Visualization and simulation of micro-catchments using 3D Game Technology

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Abstract

Real-time data visualization is an important and strategic tool for a better comprehension towards a sustainable management of the environment by farmers and workers in poor rural areas. It is usual to see that these people, even living for years in these areas, do not have a complete knowledge and understanding of their environment and are not able to comprehend the systemic interference of many factors that are present in their habitats and surroundings. This work presents the specification of a system that is being developed to visualize and simulate environmental situations in micro-catchments using 3D game technology. This sort of system can help the work done by governmental agencies in poor rural areas. This system allows a real time fly-through over a huge area, permitting both a global and local view of micro-catchments. The proposed system is based on the observation of micro-catchments located in the State of Rio de Janeiro, Brazil.

1. Introduction

The process of data visualization is fundamental for a perfect understanding of the environmental aspects by the rural communities, tecnhinicians, and other relevant natural resources managers. Very often, these managers have limited environmental awareness and therefore lack of information to support an adequate decision making to overcome the negative impacts derived from their insustainable management.

This paper presents the specification of a new system for the visualization and simulation of micro-catchments for rural stakeholders of the State of Rio de Janeiro, Brazil. Micro-catchments are ecologically-determined sub-units of watersheds, comprising a small number of villages and agricultural activities (Fig. 1). The proposed system can also be applied to real time environment monitoring and can be easily extended to encompass other types of ecological or agricultural units.

The basic assumptions of the system are that the database is three-dimensional and the visualization and simulation processes are in real time. In order to meet these requirements, it is proposed the use of 3D videogame techniques [1-6].

The use of game technology in environmental simulations is not easily found in the literature. The work by Barreteau et al. [7] is a good example of games being used in the field of renewable resource management. However, this work is concentrated on the use of multi-agents for role-playing games with no visualization involved. On the other hand, systems for real-time volume rendering of GIS data are not considered similar to the work proposed in this paper.

In the system proposed in this paper, the input data are cartographic maps and their 3D meshes, which are associated to environmental information, such as: type of the soil, vegetation, watershed, and urban data. In the proposed system, image data can be in high resolution (what is not usual in GIS software). Although the system uses ArcView, the proposed process is general and any other GIS software can be used. ArcView can automatically generate images and maps of level curves from its database. However, 3D meshes require a special program (called Surfer) to generate meshes from the maps of level curves. These meshes should be in a standard format, such as DXF and 3DS.
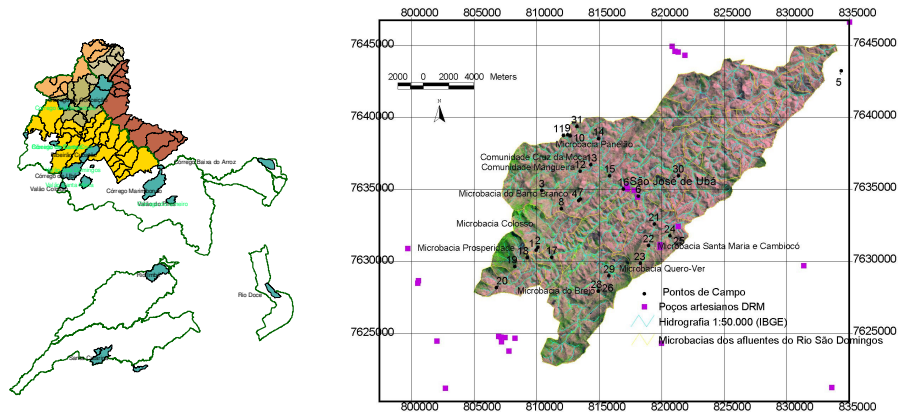
Figure 1 – A rural area (left) and one of its micro-cathchment (right).

2. Forms of visualization

The proposed visualization system is designed as a layer of tools based on 3D game technology [6]. 3D game techniques are perhaps the only practical approach that can cope with the real-time requirements of a micro-catchments visualization system.

The visualization system should have an interface similar to the one used by Google Earth (Fig.2), where the following areas are defined: the visualization area, the filter area and the area of tools. Google Earth has created a paradigm for geographic visualization, which has inspired most of other similar applications.
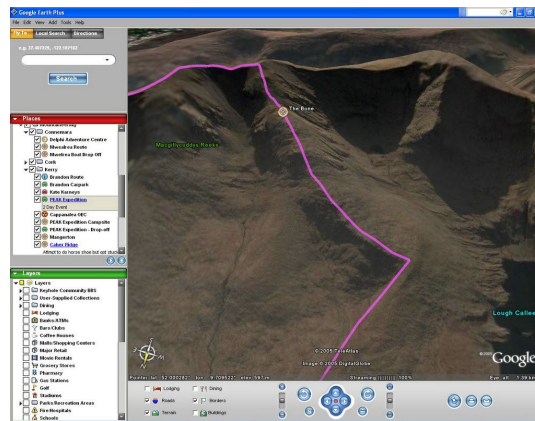

Figure 2 – Example of an interface for the micro-catchments system (image from Google Earth)

Two view modes are defined in the proposed system:

- Third-person view;
- First-person view.

The third-person view allows a user to visualize a great portion of the terrain. This mode is used to have a global view of the micro-catchment area. It is not recommended to deal with terrain details. The distance d of the observer consider the concept of the **Mesh View Limit** (d_m):

$d > d_m$: the image is the satellite image itself.
$d < d_m$: the image suffers a transition to a 3D mesh
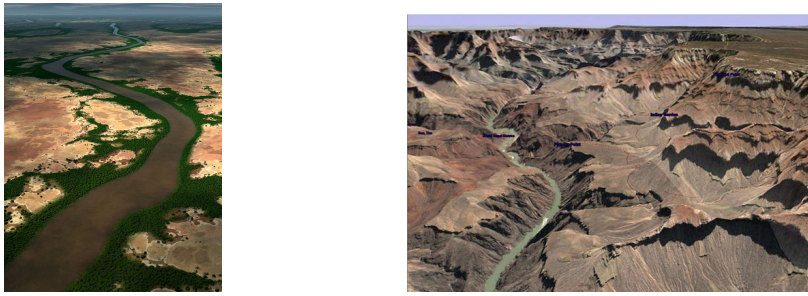
Figure 3 illustrates some situations for $d < d_m$.

Figure 3 – Examples of third-person views for distances below the Mesh View Limit (d_m)

The first-person view (similar to the paradigm of First-Person Shooter in videogames) simulates a walkthrough of a person on the surface of a micro-catchment.

In both view modes there is the concept of **Visualization Hyperlinks**. The following visualization hyperlinks are proposed:

- **Panorama Hyperlink**: if the user clicks on this option, a panorama visualization system will be presented in the point he/she is located. Fig. 4 shows a test made by the authors. This panorama shows a view of 360 degrees in which the user can rotate freely, as in the well-known software QuickTime. An improvement of this kind of view is to consider horizontal movements that interpolate successive panoramas (what is not possible in current commercial software, like QuickTime).
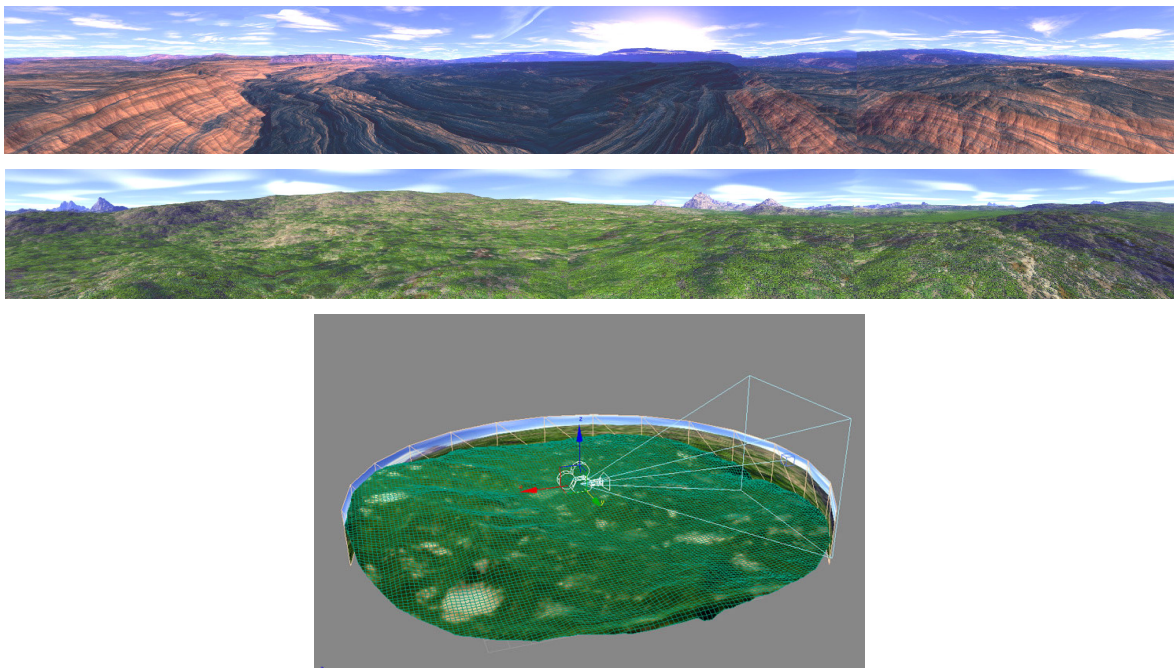

Figure 4 - An example of the panorama view.

- **Webcam Hyperlink**: if the user clicks on this option, he/she will see an image that is being captured by a webcam in real time. The main cost to implement this option in the system is to install and maintain several cameras in the micro-catchment area. Security questions should be considered in this case.
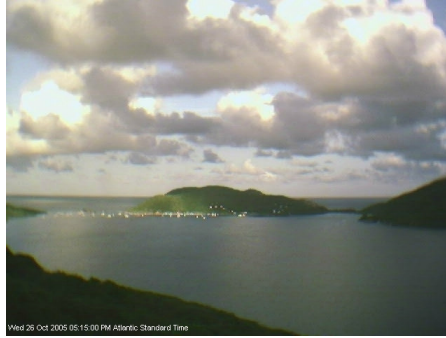
Figure 5 – Example of real-time view from a typical commercial webcam

- **Information Hyperlink**: in many situations, the user can see several types of information in a highlighted mode, such as data about rivers, types of vegetation, and types of soil (Fig. 6). The difference between the present system and a typical GIS application is that, in the former, the user is within a 3D environment with a high-quality image. The information hyperlink is implemented as a set of filters.
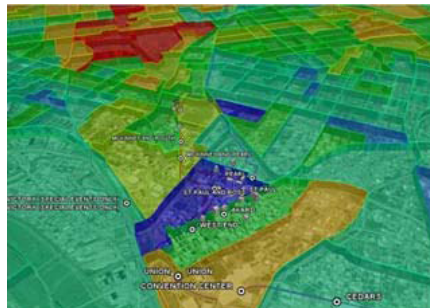

Figure 6 – Example of a filter in an information hyperlink.

- **First-Person Hyperlink**: in some specific places, the user can select this hyperlink to go to the first-person view mode. In the first-person view mode, the user can freely navigate. Fig. 7 shows examples from a well-known game.

Figure 7 – Examples of navigation in first-person mode (extracted from the game Far Cry – Ubisoft).

Most of the movements of the user in the proposed system are made through an isometric simulator. The proposed interface for this type of simulator is presented in Fig. 8. In this isometric simulator, the terrain should use a LOD (Level-Of-Detail) approach, in which the mesh can gradually go up to the resolution of 2000 x 2000 polygons. In the LOD approach, when the user moves far from the terrain, adjacent polygons are merged with their neighbors and the mesh is, consequently, reduced in number of triangles. With this sort of approach, it is possible to represent terrains in a great level of details for an area as large as 20 Km x 20 Km.
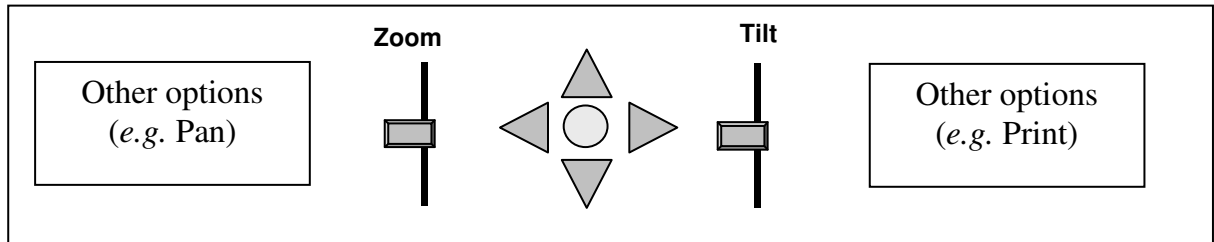
Figure 8 - The proposed interface for isometric navigation

The navigation in the first-person mode is totally made in real time and with a level of detail that cannot be reproduced in third-person mode. Furthermore, in the first-person mode, the user can get information about objects by simply clicking on them. Fig. 9 is a simulation of this type of interaction.

Figure 9 – Example of interaction in first-person mode.

3. Simulation

The second main function of the proposed system is the simulation tools in real time. Most of the physics simulations of the terrain are implemented at GPU level (Graphics Processor Unit level), which permits a very strong and realistic calculation with real-time feedback. In the proposed system, the terrain is described as a **dynamic high map** [1]. This permits that small changes, based on physical models, can be parameterized, which allows real-time erosion simulations based on different factors, like rain, soil type, and terrain slope. Vegetation is implemented with an approach that is called "vegetation map" in this paper. This technique requires a database containing 3D models of different trees, which are placed in the vegetation map (Fig. 9). This method allows any change on the vegetation layer, permitting interesting simulations, like deforestation and plantations.

The main simulations proposed in the system are:

- **Erosion**: the user defines a set of environmental conditions and the system presents the animation of the results of land degradation caused by soil erosion in the micro-catchments. The lower-right part of Fig. 10 illustrates an isometric view of a region where erosion can be simulated over a number of years.

- **Fertility**: This simulation allows the farmer to see the results of the use of a proper fertilization process. Moreover different types of culture can be simulated for decision-making. The idea is to incorporate agricultural knowledge within the system – a service almost impossible to offer in a poor region through traditional methods (such as a visit of a specialist).

- **Deforestation**: One of the worst aggressions to an ecosystem is the deforestation. Therefore the simulation of this situation is of the utmost importance. The 3D visualization of a deforestation process is perhaps the most convincing way of creating environmental awareness in the population of micro-catchment areas.

- **Pollution**: Pollution can be represented as 3D textures both in rivers and soils. Other effects on plantations can also be done by the use of texture maps.

4. The Proposed Process

Figure 10 illustrates the main steps of the proposed process:

- A 3D mesh of triangles is generated from the GIS data;
- Third-person view is supported by the 3D mesh and the GIS data;
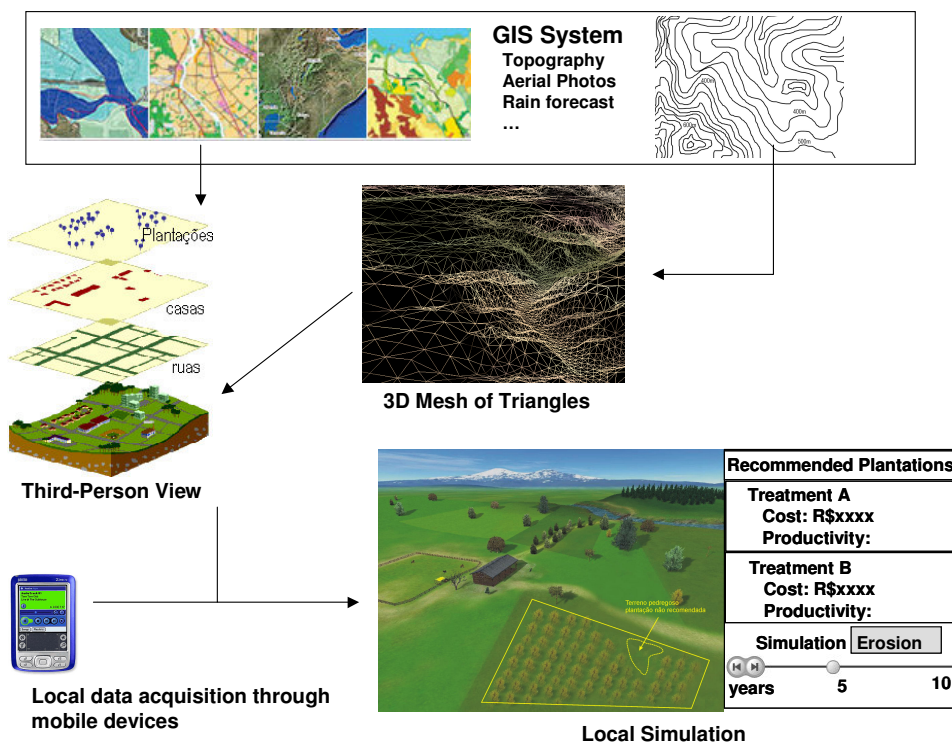- Local data aquisition (through mobile devices) provides information for the visualization and simulation module.

Figure 10 – The proposed process.

5. Conclusions

There is no reference in literature on the use of 3D game technology for soil and agricultural simulation in micro-catchments. This paper presents the specification of a new system for the visualization and simulation of micro-catchments for rural communities of the State of Rio de Janeiro, Brazil. The use of a game environment is the most adequate approach to help people from rural communities understanding their environment and making decisions about the proper

way of exploring natural resources. Games are perhaps the ultimate tool to help development agencies building environmental awareness in rural communities.

Research works are being carried on by VLab/PUC-Rio and the the Secretary of Agriculture of the State of Rio de Janeiro, Brazil, towards the development of the system described in this paper. A working system is not yet available. However, several simulations and computer algorithms are in advanced stages of development. Experiments with the following 3D engines were succcesfully made: 3D Game Studio, OGRE 3D, Torque and VLab Game Engine. The last engine is being developed by VLab/PUC-Rio. All the tests done so far have demonstrated that the approach presented in this paper is appropriate.

Acknowledgements

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