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PARTICLE SYSTEM FOR GENERATION OF TERRAIN STRUCTURES

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Abstract

This paper proposes a method that applies particle system to generation of terrain structures. The method can either start from plain height map or can be used as a deformer to some predefined, real or previously, generated height field data. Performance of the particle-based algorithm is close to real-time, thus it offers the opportunity for fast terrain surface generation. Selected landscapes can be rendered in real-time on typical desktop computers. Finally, the method can be used to simulate erosion of terrain structures caused by flow of air or water.

Streszczenie

W artykule zaproponowana jest metoda zastosowania systemu cząstek w generowaniu ukształtowania terenu. Metoda może rozpocząć swoje działanie zarówno dla pustej mapy wysokościowej, jak i może zostać użyta do deformacji predefiniowanego ukształtowania terenu , rzeczywistych lub wcześniej wygenerowanych danych mapy wysokościowej. Szybkość działania algorytmu bazującego na systemie cząstek jest zbliżona do czasu rzeczywistego, co umożliwia szybkie generowanie powierzchni terenu. Natomiast wybrane ukształtowania terenu będą mogły być wyświetlane w czasie rzeczywistym również na komputerach osobistych. Ponadto, metoda może zostać wykorzystana do symulowania postępowania erozji ukształtowania terenu wywołanej przepływem powietrza lub wody.

Keywords: terrain generation, particle system.

Słowa kluczowe: generacja terenu, system cząstek.

1. Introduction

Terrain generation algorithms has been often used as part of environment simulations for military and civilian training courses, digital entertainment and virtual reality. Different techniques of that kind are in use for modelling specified terrain structures. Methods for hills and mountains landscape differ from ones used for coastlines or islands scenery.

Originally, particle system technique was developed to improve speed and realism of real-time based modelling of "fuzzy" natural phenomena similar to fire, clouds, water, smoke, explosion or galaxies of stars, but also for modelling vegetation like grass or cereals [3][9].

In our work we used this modelling technique for generation of terrain structures based on height field data as a fast and complex alternative for currently available methods. Furthermore, our technique is fast enough to be implemented on a multi-screen virtual reality systems [12].

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2. Other works

For computer simulation and modelling of artificial landscapes, frequently used methods are fractal-based algorithms or purely iterated generation techniques.

Classical method based on Mandelbrot's Midpoint Displacement algorithm was proposed for the first time by Foumier, Fussell and Carpenter (Square subdivision) [6][7][8][10]. The method starts from initial 2x2 grid resolution. Next, in recursive subdivision of initial square of height map grid, the method increases its resolution and accuracy of generated landscape. The height values of newly generated height map nodes are calculated as an average height of neighbour points and a random displacement offset [1][10]. The method modifications presented by Miller (Diamond-Square and Square-Square subdivisions) and Mandelbrot with Musgrave (Hexagon subdivision) give an alternative models for selection of neighbour points, but the idea of algorithm remains unchanged [1][6][7][8].

Another approach for terrain generation technique is the Fault Formation algorithm. The Method was used by Voss to create fractal planet and Mandelbrot to generate fractal coastline [6][7]. In this method, height map is divided by random generated lines which create faults. One side of divided height map is raised while the other side is suppressed by the same random value [2][11]. The algorithm can be also used for simple observation of virtual earthquakes in near real-time simulations [2]. The method stops when a number of given lines is generated over a given height map.

A procedural technique proposed by Woodhouse, uses the Fluid Simulations method for hills-like landscapes generation [15]. Algorithm starts from height-field, filled with random values. Change of the height values in any height map cell, causes a cascade's changes in neighbourhood evoke a wavy effect of height modifications on the whole height-field. In each iteration, the ragged surface going smoothed and the height values are gather around a locals extremes [5][15].

3. Particle System in Terrain Generation

Simulation of falling particles is similar to the behaviour of natural phenomena like snowing or dust falling, so it is possible to use this technique for generation of terrain structures. A quality of modelling object will be depending only on system parameters.

Every particle system, regardless of modelling object, must be equipped with couple major elements, like: an emitter (or a set of emitters), a collection of particles and a defined size of algorithm's workspace.

The emitter is an element that controls the number of particles and it is responsible for generation of new objects into the system environment [3][14]. Its most important parameters are:

- position and orientation in virtual space,

- mobility, therefore capability for changing its position and / or orientation,
- size of emitter's window (plane or space) in which area, newly particle can only be created.

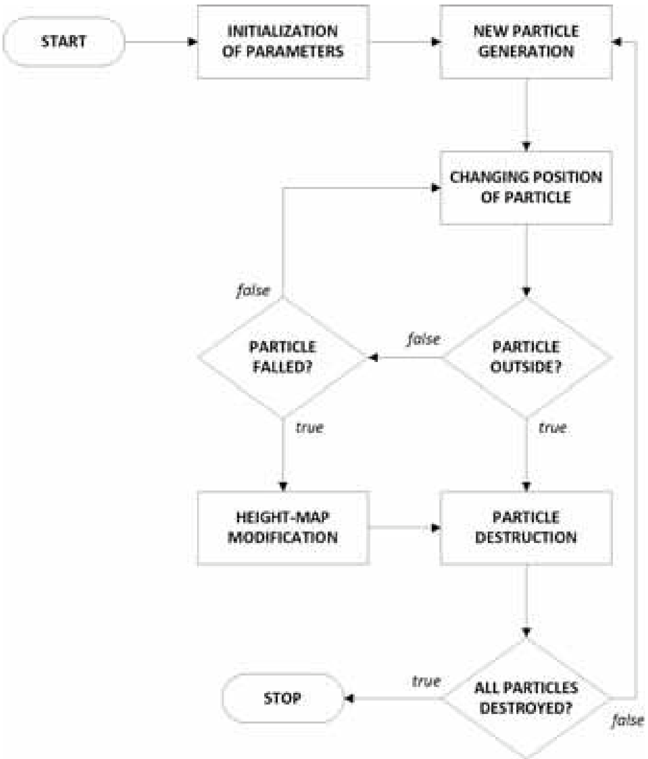

Fig. 1. Structure of the algorithm
Rys. 1. Struktura algorytmu

Another component of the system is a collection of particles. A particle can be defined as a simple point in three-dimensional space [9]. Each object of the collection can be specified by selected attributes, for example: position, orientation, direction, mass, size, hardness, velocity, colour, magnetism, viscosity, etc. The Most important parameter of a particle is its cycle of life, defined as a time between creation in an emitter's window and annihilation of the particle, when it collides with other virtual objects or its position crosses the bounds of the algorithm's workspace [9][14]. Characteristic of the modelling object will be a resultant of given parameters.

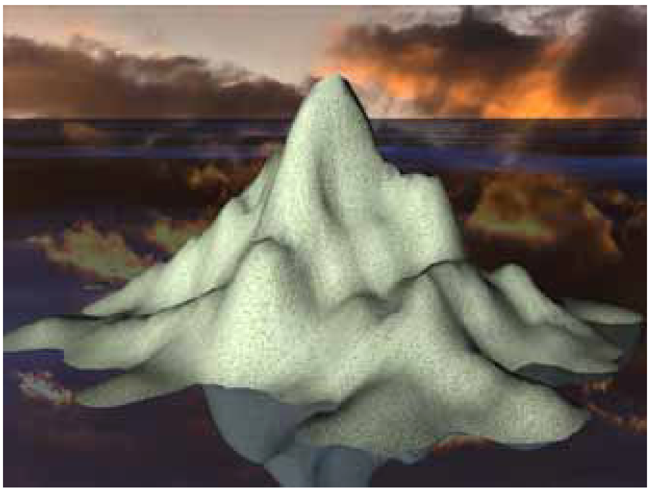

Fig. 2. Example of generated island (Rendered in Maxon Cinema 4D)
Rys. 2. Przykład wygenerowanej wyspy (Renderowany w programie Maxon Cinema 4D)

The data structure of a terrain description is a typical height-field represented as a two-dimensional matrix or one-dimensional vector (interpreted as a two dimensional-matrix) where each cell represents the height value of given coordinates. Interpretation in virtual space of a memory stored height map is a usually triangle-based regular polygons net.

The preparation phase of the rendering algorithm starts from parameterization of the height map by defining its size and initial values (plain, random generated or loaded from real data file).

Then, we set the basic parameters of the emitter (or set of emitters). Emitters should be located in some distance from the polygons net, to give a chance for particles "fly free" before they collide whit the surface of modelling terrain. Narrow size of emitter's window is conducive to generation of island-based landscape. Wide size of it, is helpful in generation of mountain-like terrain structures or rocky landscapes.

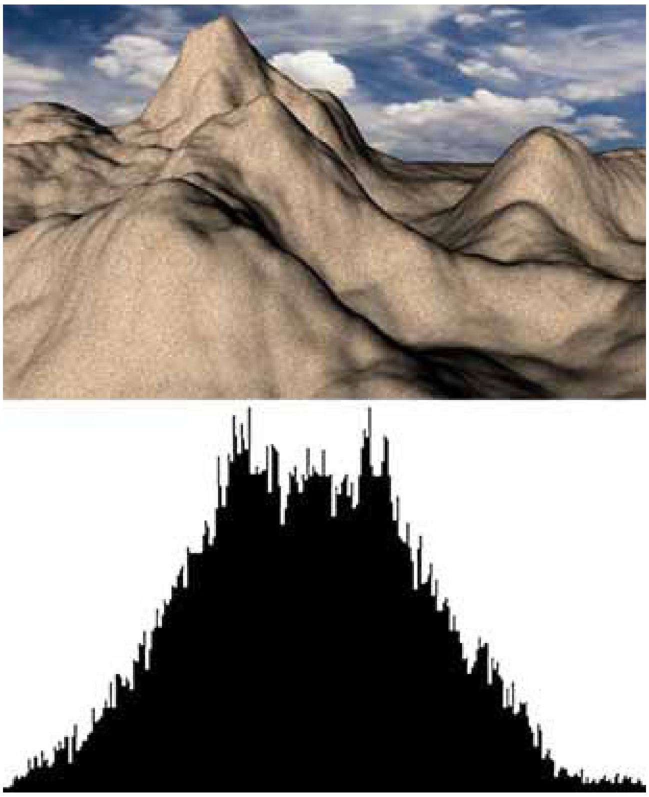

Fig. 3. Example of generated mountains terrain (Rendered in Maxon Cinema 4D) with histogram of height field values
Rys. 3. Przykład wygenerowanego teren górzystego (Renderowany w programie Maxon Cinema 4D) oraz histogram mapy wysokościowej

After setting of emitter's attributes it is necessary to proper selection of particles parameters, because they have supreme effect for generated terrain structures. Selected properties can be applied freely for all particles in a collection and each attribute can be set for all elements at the same value or it can be different for every one particle [4]. Trajectory calculations of moving particle have effect based on its attributes, like speed, velocity or orientation and global forces, like gravity, wind or collision responses. Besides, the global forces can modify particles attributes, despite of their current position, speed or orientation [4][13].

When a particle collides with a polygons net, it is bound the central point of particle influence zone (x_0, z_0) over a height field and point where a height modification (Δy_i) will be strongest. All height values modifications can be effect in the vicinity of that point and the influence is weaker with radius increasing (λ). The radius is a product of several particle properties, like size, mass or weight. The influence of the current particle on a height map diminishes when calculated increase factor of height closes zero value.

$$\Delta y_i = \lambda^2 - ((x_i - x_0)^2 + (z_i - z_0)^2) \qquad (1)$$

where:
Δy_i – increase factor of height value at calculating coordinate,
λ – radius factor of height modifications,
(x_0, z_0) – collision point,
(x_i, z_i) – calculating coordinate,

i – current index of height map.

Finally step, just before a rendering must be a normalisation of height values on whole height-field. Typically, normalisation's range is [0.0 - 1.0]. For calculations of normalised values we used a common normalisation equation, presented bellow.

$$y_i^n = (y_i - min) / (max - min) \qquad (2)$$

where:
y_i^n – normalised height value,
y_i – un-normalised height value,
min – founded minimal value on height map,
max – founded maximal value on height map,
i – current index of height map.

4. Conclusion

Proposed method enables automated generation of broad class of landscape models and can be used for modelling of simple and advanced geological structures. Parameterized algorithm can be used either for forming complex height field and limited area of it for creating of islands or archipelagos.

Performance of the proposed method depends mostly on quantity of the particle models and decreases with increasing number of particles. This property of the algorithm enables use our method as near real-time landscape generation technique we can obtain, in relatively low time, requested surface configuration. For ten thousand simulations of complex terrain structures with a spherical topology, represented by regular, 400x300 resolution height field, the time of singular landscape generation do not exceed 500 milliseconds. In addition examinations reveal an averaging property of the proposed method, is depicted in Fig. 4. The examinations process was executed on standard desktop computer (CPU: Athlon 64 4200+, RAM: 2GB DDR2 800Mhz, GPU: GeForce 7950GT).

Fig. 4. Histogram of average height field values, calculated for ten thousand simulations over 400x300 resolution height-field
Rys. 4. Uśredniony histogram map wysokości o rozdzielczości 400x300, wyliczony na podstawie dziesięciu tysięcy symulacji.

The method's great vulnerability for parameterisation enables adaptation of the algorithm's operations to the satisfactory level of the modelling terrain structure. Furthermore, it gives a tool not only for landscape creation, but also for simulation of natural phenomena, which occurs on the given territory. Thanks to specific dynamic's parameters, it will be possible to simulate snow accumulation and predict of avalanche's descent or which zones of terrain are mostly exposed for landslides. This kind of simulation permits of construction safer areas for buildings and transportation's infrastructure.

Further work will focus on definition of coherent and fully deterministic mechanism, which offers one-timing pass of the algorithm to achieve mostly realistic surface model, that uses non-spherical topology of generated terrain structures, like canyons or rock shelves.

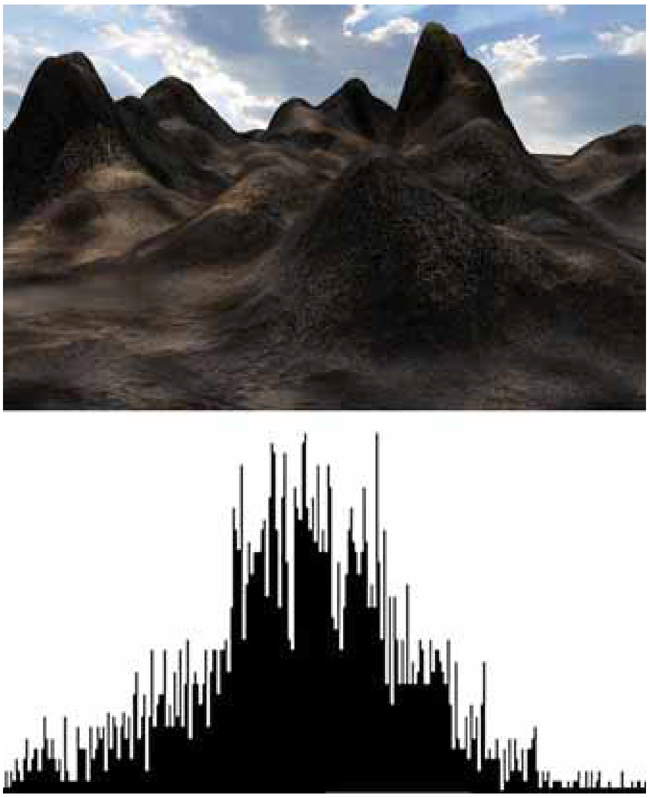

Fig. 5. Example of generated rocky landscape (Rendered in Maxon Cinema 4D) with histogram of height field values
Rys. 5. Przykład wygenerowanego krajobrazu skalistego (Renderowany w programie Maxon Cinema 4D) oraz histogram mapy wysokościowej

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Tytuł: System cząstek w generowaniu ukształtowania terenu.

Artykuł recenzowany