Airport of operation is Djibouti. Port and airport capacity determines the flow of materiel into area of operations.
2. **Transports**: Air transport permits the rapid deployment and movement of personnel and cargo to, from and within area of operations and provides tactical mobility for all mission elements.
3. **Mission**: support to enable access for humanitarian personnel and relief goods, followed by medical operations and the provision of material relief goods (such as tents, clean water and food supplies.

3.8. Multinational Logistic Planning & Timelines

The Multinational Logistic Planning is expected to follow the following schedule, the simulator will check the feasibility to respect the timelines.

Day X	contingent arrive in Djibouti
X+1	SF, 1 and 2 Company (1 BTG) and Engineers Company in OA (operation area): secure area and prepare logistic (1 flight C1230J – 1 flight transport Helo);
X+2	3 and 4 Company (1 BTG) and HQ troops in OA: complete secure area and establish C2 capability (1 flight C1230J – 1 flight transport Helo);
X+3	CIMIC Company
X+5	Medical Company
X+7	FOC (full operational capability)
X+30	Sustainability

3.9. MEL/MIL & Simulation

In this context, the following MEL/MIL (Main Event List / Main Incidents List) are proposed to be considered and evaluated by using simulation:

3.9.1. MEL/MIL 1: Transport

In a deteriorated road network, military supply (Class I subsistence/food) convoys, the greatest logistics challenge depend on the number of transportation nodes and conveyance modes involved:

- Scarcity of vehicles (especially those capable of carrying refrigerated cargo)
- Limited space container area

Increase in fuel consumption (Class III petroleum, oils, and lubricants):

- Difficulties to maintain scheduled transport
- Self-sustainment just vouched for a reduced time

3.9.2. MEL/MIL 2: Hospital

Theater Hospitalization Capability delivers health support required to medically sustain forces in the JOA. Hospitalization capabilities in the JOA deploy as modules:

- Lack of full modules capabilities reduce role 2 availability and operational readiness of critical equipment (Class VIII major end item)
- According to medical plan, three technicians and one laboratory assistant must perform mass inoculation and provide logistical support for the local authorities

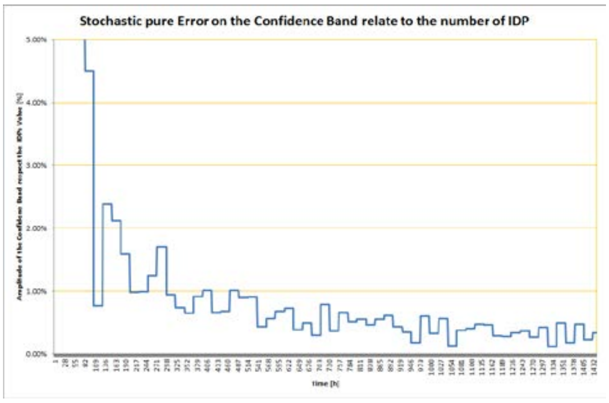

Figure 6: Experimental Error

3.9.3. MEL/MIL 3: Helo

The theatre logistic picture suffered lack of critical information about the logistic situation, sustainability and availability of key equipment:

- Joint Force Logistic Component Headquarters must coordinate a range of logistic support activities to support helo component (UH60 Helicopters)
- Lack of sustainability and availability of key equipment impact scheduled mission

3.9.4. MEL/MIL 3: Evacuation

Local situation is volatile, unstable and likely to deteriorate rapidly:

- Must be able to achieve crowd control without jeopardizing the logistic support and make it easier to carry out the operation,
- A back-and-forth organization reducing the operation's logistical constraints is necessary to plan helicopter rotations in the space of 1 day.

4. SIMULATION AND VV&A

This paper introduces a simulation solution and related scenario. In facts, the formal and static Verification and Validation of the Models has been conducted with Subject Matter Experts (SME) applying different techniques (e.g. face validation, flow charts). The use of DIES IRAE Simulation allowed to present dynamic results and graphics to the SME to proceed in the validation of the conceptual models and experimental results. The authors are currently implementing the MEL/MIL and preliminary experimental results have been carried out in order to support the VV&A based on Design of Experiments (Montgomery 2008). In figure 6 it is proposed the analysis of the experimental error due to the pure influence of stochastic component. The graph proposes the amplitude of the confidence band respect the number of the IDPs.

CONCLUSIONS

The paper proposes architecture and approach for modeling disaster relief and humanitarian missions in complex environments. The MS2G-based approach has been demonstrated and validated with SME.

The HLA architecture guarantees maximum potential in terms of interoperability with other simulation models. Currently a specific Scenario, addressing South Sudan crisis, is under experimentation. The use of IA-CGF ensures a valid representation of the population behavior and human factors as well as to automate the mission, accordingly to the plan. The stochastic simulation performs risk analysis and evaluation of alternative Courses of Actions (COA). The preliminary experimental results confirm the potential of this approach to support planners and decision makers. The author are working on extending the DIES IRAE Simulation to be effectively applied to emerging crisis situations.

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