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POLY-FUNCTIONAL INTELLIGENT AGENTS FOR COMPUTER GENERATED FORCES

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ABSTRACT

The authors present the requirement definition and methodological approach for developing a new generation of Computer Generated Forces (CGF) based on Intelligent Agents. The analysis is based on the author initiative (PIOVRA) devoted to the development of High Level Architecture (HLA) components to be integrated for training, planning and operative support. These agents require to act as smart entities in the scenarios reproducing both enemies and/or civil units; their model includes characteristics that are typical of the psychological aspects affecting troops and soldiers on the battlefields as well as operative basic tactics. The authors avoid to create intelligent units in a wide sense due to the fact that Artificial Intelligence (AI) technology is quite far to the creation of an "intelligent virtual strategists or commander"; however their entities are expected to face set of complex situations with realistic cooperative and competitive understanding and reproducing real reactions to the boundary conditions.

1 INTRODUCTION

The authors are currently developing a new project, named PIOVRA (Poly-functional Intelligent Operational Virtual Reality Agents); this project aims to develop a new generation of CGF to be used both for exercise scope, both for defense planning and support operations in an HLA Federation (Bruzzone and Mosca 2002).

HLA is a simulation interoperability standard to make different simulators cooperate simultaneously, developed by the DMSO (Bruzzone and Kerckhoffs 1996; Kuhl et al. 1999). HLA is defined by Rules governing the behavior of the overall distributed simulation and their members. The importance of using HLA Technique in the PIOVRA initiative is relevant: this could allow to create more challenging and complex scenarios for training, where different users can cooperate in the same environment (Bruzzone et al. 1998). Moreover, these CGF should be in some extent *Intelligent*, meaning that they should demonstrate cooperative and competitive behavior (coordinating units both during operative actions and situation evaluation) based on the current boundary conditions and situation (Hamilton et al. 1996). Such challenging task will be obtained by defining the most common scenarios situation outlined by military relevance analysis in order to have reference applications. The smart behavior of PIOVRA entities is devoted to support decision makers as well as trainers in creating realist simulated scenarios.

Figure 1: PIOVRA Virtual Fighter

In particular, the use of such entities generates great benefits both for the reduction of human personnel operating directly the simulation system or influencing indirectly the Virtual Battlefield through the SAF (Semi-automated forces), and for the increase of objectivity degree in the actions and the reactions of any of the simulated entities present in the battlefield, i.e., friend, foe or neutral. Finally, we should not underestimate the possibility to obtain CGF particularly "intelligent", that is, able to describe the reasons behind a particular operational behavior, thus allowing to verify not only the implemented algorithms applicability but also, in an indirect manner, the doctrine, tactics and ROE (Rules of Engagement). The evolution of simulation technology used in this initiative requires to support PIOVRA with an effective Verification, Validation and Accreditation (VV&A), customized on its specific needs, while development approach will be referring to FEDEP and HLA integration infrastructure (Bruzzone, Mosca, and Revetria 2002). Obviously the significance of PIOVRA objects is strictly related to their capability to interact in scenarios, for such reasons it will be critical to properly design the HLA federates in order to interact in simulation federations (Lorenz 1993). PIOVRA is expected to develop HLA models of three different entities to be simulated: friend, foe (including terrorists) and neutral; in particular PIOVRA research pays great attention to modeling neutral units representing civilians and their specific behaviors and logic. The PIOVRA CGF are designed for incorporating an hierarchical structure in order to be able to reach high level of details (i.e. Single persons) without loosing the possibility to model large entities and with autonomous reporting capabilities for justifying choices to external user. PIOVRA focuses on definition of conceptual models able to simulate a co-operative behavior of its CGF allowing their aggregation or separation depending on the situation, clearly keeping in mind the command hierarchies for military units and managing their dynamic evolution during actions (Fishwick 1995; Watts 1999).

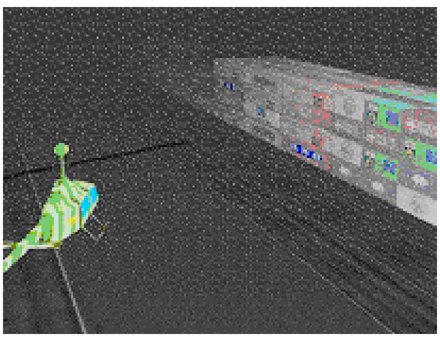

Figure 2: PIOVRA Virtual Helicopter

PIOVRA project focuses on modeling of special units such civilians or terrorist; so a significant part of the project is devoted to create models for reproducing dynamically the human behavior during the simulation of complex scenario (Bruzzone 1996). The initial part of this research is devoted to model all the aspects and parameters for properly defining the different units both in terms of ROE, "intelligent" behavior (co-operative/competitive) based on the on-going scenario evolution and unit characteristics (Nash et al. 2001); Feed backs and report shall give the user the possibility to change ROE of the relative CGF. The PIOVRA entities include psychological parameters and models (i.e. "stress level" as aggregation level and of external situation function). Modeling complex human behavior and simulating intelligent reaction capabilities requires to define in detail the scenario and action range to be reproduced in order to be able to reach successful results with current technologies (Mosca et al. 1995); so PIOVRA includes a detailed scenario definition to be used for metrics and performance evaluation of the models developed and their fidelity and effectiveness. The authors are currently involved in designing a demonstration phase on a predefined scenario to be used as framework for experimenting and analyzing the PIOVRA federation; this scenario is expected to be integrated with war gaming systems (i.e. JTLS) in order to simulate/study specific situations. Therefore, based on author experience, the use of Artificial Intelligence in hybrid hierarchical models request to combine different techniques; the PIOVRA project expect to experiment different integration architecture combining Fuzzy Logic, Artificial Neural Networks, KBS, Data Fusion and Swarm Intelligence (Padgett and Roppel 1992). The design and development of PIOVRA Models is expected to be realized introducing G-DEVS/HLA framework, tailored for this initiative, able to consider both the continuous components (i.e. Movement) and discrete (i.e. Events and actions) integrate in High Level Architecture (Ziegler et al. 1999). The interoperability of the PIOVRA components is strictly based on HLA in order to maximize their integration capabilities and improve the efficiency of their hierarchical structure (Bruzzone et al. 1997; Paterson et al. 1997). Obviously for this research VV&A represent a very important and significant task in order to guarantee the success of the initiative.

2 CGF CRITICAL ISSUES AND GOALS

In military relevant Modeling & Simulation functional areas, namely Exercise, Defense Planning and Support to Operations, the possibility to deploy simulated entities possessing specific and distinct characteristics and behavior whose parameters are user-definable per any single entity, is to be considered of major importance as it contributes in solving some very significant problems inherent to the use of any simulation system (Bruzzone, and Itmi 2003). In particular, the use of such entities generates great benefits both for the reduction of human personnel operating directly the simulation system or influencing indirectly the Virtual Battlefield through the SAF, and for the increase of objectivity degree in the actions and the reactions of any of the simulated entities present in the battlefield, i.e., Friend, foe or neutral. Finally, we should not underestimate the possibility to obtain CGF particularly "intelligent", that is, able to describe the reasons behind a particular operational behavior, thus allowing to verify not only the implemented algorithms applicability but also, in an indirect manner, the doctrine, tactics and ROE. Looking more in detail into the Exercise functional area, it's obvious that the CGF constitute the ideal "sparring partner" due to the constancy of their reactions. The latter allows for their use as Training Audience evaluation parameters, i.e., the positive or negative exercise outcome depends exclusively on the capacity of the Training Audience itself, rather than on the capabilities of human operators or military experts using auxiliary tools, e.g., SAF. As for Defense Planning, the use of CGF implementing some extent of artificial intelligence consents to verify operational plans in less time due to the absence, complete or partial, of human experts employed in the different roles foreseen by the Operational Plan under exam; in this area, as well as in the Exercise one, the objectivity, the reaction constancy, the CGF decision motivation traceability represent significant advantages and allow the user to concentrate on the Operational Plan being examined rather than on detailed handling of the scenario units. As far as Support to Operations area is concerned, the intelligent CGF are an essential element in performing realistic verification and ongoing real tactical situations possible progress evaluation by inserting them in the subject operation's simulation. Thus the two most distinguishing features of Support to Operations, i.e., Elevated degree of realism and extremely rapid simulation feedback to the Theatre Commander and his staff, become feasible only through the use of automated components whose parameters and behavioral firmware have been predetermined very precisely and carefully by expert teams.

2.1 User-Defined Initializing Parameters

The CGF behavioral algorithm structure should contain explicit parameters definable by the user (normally in numeric values) before the CGF itself is deployed in the virtual battlefield. Some examples of such parameters are: position, speed, efficiency, combat systems, sensors, ROE, stress level, Command Chain, logistics needs, logistics capability, etc. It is by assigning the values of these parameters that the user designs the scenario, implements the Operational Plan, identifies the simulation-worth real tactical situation in order to start the simulation and subsequently insert a CGF in a running simulation in the most realistic manner possible.

2.2 Analyze Surrounding Environment and React Respectively Capability

At the time a CGF is deployed, the first action it should perform is to explore the surrounding environment operating its sensors whose use has been appropriately permitted by the active ROE (e.g., A unit could possess a survey radar whose use, either totally or per specific sectors, is not authorized by an active ROE in order to avoid an ESM interception). Such exploration should provide to the CGFs Commander the elements enabling the latter to evaluate the situation and take actions in accordance with the initialization parameters and are guided by the behavioral logic implemented in the algorithm. The above considerations should be applicable also for a CGF constituted by a single element, being the latter "Commander" of itself.

2.3 Cooperative Capacity

The deployment of one or more CGF entities into the scenario and their subsequent actions therein, as described in the precedent point, should not be considered as isolated from earlier virtual battlefield state. This is particularly valid when CGF units should consider the presence of other friendly units whose supporting actions could increase the probability of success. Such cooperative behavior is distinct from Unit Aggregating, as described in the following point, because rather than being a complex unit aggregate, it's a logical and behavioral alliance between distinct CGF units whose objective could be, for example, the execution of a complex task by dividing it in easier subtasks to be performed by any CGF (Mosca, Bruzzone, and Costa 1996). The main difference between these two types of behavior consists in the non-unification of command as each CGF, though cooperating with the other CGF entities, maintains unaltered its proper Commander.

2.4 Force Aggregating/Desegregating Capability and Relevant Military Hierarchy

Whenever the behavior described in the previous point is evaluated insufficient by the highest in rank Commander, there's the need to be implemented a force aggregating or desegregating process. Force Aggregating could be described as forming a new CGF entity from two or more existing CGF units all of whose numeric parameters are redefined by the "Commander" of the new CGF entity. Some of these parameters need to be calculated by the human behavior algorithm, e.g., new morale and new stress level. Likewise, Force Desegregating is described as forming two or more new CGF entities from a single one. The parameters of the new CGF entities should be defined by the old CGF "Commander" before the desegregating takes place. In the case of Force Aggregating, the military hierarchy coherence is assured by comparing the old CGF units "Commanders" level and assigning the command to the highest in rank; in case of desegregating, the old CGF unit "Commander" chooses the new CGF units "Commanders" assigning to each of them a Command position.

2.5 Resultant Aggregation Levels Different from Aggregating/Desegregating Elements Sum/Subtraction

In performing the processes described above, the human behavior implementation algorithms need to consider that the newly formed CGF aggregation level parameters (described, for example, in terms of unit components number, operational quality level, combat systems, etc.). Could not be deduced mathematically by simply summing or subtracting the original CGF entities parameters but need to be implemented through specifically designed functions incorporating group and/or crowd behavior psychology, emulation spirit, etc.

2.6 Limit Proper Autonomy to Achieve Common Objective Capability

The "intelligent" CGF should possess some extend of decision autonomy; preferably they will have the same potential traits as a real life entity. Therefore, the adherence of CGF behavior to real life is improved by enabling the CGF units to limit proper autonomy in order to achieve a common objective. Such a capability should be evaluated through a complex function incorporating typical human factors, e.g., Sacrifice spirit and sense of duty. Particular attention should be made in enabling the user to define in detail all function parameters as to avoid that conducts formally acceptable to the algorithm are completely unrealistic from user's point of view.

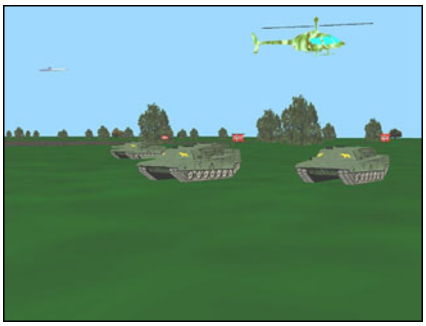

Figure 3: PIOVRA Tanks and Helicopter Operations

2.7 Stress Level Indicator for Behavior Definition

The basic parameter enabling the implementation of human behavior into a CGF entity could be defined as "Stress Level". The Stress Level is expressed in numeric values resulting from a complex function whose variables are part of the CGF itself or belong to the scenario (e.g., Health status, adjacent friend/foe unit number, number of combat systems, ROE, experience, as well as general progress of the operations, public opinion, scenario's geographic characteristics, etc.). The Stress level indicator will be applied in defining entities behavior by establishing value thresholds that would trigger the passage from a generally rationale behavioral scheme (guided by orders for military units or by legal, moral and social conventions for civil ones) to increasingly irrational and basic ones (e.g. Survival instinct, elementary needs).

2.8 Implementation of Typical Human Behavior (Survival Instinct and Moral/Ethical Motivations)

As previously pointed out, instinctive and learned human behavior should be implemented in the CGF in order to render simulated entities as closest as possible to real life ones. In particular, the user should be able to adjust the function parameters of the above-mentioned types of behavior so that more or less "civilized" CGF units are obtained.

2.9 Distinct Friend, Foe and Neutral Units

The CGF entities as described above (i.e. Autonomous simulated entities featuring specific characteristics) should be provided for all the factions present in a certain scenario. At least three types would be present any case and identified by their respective perception of each other as friend, foe and neutral. This division should be maintained by all functions involving perception and subsequent evaluation of a situation. In particular, the ROE should consider the presence of these different types of entities. In an operational scenario no ambiguity is allowed with respect to whom a unit belongs to. For example, all unarmed civilians would be classified as neutral, armed civilians (e.g. Terrorists) as foe, etc.

2.10 Explicit ROE Justifying Proper Behavior

The ROE (Rules of Engagement) are typical military concept and constitute the Behavioral Guide directing a friendly CGF's "Commander" actions. Extending this concept to foe and neutral CGF entities we'll get generic "ROE" comprising both military and extra-military behavioral guide (e.g., Social and/or religious conventions could be interpreted as "ROE" pertaining to a group). Therefore, each CGF needs a series of explicit ROE allowing it to justify the actions undertaken. It's crucial to have an unambiguous correspondence between a ROE and an action.

2.11 Military Reports to Higher Commanders Capability

The Command and Control military function could be exercised only over units whose Commander is able to issue orders and control their execution. One of the primary means for controlling how an order is executed is to request a report from proper subordinates wherein a formal description of how the order received has been executed is provided. The reports could be generated either by a Commander's request or further to an occurrence of a significant-to-the-executing-unit event. Both types of report need to be implemented in friendly CGF units behavior.

2.12 Decision Process Traceability

Further to its deployment a CGF would evaluate a situation and consequently make an operational decision (which could be also not to take action). The simulation user needs to have access to the chain of considerations that have induced a CGF to make a specific decision. Such a capability should be implemented into all CGF types, i.e., Friend, foe and neutral. The traceability facilitates a more detailed analysis and allows the user to verify and modify a CGF's behavior by modifying its parameters thus increasing simulation flexibility and power/authority.

2.13 Feedback Capability

CGF entities, like all units present in the scenario, interact not only with the other entities and units but also with other scenario elements (geographic, man-made, etc.) Or extra-scenario ones (public opinion, international relations, strategic implications, etc.). Thus, actions undertaken by a CGF could determine status alteration not only of units present in the scenario but also of extra-scenario elements and of the scenario itself. Therefore, to account for scenario variables provoked by CGF actions, is introduced a feedback function that would allow the scenario itself to modify some of the CGF entity characteristics. Here again, it's necessary that the user is enabled to regulate (or eliminate, as lowest intensity) the feedback level so that he becomes able to simulate CGF entities more o less "conscious" of their "real world" position.

2.14 CGF Entities Simulating Various Force Levels

The military simulation requirements determine the necessity to have CGF entities for each force level: from a single unit (e.g., A soldier, a ship, etc.) Up to a division level. The influence of behavioral models decreases with the increase of force level. For example, while the initially set single unit stress level (previously defined as a rational vs. Instinctive behavior threshold value) is low, the one of a division type CGF is so high as to render impossible the behavior change process itself. For this particular initiative the authors are developing the first set of the following CGF:

- An entity of a single element: a friend, a foe or a neutral one
- A team: a three elements entity
- A squad: a six elements entity
- A platoon: a 12 elements entity

3 POTENTIAL OF INTELLIGENT CGF

The use of Simulation in Defense sector benefits strongly from the possibility to study complex scenarios; obviously in this sector the intelligent presence of CGF is very critical in order to provide an effective opponent for studying policies, training people and/or evaluating new systems. In the past great efforts was spent for guarantee the high fidelity and the possibility to interconnect different models in

Figure 4: PIOVRA Integrating Federates in Anti Tank Missions

federations in order to reproduce large scenarios, however it is still critical to create "smart opponents" to be integrated with existing federates. In effect the available CGF are still characterized by rigid reactions and very explicit and extensive external command and control support. The use of AI, the branch of computer science concerned with making computers behave like humans, provided critical experiences in such area and examples where the integration of different techniques provided very interesting and quite "robust" results. In effect in this area one of the critical issue is the creation of "robust" systems able to react in smart way to the dynamic evolution of complex scenarios. The integration of different AI approaches fine tuned on the specific application area provide the corner stone in order to face effectively such problem. PIOVRA must be devoted to extend the research in this area integrating different AI approaches in order to guarantee the effective use on the management of cgfs on simulated battlefield; these cgfs will be developed as intelligent PIOVRA agents playing directly as federates in a HLA environment. The first step of this research is the creation of a set of modular parametric scenarios where PIOVRA entities will have to respect predefined behaviors, reach quantitative and qualitative targets. In this phase the definition of the scenario is critical as well as the metrics for quantitative performance measure and the VV&A criteria selection (Amico et al.2000). Due to the advanced nature of this research it will be critical to fix specific boundaries and performance in order to avoid the current limits in AI; in effect this is a research devoted to create smart CGF for reacting in complex, but defined, scenarios. Concurrently a survey check will be performed in order to define a database of features and gaps of current CGF for this application area as well current research initiatives running around the world. This action will guarantee to have a complete overview of the currently available performance in order to support the demonstration scenario creation. The second phase is devoted to explore different integrated modeling methodologies for creating the PIOVRA entities. This experience will focus on the use of data fusion and fuzzy logic as support for extracting knowledge from the environment, while artificial neural networks will be used in order to identify the correlation among different factors (Bruzzone et al. 2001). Fuzzy

Logic is a type of logic that recognizes more than simple true and false values. With fuzzy logic, propositions can be represented with degrees of truthfulness and falsehood. Fuzzy Logic theory since its theorization has proved to be particularly useful in expert system and other artificial intelligence applications (Zadeh et al. 1992). The Authors have experience in the application of fuzzy logic to data fusion, i.e. to that process that allows to combine different signals coming from different sensors in order to improve the capacity of recognizing targets. Some specific applications of Fuzzy Logic to data fusion have been successfully performed by the Authors in the past, for instance for the target tracking of aeronaval platforms in cooperation with Italian Navy, and for the planning optimization in great power plants maintenance. At a conceptual level, intelligent CGF are reactive cognitive agents. A reactive cognitive agent is a reactive knowledge based system that reads the input messages and produces output messages according to a rational behavior. The input messages are coming from the environment and contain the environment evolution information (Garrido de Ceita et al. 2004). The output messages contain the information produced by the agent and are addressed to some entities of the environment. The emission of a message represents the agent's interactions with the environment. The agent decides the action to engage with the aim of reaching its goals. The goal of an agent defines its mission. The knowledge is the media that links the input information, the goal and the actions. The research will be based on previous experiences and will be tested on simplified cases in order to estimate efficiency, precision, generalization capability and robustness. The third phase will work on the development of conceptual models embedding PIOVRA entities in HLA environment in order to interact on simulation scenarios; the requirements will be defined as reaction to the problem solving proposed by the scenarios and the characteristics of developed agents. Verification techniques will be used in order to guarantee an effective and error free process. Considering the requirements for PIOVRA entities it is proposed to use advanced G-DEVS as support for modeling. In fact, one of the advantages of Discrete Event Simulation is efficiency. The simulator is only processing computation at the time boundaries marked by significant events. The disadvantages of DES simulation include the difficulty in identifying and characterizing thresholds for the signal trajectories in order to define significant events. On the contrary, the advantage of time-stepped simulation (continuous simulation) is that it can be adapted very well to continuous processes in which thresholds for defining events lack. Most of CGF systems (i.e. Modsaf, CCTT SAF) have been implemented using a hybrid approach of discrete-event and time-stepped simulation. Underlying physical processes (such as vehicle dynamics) are generally represented by continuous models using a time-stepped simulation, In other processes (such as weapons firing) state changes are done by scheduling events onto a time-ordered event-list. In these hybrid approaches processes that could have been implemented in a DES style are actually implemented in a degenerate time-stepped fashion. In fact, CGF simulations have been biased toward implementing most models using a time-stepped simulation style. The answer proposed in PIOVRA is the G-DEVS approach which can combine the efficiency of discrete event simulation with the accuracy of time-stepped simulation. Given a real system whose output is a dynamic function of time, the traditional discrete event abstraction method (as DEVS) approximates the input, output, and state trajectories through piecewise constant segments. For systems that defy accurate modeling through piecewise constant segments, we have proposed G-DEVS, a Generalized Discrete event Specification, wherein the trajectories are organized through piecewise polynomial segments. G-DEVS promises to permit the development of models of greater accuracy while preserving the computational advantages of discrete event simulation (Banks et al. 1996). PIOVRA propose to develop a G-DEVS/HLA distributed simulation environment, tailored for PIOVRA Federation requirements, combining the G-DEVS modeling paradigm and the approach used in the DEVS/HLA environment as researched by Advance Simulation Technology Thrust (ASTT) DARPA Contract.

The proposed approach offers the following advantages:

- Efficient simulations with a good accuracy - G-DEVS modeling and simulation concepts
- Unique time representation in distributed simulations (only a continuous time representation what simplifies the problem of the time management simulation protocol)
- Modeling concepts based on modularity (from DEVS paradigm)

The G-DEVS/HLA will be an HLA-compliant modeling and simulation environment formed by mapping the G-DEVS-simulator to the C++ version of the DMSO RTI in reference to PIOVRA requirements.

While HLA supports interoperation at the simulation level, G-DEVS/HLA supports modeling level features inherited from DEVS with a well-defined concept of coupling of components, hierarchical, modular construction. Models developed in G-DEVS can be directly simulated in the G-DEVS/HLA environment over any TCP/IP, ATM, or other network of hosts executing an HLA C++ RTI. Based on model-supplied information, G-DEVS/HLA takes care of the declarations and initializations needed to create federations, joining and resigning of federates, communication among federates and time management. This applies, as well to any DEVS-compliant formalism that can be automatically translated into G-DEVS code. The HLA FEDEP fourth phase target will be focusing on developing and implementing the conceptual models; testing and verification will be extensively used during such phase operating with limited simplified federations. The integration phase will be tested in each demonstration scenarios and used for verifying networking efficiency and robustness as well as synchronization problems. Extensive experimental analysis based on DOE (Design of Experiments) will allow to check the metrics versus the reference value expected and to complete an extensive validation of PIOVRA agents in a growing complexity of scenarios (Montgomery 2002).

Figure 5: Main Battle Tanks in PIOVRA Federation

As final results the developed agents will provide an extensive analysis of state of art in intelligent CGF for land battlefield with a synthetic analysis on gaps and future trends; conceptual models of intelligent Agents provided by a co-operative/competitive behavior representing a smart understanding of the situation (Kuhn 1997). The expected results will include requirement report for the implementation of such models in HLA federates as well as a technological demonstrator running on predefined parametric scenarios.

4 KNOW-HOW AND TECHNOLOGICAL ENABLERS

Based on the author experiences it will be necessary to refer to advanced modeling and analysis techniques as well to some technology needs. In terms of knowledge modeling the uncertain nature of data running on a battlefield suggest to extensively check the use of Fuzzy Logic for controlling PIOVRA agents in order to interpret the meaning of quantitative measures and parameters.

The different nature of parameters suggest that a high level Data Fusion will be required for threat analysis as well as scenario understanding; due to the nature of the PIOVRA agents some psychological and tactical operative support will be necessary in order to model such knowledge using Data Fusion methodologies. The complex correlation among the large quantity of variables affecting a scenario understanding suggest the use of models characterized by at least limited self-learning capacity and strong model identification capability; due to these reason the use of artificial neural networks will be requested (Mosca, Giribone, and Bruzzone 1996). The co-operative nature of PIOVRA entities will be based on the application of Swarm Intelligence, the theory arguing that human intelligence derives from the interactions of individuals in a social world (Bonabeau et al. 1999; Kennedy et al. 2001), to guarantee a hierarchical automated control of such forces (Bruzzone, Briano, Simeoni, Brandolini, and Orsoni 2003). The HLA integration will require to use such infrastructure for the networking considering that PIOVRA agents success will be related to their capability to be implemented without too hard platform requirements in order to guarantee the possibility to recreate complex scenarios and being integrated in current tools. The scenario analysis will require advanced DOE and VV&A in order to obtain effective results in complex scenarios. In effect experimental methods are widely used in research as well as in industrial settings, however, sometimes for very different purposes. The primary goal in scientific research is usually to show the statistical significance of an effect that a particular factor exerts on the dependent variable of interest. So DOE is used in strict connection with VV&A of simulators. Very complex scenarios do not require just DOE and VV&A, but the authors expect the necessity to have strong experience in AI and DF (Data Fusion) applications, related to problem identification and problem solving in military/industrial case study. This background is very critical due to the fact that the integration of these techniques could be guarantee just in the case of modelers characterized by large experiences in using mostly all the DF and AI techniques and in the fine tuning and model architecture design of such complex systems; the authors expect to extensively use Neural Networks, Fuzzy Logic, Dempster Shafer, Bayesian Logic, Swarm Intelligence, however probably test will be performed integrating such techniques with other techniques such as Genetic Algorithms (computer discipline involved with modeling genetic inheritance and/or biological evolution in computers) and KBS (Knowledge Based Systems, i.e. computer programs designed to simulate the problem-solving behavior of human experts within very narrow domains or scientific disciplines). These disciplines are real key factors in the PIOVRA realization. Skills related to tactical operations and psychology will be necessary in order to support the model analysis and problem boundary identification. Support Tools for AI and skill in using will be necessary in order to speed up the conceptual model trough an heuristic testing process based on simplified examples to be completed quickly in order to provide feed-back on hypothesis and proposal related to PIOVRA entities architecture and algorithms. Strong skill in programming using multipurpose languages (C/C++) will be requested in order to guarantee a strong and effective implementation capability that could respect the complexity of conceptual models as well as the integration issue. Strong Skill in HLA projects involving complex federation development will be requested due to the complex nature of PIOVRA entities and complex interactions expected to be guarantee for a proper management of demonstration scenarios. Due to the nature of the research the use of low level platform (high performance new generation PC/workstations) is supposed to be the development environment devoted to guarantee the success of future developments in this research line. The challenge provided by PIOVRA requires large experience in VV&A applied to

HLA projects as well as Project Management experience in simulation Projects.

5 CONCLUSIONS

Based on the above described considerations, PIOVRA project expect to proceed by different phases; the first step is devoted to the Definition of Metrics, Performance Measurement Baseline and Scenario in order to clearly identify the objectives and environments where to apply PIOVRA CGF; reducing the complexity in order to produce successful results in terms of "intelligent behaviors" operating in well defined boundary conditions by using AI techniques embedded directly in HLA federate interacting dynamically during simulation. Second step is devoted to the Development of Conceptual Models for each PIOVRA component and for PIOVRA federation by using G-DEVS/HLA framework in order to support Hierarchical Distributed Hybrid Structures enabling interoperability. The design and Integration of AI techniques in the Hybrid Models needs to be complete concurrently in order to support the agent intelligent behavior; this integration will use advanced techniques for data analysis (i.e. Data Fusion, Dempster-Shafer); artificial Neural Networks for correlating complex parameters; fuzzy logic for representing the meaning of continuous variables and behavior rules, as well as KBS devoted to regulate the ROE. Due to the complexity of this initiative the Federation Design will be based on HLA approach and FEDEP processes; this will guarantee reusability potential and integration capabilities based on current M&S standards; this approach enable to guarantee dynamic co-operative interactions among PIOVRA units during the scenario. The Implementation of PIOVRA components using multipurpose languages (i.e. C++/JAVA) in order to guarantee efficiency and compliance to integration standard and regulations is probably the best solution based on author experience (Bruzzone et al. 1999). The testing phase needs to focus to measure and check components and fine-tune the parameters regulating their behavior in order to get an effective reproduction of reality. As soon as completed the fine tuning the execution of PIOVRA reference scenario will allow to measure the performance and fidelity obtained by hybrid modeling of PIOVRA CGF in complex situations and the extensive use of Design of Experiments (DOE) will summarize the results and identify the most critical components and most sensible independent variables for improving PIOVRA effectiveness. The authors are expected to develop performance meta-modeling for recreating relationships among PIOVRA CGFs and performance metrics in order to provide a support estimating their capabilities over different operative configurations.

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