

Topological and tactical study modeling into a virtual environment

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Abstract — In order to enable the conduction of military operations, we need a great amount of information to make the best possible decisions in order to reduce the damages caused to our troops as well as to the population. Much of this information is obtained by analyzing the region characteristics and drawing conclusions from possible interactions results for our Forces with the adversities encountered.

This kind of instruction is sometimes difficult to visualize inside a closed classroom. A possible way of doing it is by observing a picture and comparing it with a Military Map, but sometimes it is very difficult to understand what the instructor wants to transmit. Hence, the students are normally taken to different regions, so that they can have better contact with the terrain and understand what should be taken into account in order to better advise the Command, taking positions in places that allow the best observation in possible conditions (usually at the top of elevations).

In order to give students the possibility to improve their knowledge about this kind of study before taking place outside, by modeling any region, they can be conducted anywhere using Virtual Reality (VR). In the virtual environment, they can observe the region and its irregularities, estimate places where it is possible to place a Platoon or higher value Unities, draw their plans on the terrain, observe interactions influenced by the terrain, observe the Instructors presentation, etc.

Students wear a VR headset that they can use standing or sitting. During the instructions, they can observe and, depending on the equipment used, interact with the instructor by pointing to any place or positioning any kind of means. The Instructor, otherwise, will use a tablet that enables him/her to see what the students are looking at or, by using a scanned military map, to use the terrain to explain details using tools like presenting slides, drawing, pointing, simulating actions, and positioning any kind of means.

Motion sickness is a problem that occurs frequently just by looking to the sides when using a VR headset. In order to reduce it, we will implement the Dynamic Field of View, reducing peripheral vision while moving the head according to the intensity of the head rotation. Other fact verified was that if we put the camera too close to the ground we lose details that we can visualize better if we are in a higher height. To solve that, we position the observer where the Observation Post should be, but a higher platform is established there. One important aspect to realize is that, by positioning the observer on the terrain, we will be too close to the pixels of the images and, if there is a little detail on it or no detail at all, the understanding will be committed.

The possibilities of this kind of interaction can go beyond other instructions like fire conduction or observing the troops exercise. Besides, it is also possible to assist planners on their conclusions or even help them to transmit orders. By helping the future or present planners, this tool will help their understanding of Tactics influenced by topography.

1 Introduction

With the onset of industry 4.0, we began to think about the capabilities of today's machines. One is to develop new ways to make training for military personnel as close to reality as possible. Based on this thinking, reproducing stress at a level necessary for the trainee to make decisions during the simulation, based on doctrine, with the possibility of correcting the actions taken in real time, is possible and necessary to avoid future collateral damage.

The present work describes a simple approach on the study of the characteristics of regions with great military value, as well as their judicious use for the best

exploitation of the terrain, having the modeling in a Virtual Environment as the biggest differential, which allows a simulation into a controlled place. In this context we will be able to present several interactions (being able to be influenced, among other aspects, by climatic conditions, local geography, etc.), allowing Students of Instruction Centers and Training Schools improvements in the carried out training. Using "Unity" platform will enable the desired level of detail, as well as a range of options for instructors to interact with students.

In order to justify the suitability of this approach, its advantages, in addition to a doctrinal basis, composed of aspects that emphasize the importance of constant

study of the military aspects of the terrain, it will be shown in a simple way, but covering its influences in Offensive and Defensive actions.

To realize its importance, in order to carry out military operations, a great amount of previous information is needed to make the best possible decisions to reduce as much damages as possible caused to our troops as well as to the local population (as an example, the proximity of localities, where the actions will be carried out, is a factor that influences significantly the amount of possible damages). Much of this information is obtained by analyzing the characteristics of the region relief and drawing conclusions from possible interaction results of our Forces with the adversities encountered.

Aiming to consolidate learning, observing the school calendar and taking as a basis only 1 of the courses taught at the Admiral Sylvio de Camargo Instruction Center, where the Brazilian Marine Corps take series of courses to improve their knowledge, from 11 months of course, there are 9 events that involve, in their demands, the displacement to regions where an area is used as reference for study.

By immersion into a virtual environment, the reproduction of a region with precision will allow optimal conditions for a better use during Military Maneuvers, enabling the production of adequate, achievable and acceptable plans with more quality, in spite of the difficulties inherent to the execution of such activities. Due to resources that in the real world are not possible (such as drawing on the ground for explanation or representing a squad), the results of this interaction will bring benefits from the military point of view.

Because it is a subject sometimes difficult to visualize inside a classroom by observing a Military Charter (map of the region containing information about relief, hydrography among others), students are taken to different regions, so they can have a better contact with the terrain in general and understand what should be taken into account in order to better advise the Command, assuming positions in places that allow observation with the best possible conditions (usually at the top of elevations).

2 Military Doctrinal Motivations

To start the content, we need to understand the process where we seek to observe the characteristics of the terrain that can decisively influence the actions in a certain place, known as "Giro do Horizonte".

The time available for such preparations is short due to the school schedule, which is harmful for the best exploitation and, given the possibility of large displacements sometimes necessary to reach the positions, the time for instructions is impaired. Another important factor, if the need of additional classes is envisaged to complement the subject, would be made unfeasible by the time required for its execution (each exercise in the field consumes, on average, 10 days, including recognition, preparation and training).

By definition, "Giro do Horizonte" is the identification in a Military Letter (ML) of the various points of the terrain, which is made up till the horizon line [1]. This line is limited to a distance of 4 kilometers because of the difficulty of observing without proper equipment beyond this one. The criteria or precautions that must be taken in carrying it out are the following:

- Occupy a position that best observes the region to be identified, usually an Observation Point (OP), which we will call the Station Point (SP).
- Determine the Station Point (current location) and orient the ML.
- Perform a summary inspection of the most notable surrounding accidents, identifying them with the ML, to make sure the orientation is correct.
- Stand next to those who will watch the presentation of the "Giro do Horizonte".
- Present the SP.
- Present the general direction of the North (or South);
- Divide the land to be identified in lines (bands or sectors).
- For each line start the identification from left to right and from closest to further.
- Present the altimetric details and then the planimetric details.

2.1 The military problem

Leading military personnel to a training outside the barracks places demands a big amount of material and personnel. Its exploitation, depending on the level of prior knowledge on the subject, is a result that can grow exponentially if exercised in advance, healing potential doubts and gaining valuable time.

For the execution of the exercises, the following factors should be considered:

2.1.1 Availability

Planning and preparing a training involves a several number of details, such as: the need for vehicles to move with the teams (in some cases it requires the purchase of both air and land tickets), search for accommodation and food for the personnel involved (in cities that there are no Military Unity close), knowledge of the safety of the place where it will run, recognition of the positions, check for changes and preparation of the details of the instruction.

2.1.2 Costs

To make travel possible, there are costs for purchasing tickets, lodging, fuel and food in addition to the usual ones. For a number of trainings by visiting 9 different regions, about R\$ 550,000.00 is spent for an average of 35 students and 15 instructors. In case of visiting 10 more places with a higher number of instructors and students, this value is practically unfeasible.

2.1.3 Personnel involved

For the instruction in the field, besides the instructor and the students, it is necessary to employ personnel involved in transportation, security, food, quartering area, among others. This demand influences the routine of the Units as well as the removal of the military from their homes.

2.1.4 Preparation for training

It is not always possible to have a place in the barracks for the preparation of the exercise that is close to what will be found in the training area. It tries, in a way, to compensate by means of interactive instructions that approach a little an optimum simulation.

3 Proposed Solution

3.1 Mapping of terrain characteristics

The most important part of the Virtual Environment Observation Point (VEOP) is the creation of the place where we will make the analysis. Its level of detail is essential for a better understanding of the students and allows greater immersion in the exercise. If this is so, it is not enough take a snapshot of a region and make it available to the study and it is not adequate for the purposes of the training. It is necessary to obtain the data series of relief, vegetation, hydrography, road networks and work structures but, by doing that in a large area, if it is not obtained by an efficient process, it may require a great effort to have a satisfactory result.

3.1.1 Obtaining the region to be studied

For the creation of the area, we must keep in mind, for study purposes, to use the 4,000 m limit because beyond that it is difficult to make good analysis without equipment. Another important detail is that large rendered areas require large amounts of processing and memory usage, which will become a slow process and applies to failures. Therefore, it is ideal to determine the OP and, from this, choose a desired area, creating only one OP per scene.

Using the Unity's Asset "Real World Terrain" (figure 1), "Opening Street Maps" and "Bus Radar Topography Mission (SRTM)", among others, obtains, respectively, the image of the area, that is inserted as the texture, as well as the height map (matrix containing the coordinates and heights relative to a provoked region) [2]. This Asset creates pimples ternances according to Spoon specifications for, after their creation, put them

together on a larger plot. It is important, for the treatments of future filters in the region, when choosing the smaller areas that will be used, to use limits of 1000 square meters.

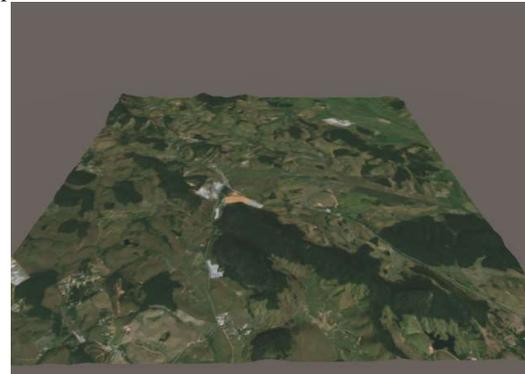


Fig. 1 Terrain generated by the Asset "Real World Terrain"

3.1.2 Obtaining vegetation

After obtaining the region, because it is a place where we will position the camera very close to the surface of the terrain and also by the need to observe the area with the maximum of fidelity possible to exist a better exchange of information (as for example the correct observation of what would be determined device being in an area covered by trees), there is a demand for greater detail in its vicinity (figure 2). To improve the conditions of observation, we will insert the vegetation as grass and trees.

For this we can, through photos, continue to observe their characteristics and placing the objects individually which, depending on the size of the terrain, may require a lot of time. Another possibility would be, through algorithms that interpret the green coloring produced in the image and, using the pre-manufactured objects by Asset "Gaia", insert the objects automatically and correct any errors or outdated results resulting from the importation of the land [3, 4].



Fig. 2 Observation Post where we can verify the need for detailing (some positions are in greater detail and others are not)

The image filter used to obtain the necessary data uses Python language and OpenCV and Numpy libraries and obeys the following sequence of actions:

1. Obtaining the Image;
2. Converts BGR color to HSV (figure 3);
3. Using a threshold of the green region of the HSV color map that obeys the necessary saturation for both grass and tree coloring, it traverses the image looking for the colors that meet the established limits (in this case, what is outside this threshold will be converted to the color black and what is in it will be to the color white);
4. Returns a black and white image where the white area tells Asset "Gaia" the locations to insert the required Prefabs (figure 4).

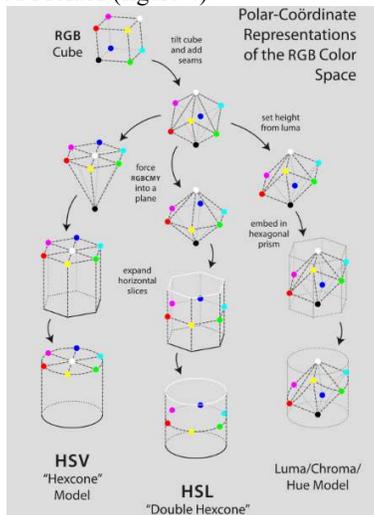


Fig. 3 Geometric derivation from RGB to HSV among others.



Fig. 4 (a) main photo and (b) photo after its conversion to the HSV (Hue, Saturation and Value) color system.

The images initially used are in BGR (Blue, Green, Red), represented color scale, as well as in RGB color system (Red, Green, Blue)(figure 5) for 3 numbers corresponding to colors and used by OpenCV, but with priorities different according to the order of their acronyms. This system is converted to HSV (Hue, Saturation, Value), where the saturation settings are changed (figure 6) [5].

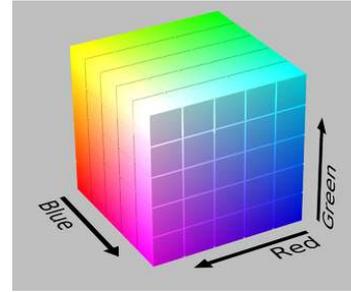


Fig. 5 Gamut representing the RGB colors

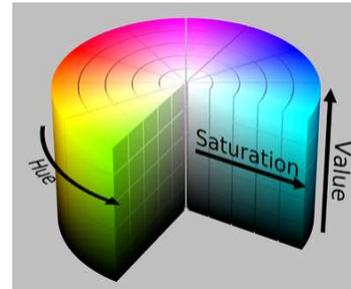


Fig. 6 Gamut representing the HSV colors

3.1.3 Obtaining roads

Another object that is very important to assist in the study of the region is the road networks. Its obtaining and implementation, as well as the vegetation, grows of difficulty with the increase of the volume of its network in the imported area. For your survey we will use a code that obtains the data of open sources of the "Open Street Maps", using its survey of obtained points and distances between them, obtaining the networks of roads by means of graphs.

3.2 Mapping of the Military aspects

3.2.1 Station Point

In order to determine the exact location of the Station Point to perform the more detailed activities (some initial detail must be initialized in order to gain time), a direction should be sought from the Intelligence Officer or, in case of training, seek the region with greater possibility of transmitting information in a more didactic way. For this, you can use a Military Letter to obtain such information or even search for more detailed satellites or photos. The designation of the Station Point in the VEOP can be done by means of a letter that appears every time the Student looks down, and can illuminate in this the correct position.

3.2.2 Northern General Direction

It should be considered both in the glasses used by the Students and in the equipment used by the Instructor,

being optional or not, in order to increase the speed of the instructions when necessary.

It may appear non-diegetically (when the information is explicit on the observer's screen without the need to perform a particular non-diegetically type of interaction, such as a point counter in a game) or diegetic (when interacting with an object and receiving a result in exchange), this type of information may appear on the ground or even in a Military Letter that appears when looking down (a compass can be modeled in the corner of the chart to help guide the student on the ground or as a form of exercise also).

One possibility, in order to assist the Instructor in the orientation of the Student, would be the capacity to observe, in their equipment, the direction in which a particular student would be looking at, and with this guide him to the correct direction by using arrows that appear on the screen, indicating where the student should look (this can occur with the instructor pointing at a particular location on his virtual ML and an arrow would appear on the Student's glasses directing them to where they should look).

3.2.3 Grids

The ML used in military operations, in general, have a series of straight lines that intersect at regular intervals (grid), forming squares called grids (figure 7). This grid, therefore, can be easily designated by the numbers indicative of the lines intersecting in its lower left corner [1].



Fig. 7 Part of a Military Letter containing grids

Like the General Direction of the North, these can appear in the terrain or in a letter in the form of texture, being important to insert the coordinates of the square to allow the better identification. Important detail is that these must be faithful in both the glasses and the letter of the equipment to be used by the Instructor.

3.2.4 Relay

Its influence can change the course of combat, so its detail must be large. If possible, photographs obtained by reconnaissance of the positions where the study will take

place confirm, for example, if one elevation can be seen even after the other. A Military letter is an important part of an analysis to increase the reliability of the result. One possibility of use would be the lighting of the elevation when requested by both the Student and the Instructor.

3.2.5 Hydrography

Because it is sometimes covered by vegetation and, depending on its size, it prevents the Troop from moving, data such as its depth, current and width must be considered, and can be displayed separately or together if requested. Another aspect would be to illuminate the river so that its extension can be observed, as well as possible waypoints like bridges.

3.2.6 Planimetry

Following the molds of the methods used to obtain both relief and hydrographical data (with exceptions that do not fit the reality, such as the depth of a river), the information also adds important details to the Intelligence, which must be collected or, in case of exercise, simulated.

In this case, roads can be illuminated, vegetation can be displayed in a standardized way in order to provide a better understanding (an example would be a standard vegetation for a very dense forest area and, for other types, other models). Facilities could be highlighted in a certain region as well as the display of more details in a window (floor plan of the installation, recent photos, etc).

3.2.7 Weather conditions and reduced visibility

In order to make possible a better study of the terrain, we inserted a possibility of altering the conditions of visibility so that one can better understand the conditions in which the troops will carry out their actions. Thus, the option of being able to position and move around the route where the troop would pass would make the experience better and bring more reliable results to reality.

3.2.8 Animations

When you try to explain how actions will take place in a certain region, sometimes making yourself understood is not easy. A simulation of a displacement in conduct using tactical formations or even the kinematics of the logistics of an operation, in spite of the diverse ways adopted for such, can be better understood. In order to be more realistic and to convey reliable information, the troop on the move must behave according to the obstacles imposed by the terrain when it is influenced by the conditions of time and luminosity.

3.2.9 Positioning of troops on the ground

One of the difficulties of the Students to observe and believe that at a certain elevation a Company can establish a defensive position or even that in a certain region there is room for the establishment of a Logistics Facility (known as a Summary Logistic Facility) that needs, by positioning itself in places of imminent risk, great camouflage not to be seen by the adverse forces.

Based on this need, and using manual data, models that can be distributed correctly and that obey the distances of security, being able to use military symbols or prefabricated miniatures of Platoons, Companies, Battalions among others.

3.2.10 Interaction between Instructor and Students

3.2.10.1 Place of employment

Because it does not depend, after its data has been inserted and the region has already been modeled, of connection with the internet, one can carry out the activities through an internal network, enabling its use in both classroom and inhospitable regions where a connection to the World Wide Web could deliver the position. Advantages and disadvantages for use both in the room and on the ground would be in aspects related to the logistics of all hardware for the experience (maintenance, transportation, availability of points of electric energy for the equipment).

3.2.10.2 Possibilities

In order to enable the Instructor / Student interaction, there is a need for a CPU with considerable Graphing capability as well as Glasses that allows the display of content focused on Virtual Reality (Oculus Rift, HTC), device that allows hands to be used to allow certain (HTC VIVE, Leap Motion among others to enable the student to obtain specific information such as lighting a stream or pointing to a particular direction) and an internal network (wireless or wired).

3.2.10.3 Instructor

Because it is an information disseminator, it should have complete freedom to enter and exit in the Virtual Environment where the Students are in order to be able to observe their doubts and to take them, as well as the ability to minister their instruction in the best way that suits them, is presenting slides, creating examples, making drawings or writing (whether on the ground or on a white board). For this, the use of a tablet delivers a great mobility and ability to fulfill these tasks, having the ability to:

- a) Control the conditions of visibility (climate, night with moon or not);

- b) Illuminate the North or positions on the ground, attracting the students, either by means of arrows, as well as inserting squares in the region;
- c) Make drawings using different colors either on a blank screen (this is displayed as a window for the Students), or on the chart (in order to illuminate or discriminate a certain idea that you want to pass). Both cases in real time or not;
- d) Measure distances to help students understand distances and regions);
- e) Simulate actions already done with speed control (coordinated attack, air strike, marches);
- f) Positioning already modeled maneuvers and installations in order to better exemplify the capacity of a particular place to receive them;
- g) To change the places to be studied (PO);
- h) Observe the position of the Student Officers on the ground as well as where they would be looking; and
- i) Design slides in the glasses for explanations.

3.2.10.4 Students

As they are receivers of information, they should be able to observe the explanations given by the Instructor, but with the most practicality possible in a platform of friendly use that allows to ask diverse doubts (to confirm locations and directions, as well as doubts regarding the instruction). For this they will use glasses of Virtual Reality, having as possibilities:

- a) Observe the interactions that the instructor makes available, be they presentation of slides, white board, drafts done in the field among others;
- b) Aim and plot a point on the ground to answer questions (when authorized by the Instructor);
- c) Position objects on the ground (when authorized by the Instructor);
- d) Observe what other students are doing (pointing, positioning objects on the ground, etc.);

4. Motion sickness

In order to avoid the motion sickness phenomenon in a room, students learn about various sitting subjects, as well as the implementation of dynamic FOV that reduces feelings of nausea in case of rapid movement.

5. Future projects

The possibilities that come with the implementation of this tool go beyond training related to the occupation of Observation Posts (fire conduction, Vigilance Stations, etc.). The interaction between the tablet and the Virtual Reality equipment that is established allows the appearance of different types of manipulation, being able to evolve to Augmented Reality, effectively shifting to the terrain and using the resources in the place where the instruction occurs.

Its integration with other systems makes it possible to observe the execution of games that can occur from the Operational to the Tactical level, such as entry simulations in the compartment, making possible future corrections with explanations containing sketches seen by the equipment in the place, besides the observation of maneuvers with the Troop on the ground and in real time, being able to go in the details of its executions at the operational level.

The use of adaptations to the equipment already used (in armaments with the possibility of control of the barrel, in the vests allowing to identify the locations of impact of the armament and the degree of damage of both the vest and the user, among other possibilities) integrated to the tool will allow better observation by both (Instructors and Students) of the mistakes made and possible corrections.

Such activities, in addition to the availability of remote use, allow all of the aforementioned aspects to be executed from different locations with great distances involved, where a Unit, performing activities or receiving training without leaving its quartering area, receives instructions from a Simulation Center that coordinates the various instructions, involving only the personnel needed to take the material to the place and make it possible to use it.

6. Conclusions

Immersion in a Virtually Modeled Environment, seeking the level of detail that allows the maximum immersion possible, allows the optimal exploitation of the capacity of each military, delivering positive feedback in real time, preparing it in the best possible way for combat. The quality of the information transmitted with the resources that can be made available (in spite of the ability to better observe the "movement" of the terrain) can grow exponentially, significantly increasing learning and evaluation in the teaching-learning process.

With the availability of this tool, training in places never before used, whether in regions of Brazil or even abroad, will be possible through the modeling of any selected area. The solutions found make it possible to create adequate terrains for training in a significantly better time than that used in the manual method, thus increasing the possibility of expanding and making the capacity of instructional resources more flexible, improving students' preparation for their analysis of the conditions of the aspects with the consequent advisement of its Commander in a safe way.

Not only on the subject of this document, the POAV can expand its purpose for other types of activities, be it training on conducting Artillery fires, Surveillance posts, among others. Its integration will allow future flexibilizations and improvements in the diverse Tactical

and Operational existing training, allowing distance teaching with better quality and diversity. Its concept allows for a significant increase in the various types of activities reaffirming that there is always the ability to explore more and more instructions, training and maneuvers.

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References

- [1] Marinha do Brasil, Corpo de Fuzileiros Navais, Comando-Geral, **CGCFN 1003**: Manual Básico do Fuzileiro Naval, Rio de Janeiro (2008)
- [2] <http://infinity-code.com/en/docs/real-world-terrain>, accessed at 11:41 a.m. on December 6 (2018)
- [3] <https://stackoverflow.com/questions/47483951/how-to-define-a-threshold-value-to-detect-only-green-colour-objects-in-an-image>, accessed at 11:00 a.m. on December 6 (2018)
- [4] R. Lukac, K. N. Plataniotis, *Color Image Processing* (2007)
- [5] A. Hanbury, Pattern Recognition and Image Processing Group (PRIP), Institute of Computer-Aided Automation, University of Technology, Vienna, Austria, *Constructing Cylindrical Coordinate Colour Spaces* (2007)

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