DIDACTIC GAMES SYSTEM: FIFTEEN YEARS OF DEVELOPMENT IN MILITARY SIMULATION

Gustavo Henrique Soares de Oliveira Lyrio [1]
Roberto de Beauclair Seixas [1,2]

[1]PUC-Rio–Pontifical Catholic University
TECGRAF–Computer Graphics Technology Group
Rua Marquês de São Vicente 225, 22453-900 Rio de Janeiro, RJ, Brazil

[2]IMPA–National Institute for Pure and Applied Mathematics
Estrada Dona Castorina 110, 22460-320 Rio de Janeiro, RJ, Brazil

emails: glyrio@tecgraf.puc-rio.br
rbs@impa.br

KEYWORDS
Warfare Games, Military Modeling and Simulation,

ABSTRACT

This work has the goal of presenting the author's experience through the last fifteen years developing military simulation games for the Brazilian Marine Corps. Starting from the birth of the idea of a didactic training game, we pass through the problems found and the solutions adopted to nowadays, where the system covers all kinds of attributions that a Brazilian Marine officer could receive.

INTRODUCTION

The history of war games are as old as the history of organized conflicts. he first use of a war game as a teaching tool is said to be a game developed by the Prussian Guard artillery lieutenant George Heinrich Rudolf Von Reisswitz and his father, Reisswitz Baron, to teach Prussian Guard officers. (Wilbur 1995)

In Brazil, the first notice of wargamming came from a small volume stored in Escola de Guerra Naval ("Naval War School") library called "Como jogar o Jogo de Guerra Naval" ("How to play the Naval War Game") dated from 1915. Since that year, war gaming was a reality to Brazilian Navy officers, first as sand boxes, board games, and then maps and computers after 1985.

The Brazilian Marine Corps, which is a division of the Brazilian Navy had foreseen the necessity of their own didactic war game system in 1997. Then, a partnership program was started with Tecgraf/PUC-Rio to its development.

The next sessions will present the journey through this years of civilian and military joint work, making a overview of the system developed, the obstacles found and the solutions adopted to make this partnership a case of success through all this years.

THE CHALLENGE OF THE FIRST YEARS

It's common sense that the first step is always the hard one. That was truth in the case of the development of a Didactic Game System that could achieve the goals of the Brazilian Marine Corps. As said above, in 1997, other systems that already use computer simulation were running in the Brazilian Navy, but nothing like the Marine Corps had expected. The system running at the Naval War School was conceived (and still is) to teach sea operations, which means flat surfaces, low detailed maps and lots of simplifications.

Those simplifications could not be applied when taking trainment of Marine officers in consideration. The modeling should start by the most common operation, which is also the most complex of all military maneuvers: Amphibious Operations. This kind of warfare means the use of naval firepower, logistics and strategy to project military power ashore and allow the landing of troops in a non-contiguous enemy-held terrain.
The idea was that the new system should be able to allow the training of Marine officers in Amphibious Operations with low cost, avoiding the necessity of sending troops to real terrain. With that in mind, the system's specifications became our first problem. The request for development of the Marines' new system came with a lot of complex, yet relevant, demands like 3D real terrain, high detailed land with different kinds

of soil, vegetation, climatic and astronomic conditions and everything that could affect a ground war theater.

In technical terms, the system demands are mainly a high detailed GIS (Geographic Information System) software with large real 3D terrain models (currently 21 layers of information). Everything should be persistent and consistent with the way Brazilian Marines conduct their operations making the system able to be compared to real training. All that just in 1997!

When the first contact between the Brazilian Marine Corps and Tecgraf/PUC-Rio was made, the idea was evaluate if there were technology available in Brazil to do something as huge as such system demanded. Then, a PhD was requested to know the system specification and to write a report either indicating which research institution could perform such task or suggesting the acquisition an existing foreigner system.

After 3 months, the first version of what would became the Didactic Games System was born. The Marines became satisfied with what they saw and decide to sign the first partnership contract and proceed with the development.

In this version (Figure 1) we presented some units positioned, using UTM (Universal Transverse Mercator) coordinates, in a real terrain that were able to move, see each other and interact thought mathematical models based on Lanchester equations to determine casualties. This system of differential equations is based on the principle of losses imposed to one force are proportional to the number of elements in the other side.

$$dx = \frac{-aY}{dt}$$

$$dy = \frac{-bY}{dt}$$

Lanchester differential equations Where a and b are the efficacy coefficients of the forces Y and X, respectively.

$$ACP = \sum_{i=1}^{all\ weapons} (qty(i)cad(i)let(i))$$

Combat power equation where qty is the amount of weapons, cad is the cadence of the weapon and let is the lethality of the weapon when using specific ammunition.

The main drawback in using Lanchesters model is the fact that the correct values of a and b depend on: weapons characteristics, elements' capacity of reaction and on command and control. We choose to made our engagement model determining how the accumulated combat power (ACP) of each element will be calculated which lead us to the previous equation.

The system was composed by four different components: database, geoprocessing, engine and user interface. After a few years using commercial softwares, was necessary to reduce budget to spend more with hardware update. The natural decision was to migrate to free software. So we chose Linux as the operational system.

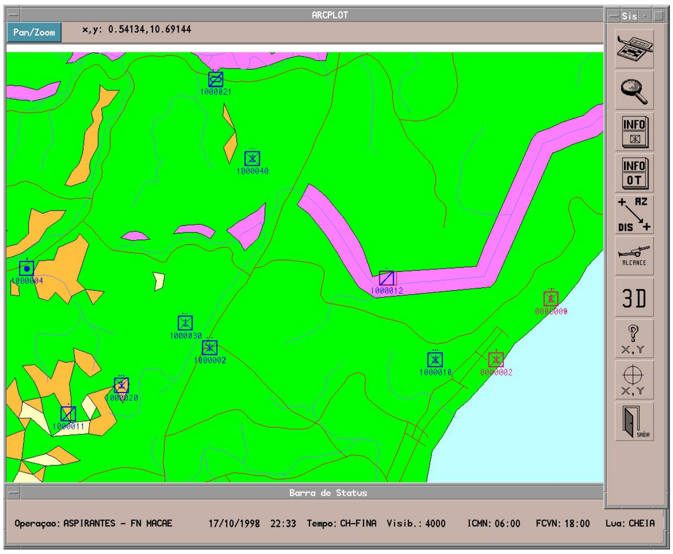

Figure 1: Screenshot displaying the first version of system interface.

For the database, the first selection was Informix because at that time it was also free. The user interface received a special treatment due to the fact the officers that would use the system were not familiar with Linux. So we agreed to make it for Windows but with the restriction that it had to be portable further.

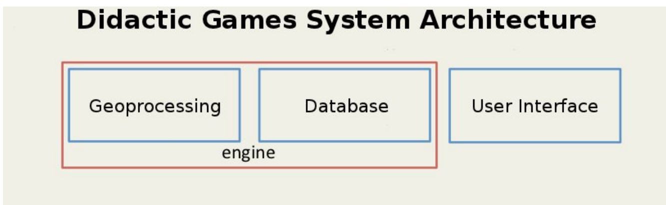

Figure 2: Schema illustrating the first system architecture.

The work on the following years was something unexpected for both parts. The Marines start to teach us how to be a Marine and, in return, we start to teach then how to be software developers.

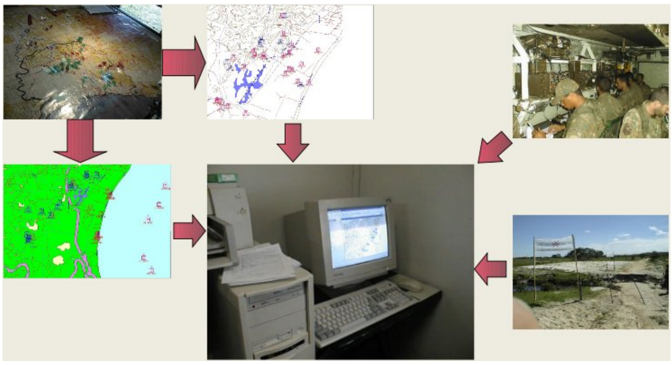

Figure 3: The goal of the project was to make everything available to the officers inside the simulation.

SUCCESS BRINGS MORE WORK AND EXTRA RESPONSIBILITY

In 2002, with the system fully operative, the goal was achieved. The Didactic Games System became reality and it has been used even by the Brazilian Army in joint exercises.

Later came the idea of extend it to cover other than amphibious operations. The first change requested was that the system should cover both Amphibious and Riverine Operations. The choice for Riverine operations prior to other Marines' attributions was due to the fact that a large part of Brazilian territory borders is covered by the Amazon Basin, the world's largest river basin and also the world's largest rain forest and Pantanal(both riverine terrain), making it a constant hideout for drug dialers and paramilitary forces. Also the local population suffers from a lot of necessities (like basic health service) due to difficult access to this area by the Brazilian Government. All that characteristics made the Riverine Operations the second most common operation for Brazilian Marines, and our second modeling goal.

Adapting the system to Riverine Operations was an entirely new challenge. This because while the first system had no predecessors in Brazil, in the case of riverine operation simulation systems the authors didn't know about the public existence of such a system anywhere in the World.

The responsibility increased because the partnership has proved that if it was possible to build a system to cover Amphibious Operations and to publish papers about the technology been used, it would be also possible for us to extend it to cover Riverine Operations.

Research results achieved by the project until 2002 were 1 Phd thesis, 4 master dissertations and 8 published papers.

The first and most radical change that we have made in this phase of development was to change the engine development language from INFORMIX-4GL to Lua. This decision was taken due to the necessity of the system to be portable, and INFORMIX-4GL had been a language that came from the choice of a particular database system. The choice for Lua was very natural because we were already using it to build user interfaces. In addition, Lua's fast curve of learning and the fact that it was developed inside Tecgraf/PUC-Rio helped us in the choice of the system development language. So, we gained speed in new developers training and in technology transference to the Marines. Thus, we kept the entire system wrote in a single language, reducing the specialization requirements for new developers in order to be involved in the project.

That was a blessed decision because few months later Informix was brought by IBM and we decided to change the Didactic Games System database to PostgreSQL. Following, PostgreSQL started to be part on all Linux distributions providing kernel integration, which turned the communications between the interface and engine even faster. Also we detached the geoprocessing component from the engine and moved it to pre-processing phase, with that we made the engine, the database and the user interface independent from each other.

Another change required was relative to the terrain. In Riverine Operations terrain changes completely when compared with Amphibious Operations. The terrain may change even when comparing different riverine terrains, like Amazon (mostly composed by dense jungle and rivers) and Pantanal (a huge plain of flooding areas), for instance. Besides the terrain characteristics, it was necessary to improve the terrain details due to the fact that in Riverine Operations the troops are divided into small fractions. Add to that the difficulty in obtaining detailed digital data of this kind of region, such as satellite images.

The solution came in applying a quantization algorithm to the satellite images to reduce the colors to the number of different types of soil and vegetation needed in the simulation.
Additional adaptations were made to turn the previous version of the system capable of simulating a riverine operation. It worth to mention here the modeling of the local population. Its role is extremely important in this kind of operation due to the fact that the guerrilla soldiers usually are recruited in the local people, making then look like, dress like and speak like local people. The only difference between a local citizen and a guerrilla soldier in this kind of area is the fact that the soldier is carrying a weapon. The guerrilla knows and makes use of it. They hide their weapons in the jungle,

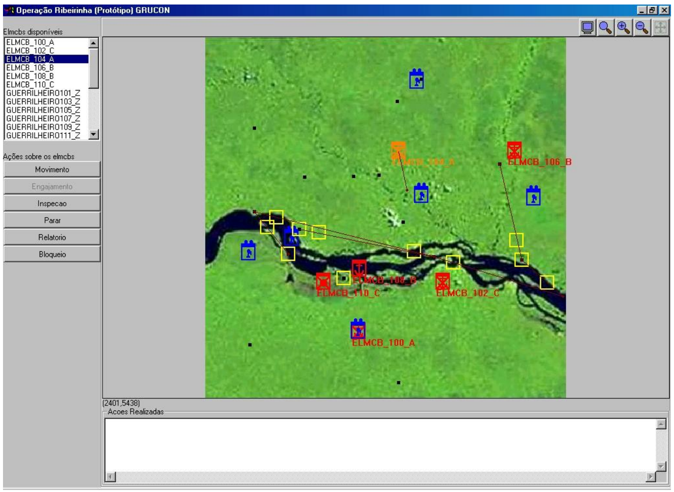

Figure 4: The Riverine Operations interface showing enemy, friend and neutral elements spread over the Amazon.

in the boats, and try to look like innocent persons walking side by side with the population. That fact made the local population a must have characteristic in riverine operations simulation.(Figure 4).

With the necessity of modeling the local population, came the demand of some artificial intelligence to take control of this new role (neutral). Until now the system had two well defined sides (friend and enemy) each one controlled by users. To accomplish that, we developed an artificial intelligence library based on agents with predefined behavior called MARE (Modeling Agents for Real Environments) (Lyrio and Seixas 2007), whose objective is not only to take care of the local population in Riverine Operations, but also to deal with the fact that the Marines, at least in Brazil, are not prepared to defend (Figure 5). In other words, the officers who took the role of the enemy during the simulations wasted part of their training time with a task that they usually were not trained for.

It is important to notice that we had to develop a new engagement model over the Lanchester equations in order to adapt it to guerrilla and also to respect the relationship between friend and enemy combat power of 10 to 1, adopted when taking non-conventional enemy forces in consideration (to be consistent with doctrinal rules). To achieve that we added a factor representing the number soldiers in the friend troop to the first Lanchester equation that would represent the guerrilla and leaved the second one unchanged to the conventional force.

In 2004 we published a paper and delivered to the Marines the first version of the Didactic Games System supporting Riverine Operations. (Lyrio and Seixas 2004)

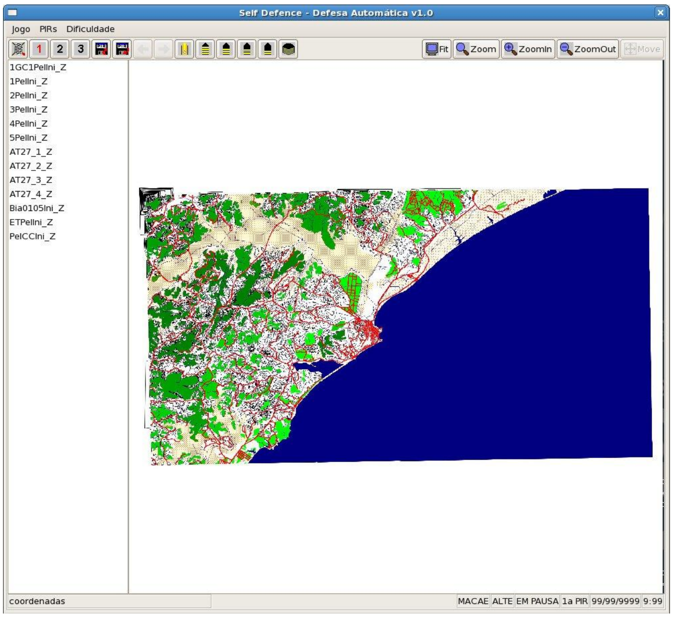

Figure 5: Automatic defense interface using Brazilian Navy graduations to define difficulty levels.

COVERING ALL THE DUTIES - INCURSION AND OPERATIONS OTHER THAN WAR

After the success achieved with the Riverine Operations simulator, we receive the request do extend the system even further covering all the duties a marine officer could receive. The goal was then to model Incursion and Operations Other Than War (OOTW), which means urban terrain operations.

In few words, Incursion is an operation where the marines have to enter a hostile territory, do some fast actions like hostages rescue or target elimination, and leave. We can take as example the action in the Japanese embassy hostage crisis in Lima, Peru.

By operations other than war we understand the actions to keep or recover peace in a territory, in special or critical moments. Again, as an example we can take the actions recently made by the United Nations (UN) in Haiti.

We put this two apparently different kinds of operation in a single session due to the fact that their modeling and the difficulties that we found were common in both cases. The most important difficulty that appeared during the process of adapting the system was to deal with constructions.

In the previous operations a construction was not relevant because the actions were all taken in countryside. Now the constructions play a main role in the scenario. For instance, lets take our first example and imagine

$$dx = \frac{-aXY}{dt}$$

$$dy = \frac{-bX}{dt}$$

$$\frac{dy}{dx} = \frac{b}{aY}$$

$$\int \frac{dy}{dx}\, dt = \int \frac{b}{aY}\, dt$$

$$aY^2(t) = 2bx(t) + M$$

or yet

$$M = ay_0^2 - 2bx_0$$

If $M < 0$ then the guerrilla wins. If $M > 0$ the marines win. If $M = 0$ there is a tie between the opposite forces. For usual values of a and b, one can conclude that:

$$\frac{y}{x} \approx \sqrt{\frac{2b}{ax}}$$

or

$$y \approx 10x$$

Modified Lanchester differential equations for guerrilla and conventional forces respectively. Note the new factor X on the first equation.

that an embassy was taken by hostiles and the marines need to rescue the people that were working there during the attack. The whole action will occur in the embassy neighborhood. The entire area is now extremely important to the simulation as the officers need to decide how to block streets, where to take position in nearby buildings, how to inspect citizens that pass through the area and so on (Figure 6). There is a movie called Black Hawk Down that shows how complex may be an Incursion.

In Operations Other Then War, the construction play similar role. The goal in this kind of operation is to help citizens oppressed by a local force, a guerrilla or after a disaster.

Constructions became a problem because, as far as we know, there is no available data showing the buildings that compound the Brazilian marines training areas. To overtake this difficult we made, by hand, a model of each block of the urban training areas estimating an average height based on the amount of houses, buildings and other constructions on the block (Figure 7). The results, despite the fact that are far from reality, was accepted by the Brazilian Marines as a temporary solution, making possible to the instructors to check if the officers were taking correct actions during the operation training.

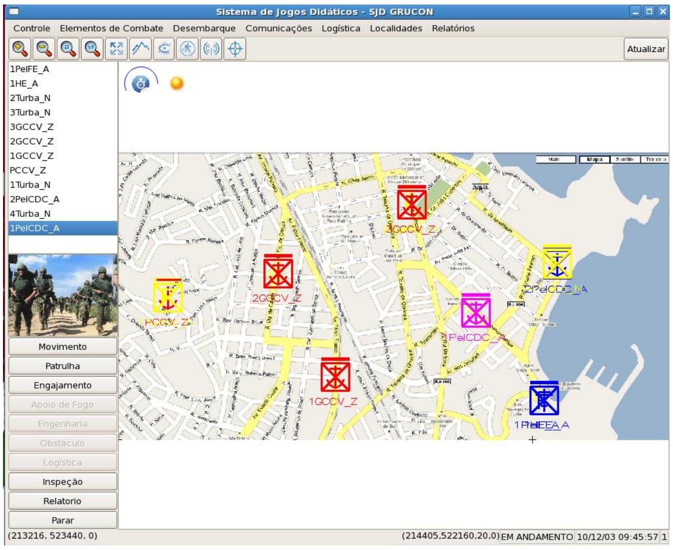

Figure 6: Incursion and OOTW interface modification using Google Maps image to display city blocks.

With the demand for constructions other obstacles arose, as terrain details, for instance. If we had trouble with terrain details in Riverine Operations, the problem now became even worst. In Riverine Operations the terrain was open and mobility was only affected by vegetation permissiveness, so a unit moving along the jungle would have it's velocity changing depending on the vegetation and soil type. Now, with the introduction of constructions, the lack of details about streets and alleys makes the movement during game almost impossible. It's true that a lot of tools like Bing and Google Maps have made incredible street details of almost everywhere in the world. The problem is that such tools do not provide other information like elevation, soil, vegetation, hydrography and other geo-referenced layers that the system need to work properly.

Other change that deserves to be mentioned here was the necessity to model a new role in the simulation. Until the development of OOTW the enemy was well defined and lethal force was always used. Now, in most cases where an OOTW simulation is requested we have a role that is played not by enemy, but by unpleased or oppressed groups of citizen that protest or try to satisfy their basic necessities that the government isn't providing. The first approach was to use the local citizens already modeled in Riverine Operations. Despite the fact that in OOTW citizens have an entire new behavior, that wasn't an lost effort.

Most of the time, the riverine citizens are not taking part in the conflict. But, in a particular case they do. Guerrilla some times coerce local people and that is very close to what happens in OOTW. The difference is that when a riverine person is coerced by the guerrilla they became part of it and the citizens in OOTW don't. In OOTW mostly of times people goals are (requested by enemy forces, or to protest) to disturb the order and make chaos in the neighborhood but they are mostly not armed and don't intent to engage the troops.

That brought to us the next improvement in the Didactic Games System. The troops needed to restrain the disorder caused by civilians, something we never thought about during all this developing years due to the well defined enemy behavior in the simulation: the use of non-lethal weapons.

After some discussion we agreed that the best way to insert non-lethal weapons in the simulation was to distinguish it from the lethal ones by the way it affects a target. A surprising conclusion was that it's not so different. The explanation is that when a enemy troop is attacked by lethal weapons it receives casualties. However, when a mob receives a non-lethal attack it also lose men, the difference is that instead of die, they run away and may reorganize in other place after a while. So, based in that conclusion we modeled the non-lethal engagement using exactly the same engagement model we use for lethal except for the fact that the term lethality, in this case, is named power of dispersion. Once a mob lose a percentage of its members (meaning they run away, not died), after some time, we "transfer" this mob to a new position in the terrain near the enemy headquarters in order to simulate a reorganization. With that idea we could insert non-lethal weapons and mobs in the simulation with almost no cost.

$$ACP = \sum_{i=1}^{all\ weapons} (qty(i)cad(i)disp(i))$$

Combat power equation used in non-lethal engagements. Note that the equations is the same as the one presented before expect for the fact that lethality was replaced by dispersion (*disp*) to represent the power of dispersion of the weapon when using non-lethal ammunition.

TURNING THE PROJECT TO THE WEB

During 2008 we have foreseen the possibility of using web 2.0 tools to help to overcome some common problems found during all this years of development. The first problem was how to deal with 3D terrain models of real world areas. We realize that this kind of model would not only demand a detailed model of a real area of the earth but also models of the structures and units that act over this area.

Fortunately, in the same year, Google released the

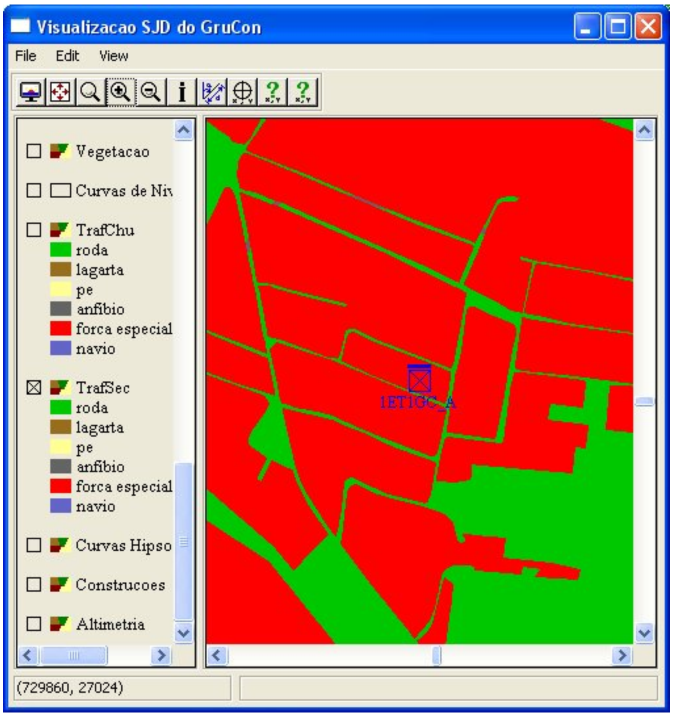

Figure 7: Trafficability map displaying the adopted solution of treating blocks instead of each construction.

Google earth API, which allow developers to display data from Google Earth inside web page. So we choose to use this API and got promising results.

Another issue was how to model troops communication during the simulation with all its characteristics and difficulties like statics, interferences and electronic warfare. Again a solution was found in a web 2.0 tool. In this case we choose to work with Team Speak SDK that became popular in Brazil due to the Counter Strike game, so it was a natural first choice. We also considered that Skype could do the job.

The last problem we faced was related to an user's complain about the lack of ways of keeping track of their units actions during the simulation. The goal of keeping track of units is to permit debriefs where users should be able to discuss wrong line of actions, propose improvements or even show a great maneuver that all other users should take notice. Our line of action in this case was to create a micro blog account for each unit where the units by itself post which actions were taken in the simulation, producing a real time tracker of all the simulation unit by unit. The tool chosen here was Twitter.

A paper called REAL-TIME WARFARE SIMULATION GOES WEB 2.0 was published in 2009 detailing the whole experience. (Lyrio and Seixas 2009)

CONCLUSION

After fifteen years of development we were able to extend the main idea of a simulation system to help training marine officers in Amphibious Operations into a system covering all the Brazilian Marine Corps assignments. The system is capable of simulating climatic and astronomical conditions, movement, communications, fire support, aerial and anti-aerial support, logistics, engineering, non-lethal weapons, electronic warfare, anti-aerial, citizens, mobs, guerrilla, enticement, coercion, endemic diseases and works with the following additional systems and libraries:

- Artificial Intelligence library M.A.R.E.
- Automatic Defense System
- Decision Making Tool to Military Planning
- Maneuver and Attrition Warfare Simulation System
- Command and Control Remotely Monitor System
- 3D Aerial Reconnaissance System

The first conclusion that we take from all this years of development is that the correct choice of the architecture is fundamental. As we mentioned before, we had to replace each of the three parts that compound the Didactic Games System during along these years in different times, and the choice of having this parts independent from each other has made it possible with just a few extra work.

We also learned that having a portable system is important. As the news of the system success reached different locations inside the Brazilian Navy, we received requests to move the entire system to different locations with different hardware and software architectures.

Finally, and perhaps the most important lesson learned is to know well your partners. Because they probably don't know about your development capability, they will not be able to provide all necessary specifications. It's important to by familiarized with partner's demands and necessities in order to build a long and fruitful partnership.

REFERENCES

Campos D.V.; Seixas R., 2011. *Command and Control: A low cost framework to remotely monitor military training.* In *Proceedings of Spring Simulation Multiconference - SpringSim'11, in Military Modeling and Simulation Symposium - MMS.*

Lyrio G. and Seixas R., 2004. *Riverine Operations: Modeling and Simulation.* In *Proceedings of Advanced Simulation Technologies Conference - ASTC, in Military, Government, and Aerospace Simulation Symposium.* 33–39.

Lyrio G. and Seixas R., 2007. *Modeling Agents for Real Environment.* In *Proceedings of The North American Simulation and AI in Games Conference.* EUROSIS.

Lyrio G. and Seixas R., 2009. *Real-Time Warfare Simulation Goes Web 2.0, , , Georgia, USA, 2009.* In *Proceedings of The North American Simulation and AI in Games Conference - GAMEON-NA.* EUROSIS.

Savelli R.M.; Lyrio G.S.R., 2004. *The Maneuver and Attrition Warfare Simulation System.* In *Simpsio de Pesquisa Operacional e Logstica da Marinha - SPOLM 2004.*

Seixas R.B.; Lauro A., 2003. *A Decision-Making Tool to Military Planning Process Based in Dynamic-Cost Matrices.* In *Proceedings of Advanced Simulation Technologies Conference - ASTC, in Military, Government, and Aerospace Simulation Symposium.* 70–75.

Seixas R.B. Mediano M. and Gattass M., 1999. *Efficient Line-of-Sight Algorithms for Real Terrain Data.* In *III Simpsio de Pesquisa Operacional e IV Simpsio de Logstica da Marinha - SPOLM'99.*

Wilbur G., 1995. *Playing War: the Applicability of Commercial Conflict Simulations to Military Intelligence Training and Education.* Master's thesis, DIA Joint Military Intelligence College, Bolling AFB, DC.

BIOGRAPHY

Roberto de Beauclair Seixas works with Research and Development at Institute of Pure and Applied Mathematics – IMPA. He got his Ph.D. degree in Computer Science at Pontifical Catholic University of Rio de Janeiro – (PUC-Rio), where he works with the Computer Graphics Technology Group - TeCGraf. Since 1999 at IMPA, he works as IT Manager and project leader of technical-scientific multi institutional projects. He also is advisor of Warfare Games Center of the Brazilian Navy Marines Corps.

Gustavo Henrique Soares de Oliveria Lyrio works with the Computer Graphics Technology Group - TecGraf. He got his B.Sc. in Computer Engineering at Pontifical Catholic University of Rio de Janeiro - PUC-Rio. His interests include Computer Graphics and Warfare Training Games. Currently he is developer of Warfare Games Center of the Brazilian Navy Marines Corps.