

GIS and simulation system integration in a virtual reality environment

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1. Introduction

The purpose of this paper is to show a mix between the SIG and the Event Scheduling discrete simulation paradigm through cellular automates. This link enables the possibility of construct discrete simulation models that use GIS data, allowing the simulator engine interaction with the landscape

This interaction allows the creation of new and powerful models based in outdoor systems, and improves the system understanding, and maybe predicts, some different natural and complex systems behaviour like flows, avalanches, earthquake consequences or wildfires, for instance.

In this paper we introduce a wildfire simulation model. This is a sample of the possible integration between a discrete event simulator (like LeanSim®, developed by Computing Laboratory of the Barcelona School of Informatics), and a Virtual GIS (like VirtualLands®, developed by Gea4D), in a model that represents the fire propagation in a landscape defined in the GIS (the structure) and in the simulator (the propagation model).

Model's evolution is displayed using virtual reality techniques, and the wildfire Propagation model is based in Rothermel's mathematic model (Rothermel's, 1972; Rothermel's, 1983) .

2. GIS, Simulation and Virtual Reality

Outdoor simulation models may require a huge set of GIS data, consequently is necessary establish an interface, between this data and the simulation model, that enables the representation and his use in the model possibility.

Virtual reality enables the landscape representation chance, theoretically closer that any other representation. The relevance of this technology is not only in the visual representation facet, also in his computer data representation. Virtual reality stores the physical structures of the landscape, and the simulator require these physical structures in order to enable the interaction with the landscape elements. This also enables active queries possibility over the outdoor simulation model.

3. Automating data from GIS to Virtual Reality

Last years the main providers of GIS tools have been developed several techniques for improving data representation, specially, in 3D view. Some of them only show a static 3D

view while others allow 3D view with the navigation possibility, free fly or animation recorded, over the data representation.

In our approach virtual reality techniques, (using VRML 2.0 as standard representation language, see Andrea L. Ames 2000), has been used to enable a powerful interaction possibility with the different models elements. Obviously is necessary to prepare the GIS data, transforming this data to VRML, adding sensors, scripts for dynamic behaviour and other functionalities based in EAI (External Authoring Interface) standard.

In our wildfire implementation, the GIS stores in virtual reality format the data that represents the landscape, fundamentally the DEM model and the vegetation structure. Through this representation the simulation model knows the terrain configuration, and enables the interaction possibility with the terrain and with the different elements that shape the model.

The difference between the virtual DEM representation and a simple DEM is the interaction. Virtual DEM representation enables this interaction possibility, with one or more users, which can navigate through the landscape respecting some rules, like the collision detection or gravity for instance, which can be defined in the virtual representation of a DEM, but are never defined in a DEM.

This rules definition is useful because the simulator not only needs the landscape structure, also needs the more important rules applied to the landscape (gravity, collision detection, lights, etc).

These rules determine the relation between the simulation model and the landscape and are defined in a GIS with the virtual cartography generation possibility

4. Virtual landscape generation

Automating data from GIS to Virtual Reality is, possible using specific tools as VirtualLands© (figure 1), which imported several format files (shape, raster, DEM ...) from a GIS and convert to analogous layers in VRML, export data to Leansim® files format, and build a VRML file that contains all information needed for simulate or query the GIS data in 3D View.

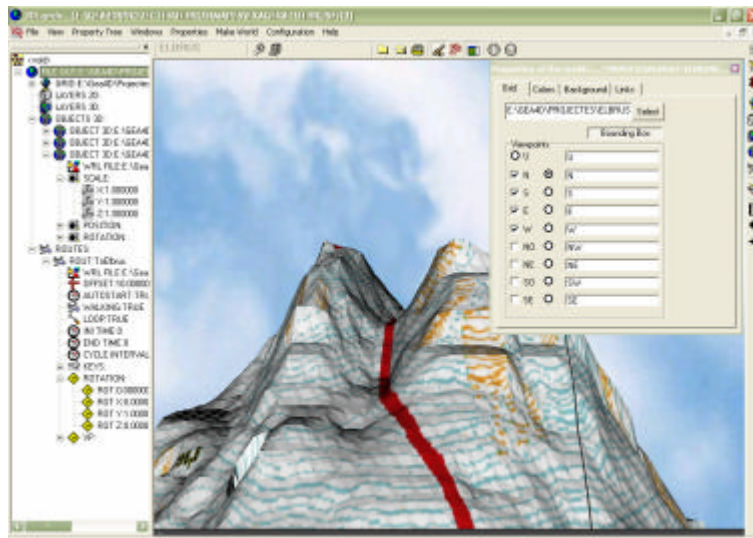


Figure 1 VirtualLands

The main VirtualLands© goal is generate virtual cartography (based in VRML format), but also structures the data in layers depending his nature, and enables the option of add interaction with some layers or individual objects. VirtualLands© also enables the possibility of make queries to the geographical data, and the answer is represented in virtual reality format.

Is important to remark that all the different elements that are suitable to be represented in a virtual landscape can have his own behaviour in the reality, and hence his own comportment in the simulation model. These structures can be the common structures of the 2D cartography, plus some other structures characteristic of the virtual cartography. All these structures are organized in layers, which can be added over a DEM. In the next lines there's a description of the different layers structures, that VirtualLands© have, suitable to be used in the simulation model.

4.1. 2DLayers (Vectorial Layers)

These layers represent the common geography layers represented in a GIS, like point, polylines, texts or lines. These elements added to the virtual model, usually represent information for the observer, but not represent information for the simulation model, and usually don't have any specific behaviour. However is possible to define some simple behaviour to the entire layer. Usually these layers are represented in vectorial files.

4.2. 3DLayers (Rasters Layers)

These layers appear when is necessary to represent a fixed population of elements, like a forest or a city (each tree have his own position over the DEM). The restriction for these elements is that all have the same virtual representation and the same behaviour.

To establish the exact position for each object a raster file is used. This file contains a matrix of data that shows the element position. There are two different kinds of raster file.

The first kind of data structure is a binary data, which only represent the absence or presence of the object represented by the 3DLayer in a selected position; in this case the object is situated just over the DEM. The second kind of data is a matrix that represents the position of the object in the Y axis position (elevation). Obviously, in this second approach the no-data value shows that there's no element in this position.

In the wildfire sample, we use 3DLayers to represent the forest trees that can be burned by the fire. The simulator can interact individually with these elements in order to simulate the wildfire propagation.

4.3. Objects

The limitation of the layers is that all the elements have the same behaviour. If is necessary to represent element with an individual or concrete behaviour is necessary to use "Objects" (2DObjects or 3DObjects).

4.3.1.2DObjects

These objects represent lines polylines, texts and points with an individual behaviour, for instance a point with a touch sensor that shows some information.

4.3.2.3DObjects

The 3DObjects are virtual objects that are not associated with any layer. These objects can have own behaviour represented by a script or program connected with the world through EAI.

4.4. Routes

The routes define 3DObjects movements through the virtual Landscape. These objects can be part of a 3DLayer or not. Also these routes can be defined by the simulator, and enables the possibility of move the different elements thought the Landscape following the simulator logic.

5. GPS layers integration

Thanks the integration of some 3DObjects with a GPS, the simulator have the possibility of implement training systems, because is capable to locate the elements in the real world and place these elements in the model, and hence determine the implications of his situations or actions.

In the next table there's a description of the GPS layer integration.

<i>Layer</i>	<i>GPS integration</i>
DEM	Geo referenced
2DLayers	Geo referenced

3DLayers	Geo referenced
Routes	Track points
2DObjects	Waypoints
3DObjects	Waypoints

Table 1. GPS integration

6. LeanSim® system

There are very different ways to model a real system, which differs in the different conception or definition for the elements that compose the system representation (the model).

The paradigm used in LeanSim® is the process iteration. In this paradigm the user defines the behaviour of the different system elements through the process definition.

Each process gives the complete information of the different operations or activities that can be made in the model to the different entities.

The main LeanSim® characteristic is the model virtual representation integration. This feature allows the elements behaviour definition not only in the process aspect also in the structure aspect.

6.1. Cellular Automata LeanSim® element.

In LeanSim® there are different machines, or elements, that allow the simulation system construction (figure 2). For instance, the *generator* allows the introduction of elements in the system, and the *generic*, allows the delay or model elements transformation.

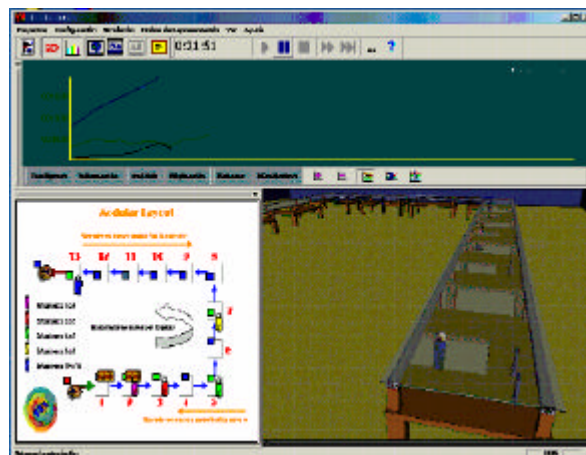


Figure 2: LeanSim® simulation engine

For the simulation model integration with the GIS data is necessary to use the *Cellular automata* element. This element implements a matrix of cells; each of them has a data structure, and, over this matrix, cellular automata logic defines the data modifications for each cell.

In the next sections there are descriptions about the use in the simulation model of cellular automata, and other LeanSim® elements, to represent the different Layers and objects that configure the landscape in a virtual GIS.

6.2. Objects (2D and 3D) modelling

The representation of these objects is direct, and only is necessary to select the object, from the LeanSim® objects library, that represents better the behaviour of the element.

In the wildfire sample is possible to represent the water fountains with a *generator* element, which generates the water that can be used by the fireman to fight the fire.

6.3. 2DLayers modelling

VirtualLands© generate one single object that represents the entire 2D layer. These objects can be added to the model with his own behaviour. Usually these elements don't have implications in the model, and are only used to represent information to the user, for instance territorial divisions.

6.4. 3DLayers modelling using cellular automata

In 4.2 we see that the representation for the 3DLayers is based in raster files. These files are stored in a cellular automata element that has a structure (a matrix) that represents the positions and the characteristics of each of these elements.

In the Wild fire example there are one *Cellular automata* element for each 3D Layer, each of them can represent different forest elements, like different kinds of trees or vegetation. With the cellular automata is possible simulate the fire propagation and integrate this fire evolution in the discrete simulation model.

6.5. WildFire Model integration

In the propagation model (based in the Rothermel mathematical model), the characteristics of every cell studied is extracted from the Cellular automata, that represents the landscape structure.

The events that drive the propagation model are:

- **EBurn:** Associate to ignite fire into simulation cell.
- **EPropagation:** Programmed time for fire propagation to neighbour cell
- **EExtinguish:** Programmed time for put out fire in a cell

The cellular automata process the event EBurn and, using the Rothermel model that implements, generates new simulation events like EPropagation.

The simulation engine processes the new events and sends these events to the different simulation elements affected by them.

Obviously some of these events are received by the cellular automata that represent the

landscape, processing these events and generating new events following the Rothermel model.

Parallel to the main execution is possible to run a containment model that interacts with propagation model.

This architecture enables the simulation model construction possibility using GIS data inside the model easily.

In the picture (Figure 3) is showed the front line fire evolution over virtual map.

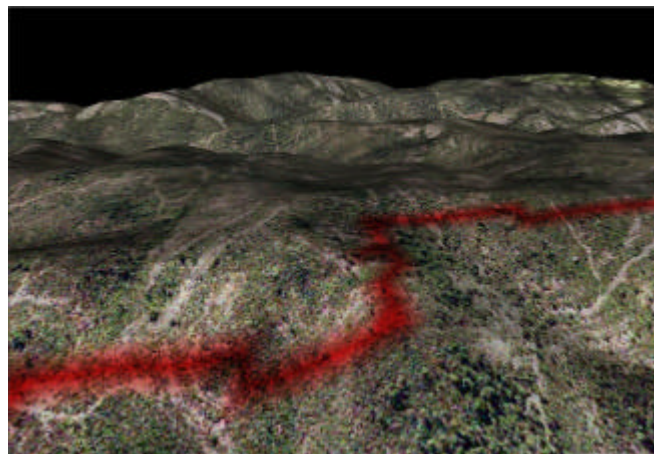


Figure 3: Wildfire frontline in LeanSim®

7. Conclusions

The integration between simulation systems and GIS enables the creation of simulation models that incorporate the geography complexity. Traditionally the main areas of simulation are the industry and the traffic flow. With the join with the GIS, systems concerning the landscape are suitable to be modelled.

The virtual reality GIS data representation simplify the simulation engine interaction with the landscape model, and enables the possibility of add individual behaviours for each element represented in the virtual model.

The cellular automata application simplifies the use of geographic structures, using GIS layers in the simulation model through the cellular automata, because the geographical data can be used like a common simulation object, sending and processing events without any difference with the other model elements.

The inherent cellular automata logic simplifies the model definition and implementation. For instance, is possible to build a cellular automata witch represents the DEM landscape structure, and implements the wildfire logic propagation.

The simulation engine can merge in one model different cellular automata, each of them with his own behaviour (the logic that implements the cellular automata), enabling the constructions of detailed outdoor models that use GIS data without modify the structure of

the discrete event simulation paradigm.

This new architecture allows simplifies the join of simulation and SIG in the decision support systems, and enables the constructions of detailed models that incorporate GIS data in a way closer to the GIS common data representation, using common layers inside the simulation model, without the necessity of modify the discrete simulation engine.

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Biography

Pau Fonseca i Casas actually is full time professor of the Polytechnics university of Catalonia, teaching in the statistics and simulation area. He work's in the LCFIB (Barcelona faculty of science computer calculus laboratory) developing Simulation projects since 1998, also are member of the Gea4D group dedicated to the research and developing of GIS virtual tools.

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