SIBGRAPI 2011

Real-time Terrain Modeling using CPU-GPU Coupled Computation

Adrien Bernhardt (INRIA)
André Maximo (IMPA)
Luiz Velho (IMPA)
Houssam Hnaidi (U. Lyon 1)
Marie-Paule Cani (INRIA)

Maceió – Alagoas – Brazil

INRIA impa cnrs

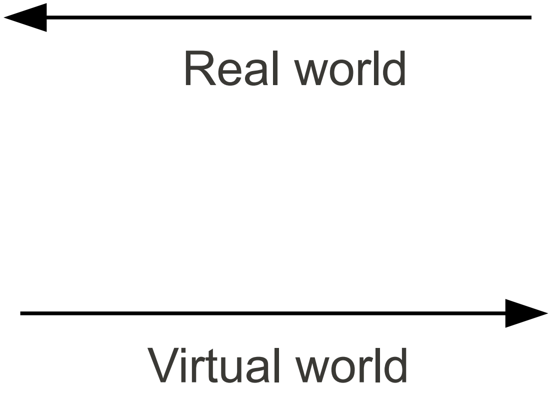
introduction

introduction

why editing is important?

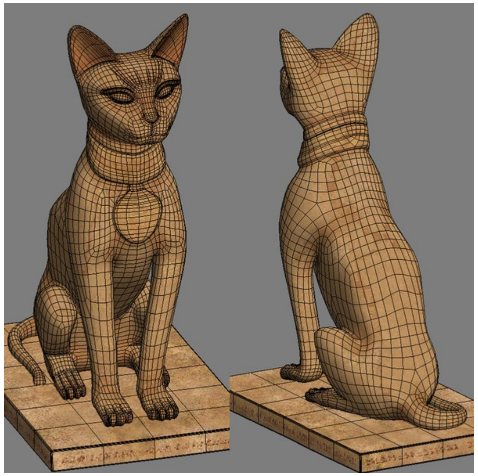
modeling tool features

Venus sculpture



Real world

Virtual world



3D modeling example

introduction

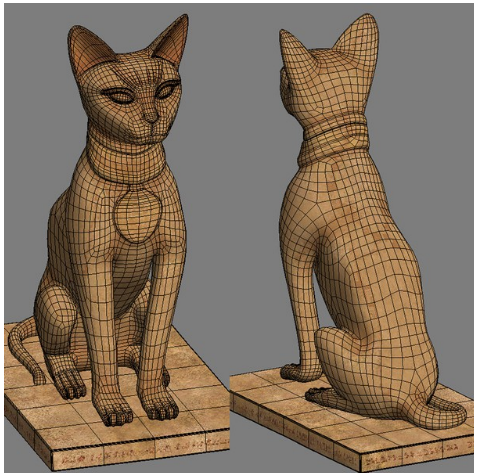
why editing is important?

Venus sculpture

simple way

Scanned

modeling tool features



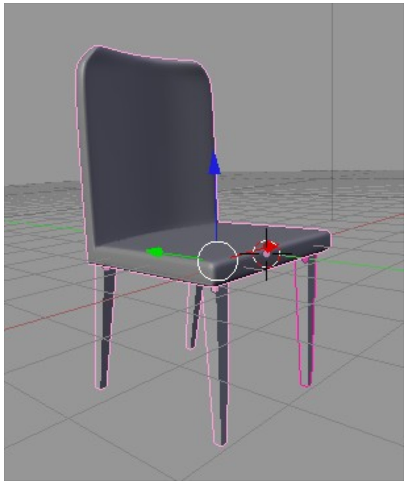
3D modeling example

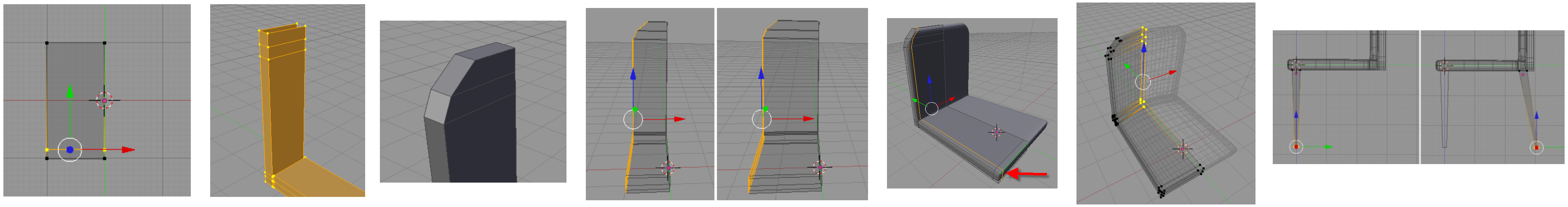
introduction

why editing is difficult?

vertex-by-vertex modeling
can be tedious

Modeling of a chair



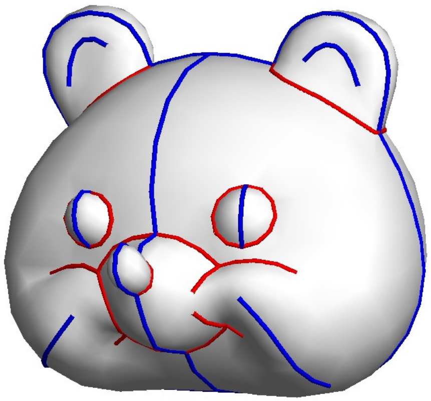


http://www.packtpub.com/article/modeling-furniture-in-blender

introduction

inspiration

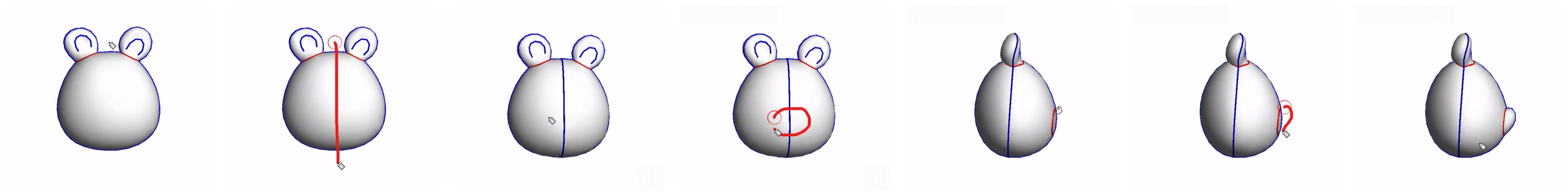
FiberMesh



modeling using 3D curves

easy to interact

automatic generation
curve → surface geometry



A. Nealen, T. Igarashi, O. Sorkine, and M. Alexa, "FiberMesh: Designing Freeform Surfaces with 3D Curves," in *ACM SIGGRAPH 2007 papers*, ser. SIGGRAPH '07. New York, NY, USA: ACM, 2007. [Online]. Available: http://doi.acm.org/10.1145/1275808.1276429

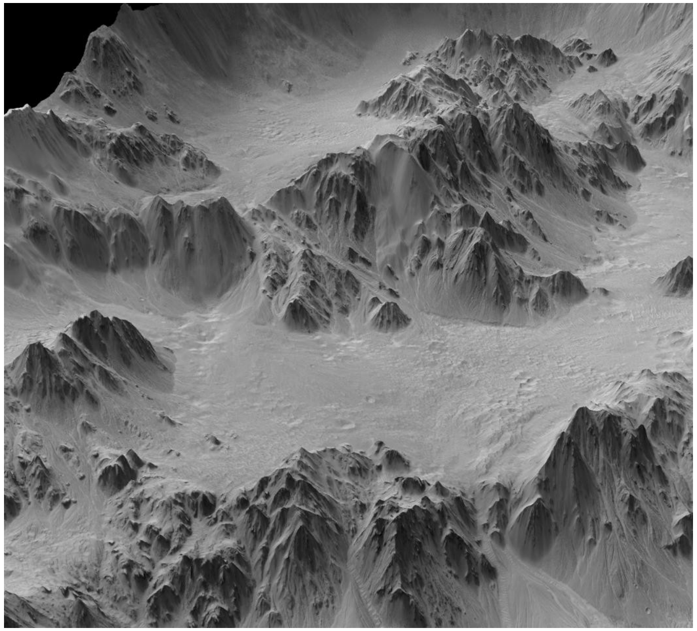
introduction

and what about terrains?

real

Artistic creation

virtual



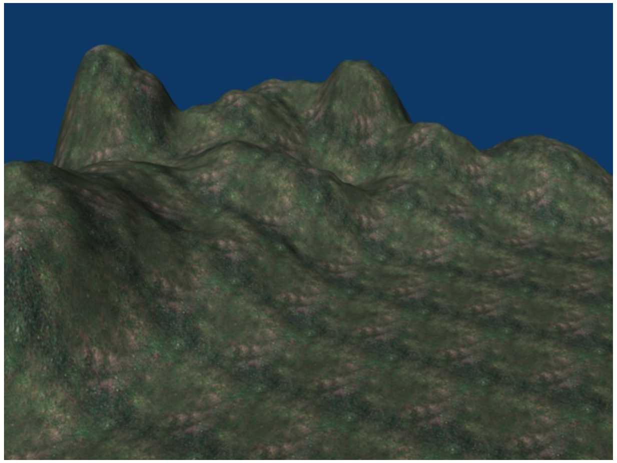
3D model of Mars

introduction

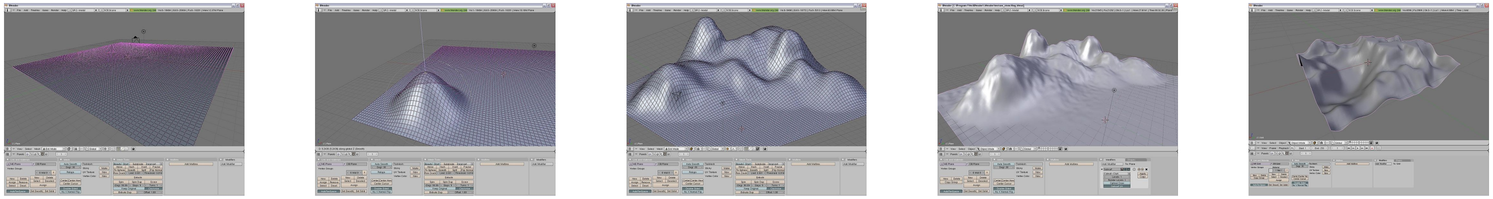
terrain editing can be difficult too!

vertex-by-vertex peaks

Modeling of mountains



add noise



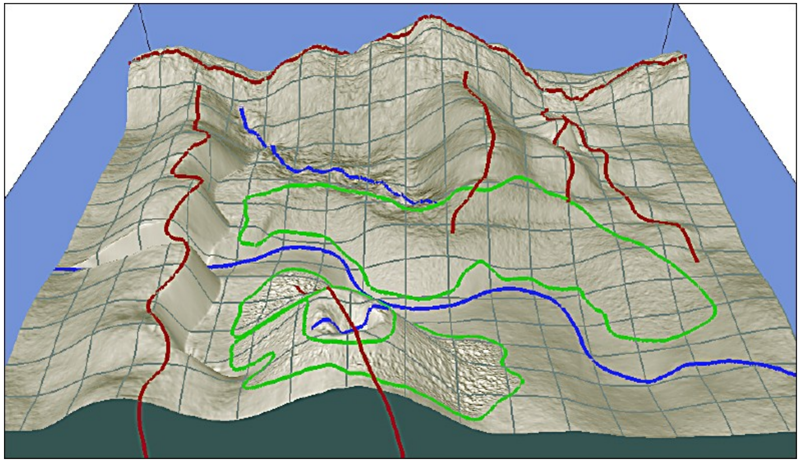
http://en.wikibooks.org/wiki/Blender_3D:_Noob_to_Pro/Landscape_Modeling_I:_Basic_Terrain

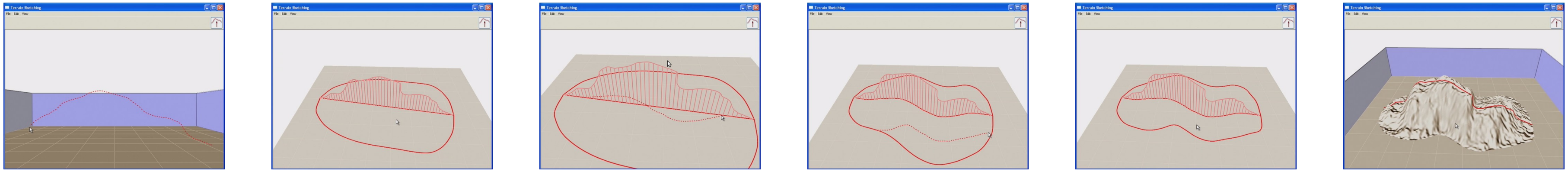
introduction

inspiration

modeling with curves

Terrain Sketching



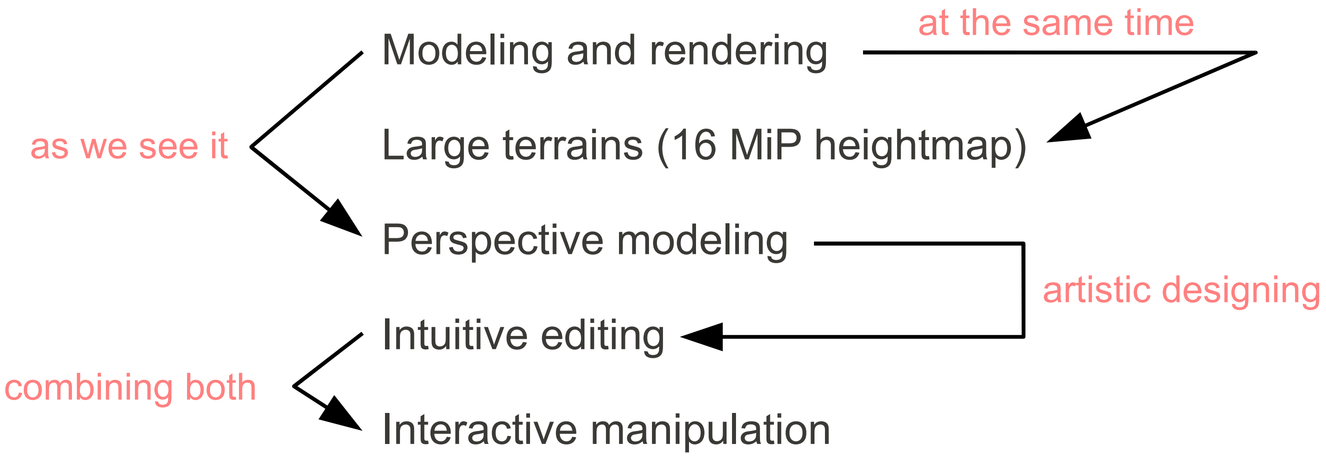


J. Gain, P. Marais, and W. Straßer, “Terrain Sketching,” in *Proceedings of the Symposium on Interactive 3D Graphics and Games*, ser. I3D ’09. New York, NY, USA: ACM, 2009, pp. 31–38. [Online]. Available: http://doi.acm.org/10.1145/1507149.1507155

real-time
terrain modeling

terrain modeling

problem statement



as we see it

Modeling and rendering

at the same time

Large terrains (16 MiP heightmap)

Perspective modeling

artistic designing

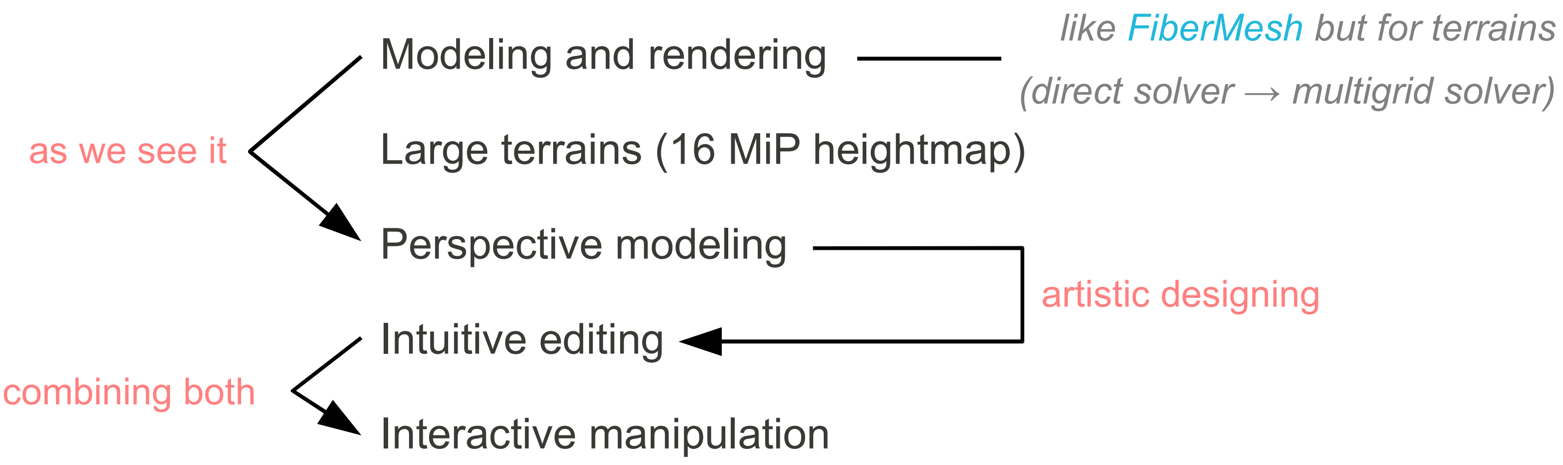
Intuitive editing

combining both

Interactive manipulation

terrain modeling

problem statement



as we see it

Modeling and rendering

like *FiberMesh* but for terrains

(direct solver → multigrid solver)

Large terrains (16 MiP heightmap)

Perspective modeling

artistic designing

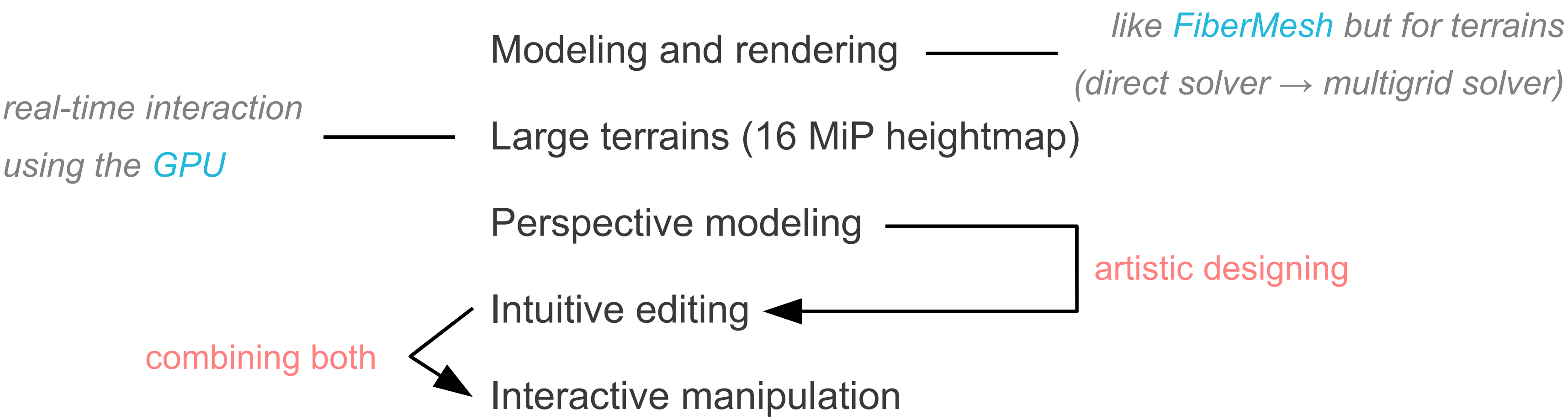
Intuitive editing

combining both

Interactive manipulation

terrain modeling

problem statement



Modeling and rendering

Large terrains (16 MiP heightmap)

Perspective modeling

Intuitive editing

Interactive manipulation

like FiberMesh but for terrains

(direct solver → multigrid solver)

real-time interaction

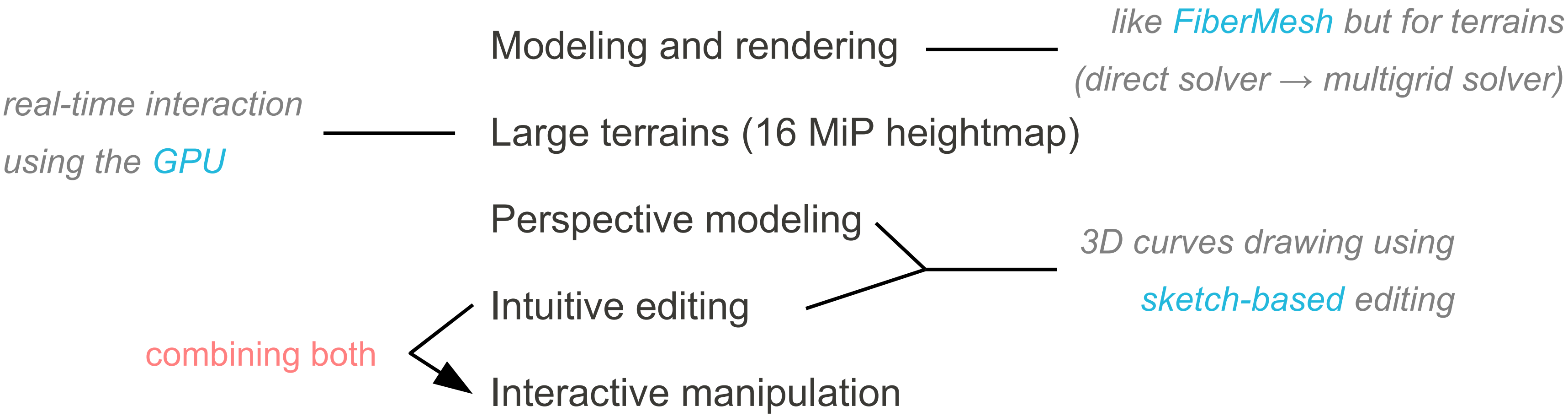
using the GPU

artistic designing

combining both

terrain modeling

problem statement



Modeling and rendering

like FiberMesh but for terrains

(direct solver → multigrid solver)

real-time interaction

using the GPU

Large terrains (16 MiP heightmap)

Perspective modeling

3D curves drawing using

sketch-based editing

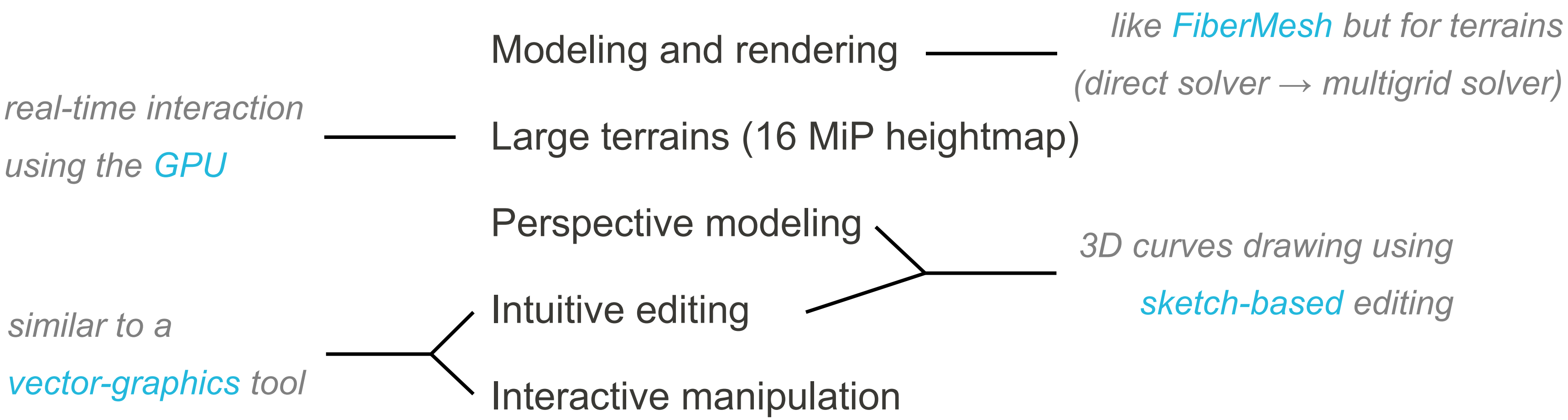
Intuitive editing

combining both

Interactive manipulation

terrain modeling

problem statement



Modeling and rendering

Large terrains (16 MiP heightmap)

Perspective modeling

Intuitive editing

Interactive manipulation

like FiberMesh but for terrains

(direct solver → multigrid solver)

real-time interaction

using the GPU

3D curves drawing using

sketch-based editing

similar to a

vector-graphics tool

terrain modeling

overview

1	Modeling by *sketch*	
2	Light and *adaptive* control of the terrain on the CPU	quadtree
3	Terrain *generation* on the GPU	multigrid solver
4	Terrain *rendering* reducing CPU-GPU communication	tessellation shaders
5	Multiresolution *texture* heightmap	

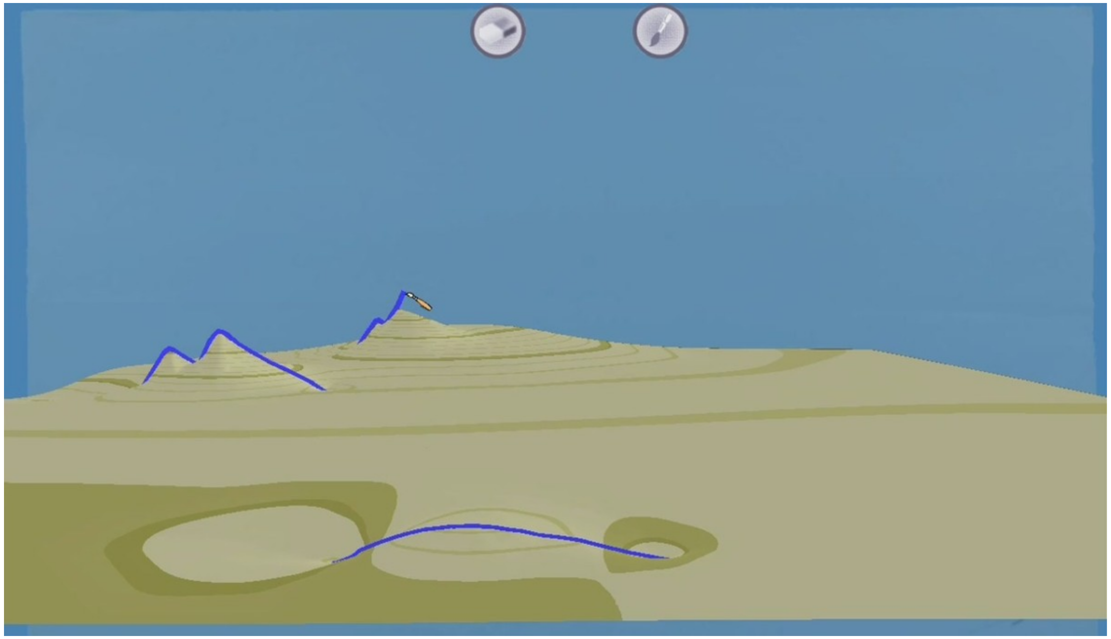
terrain modeling

sketching

the user can navigate over the terrain stopping at any position

The canvas is the

viewing plane



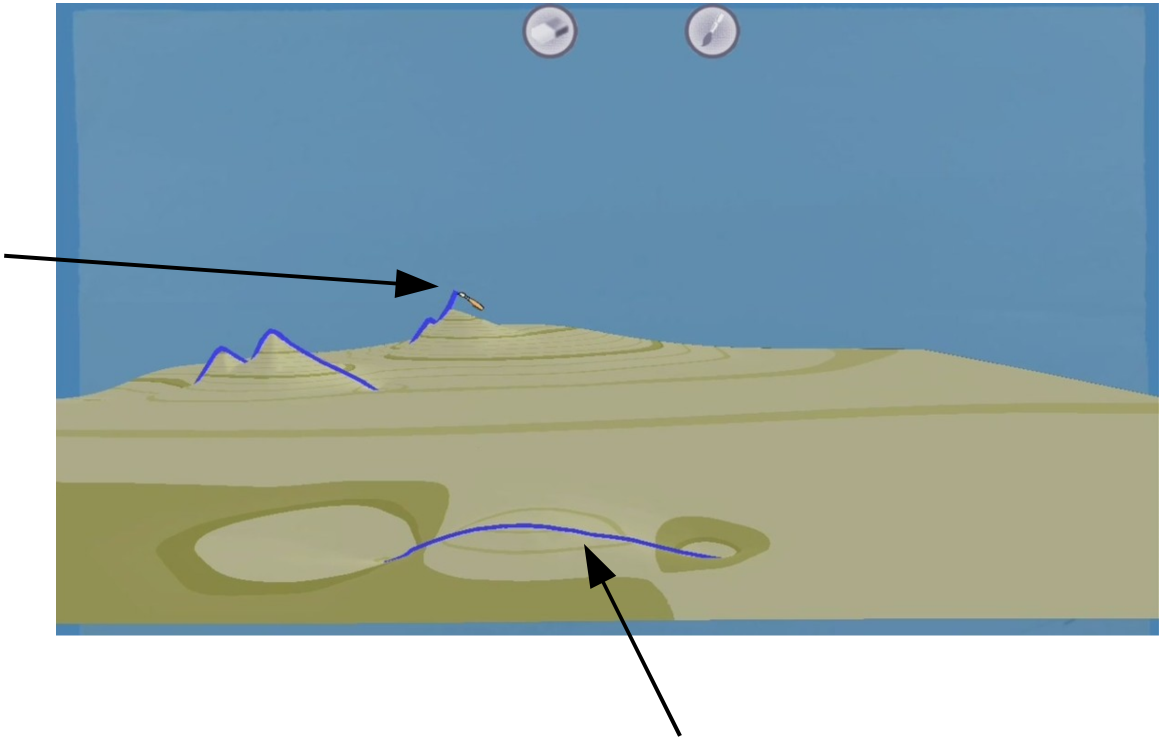
terrain modeling

sketching

the user can navigate over the terrain stopping at any position

The canvas is the viewing plane

Click *or touch* starts drawing primitives



mountain primitive

terrain modeling

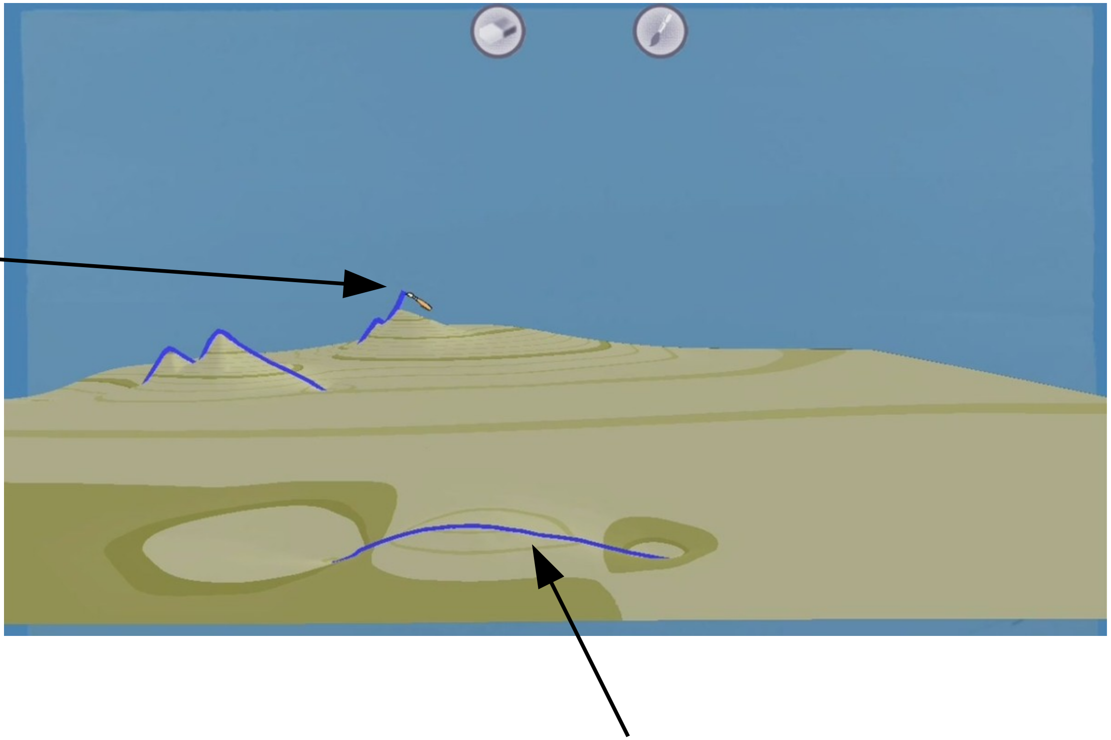
sketching

the user can navigate over the terrain stopping at any position

The canvas is the viewing plane

Click *or touch* starts drawing primitives

First and last points define the drawing depth of the primitive



mountain primitive

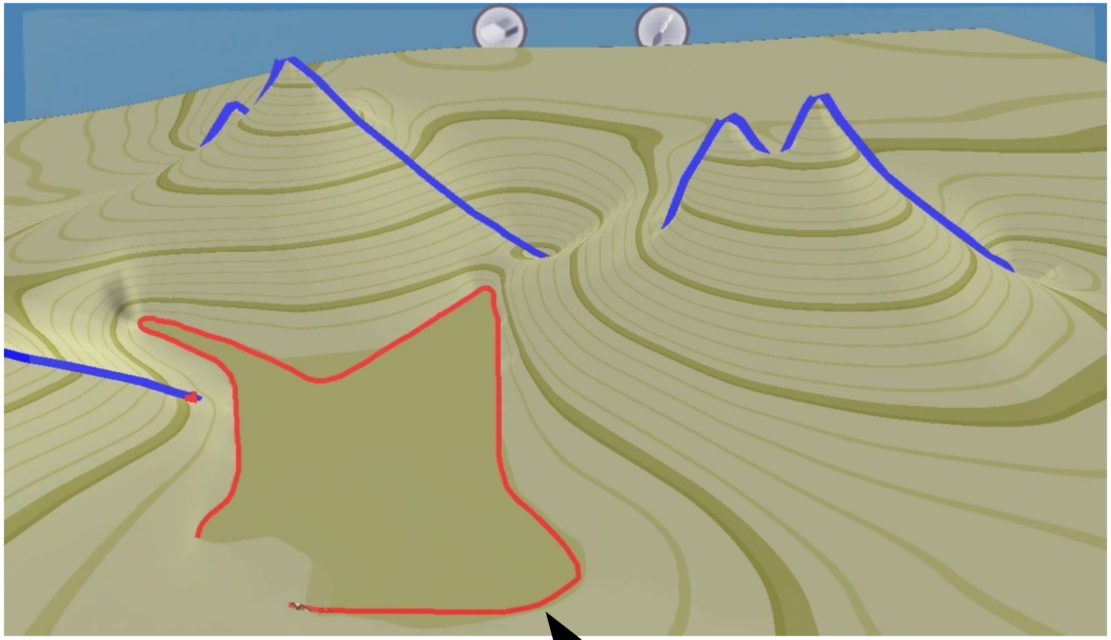
terrain modeling

sketching

the user can change the primitive draw mode

Other primitives are possible

With a different terrain perspective in this example



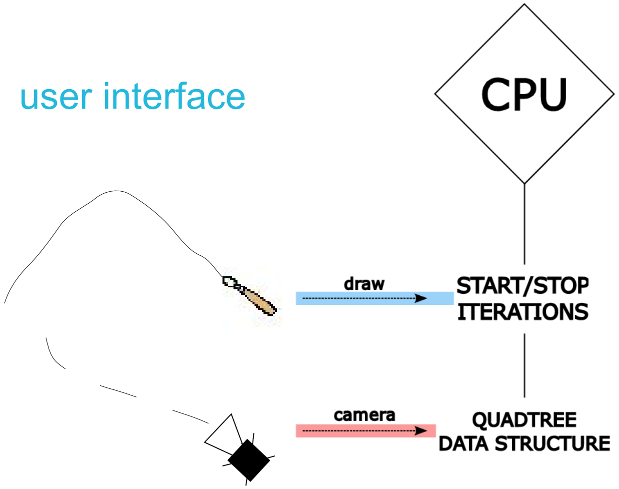
plateaux primitive

terrain modeling

cpu-gpu coupled computation

The CPU acts as a controller

user interface



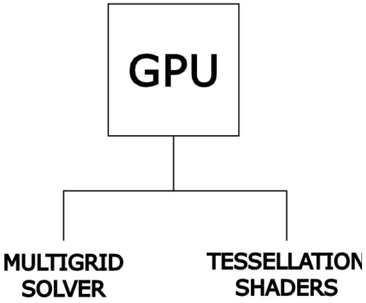
generation of the terrain

rendering of the terrain

terrain modeling

cpu-gpu coupled computation

The GPU offers massive parallelism



GPU

MULTIGRID SOLVER

TESSELLATION SHADERS

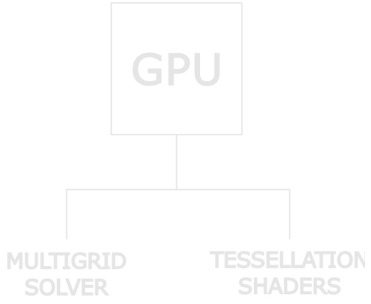
generate the terrain *heightmap*

tessellate the terrain *triangles*

terrain modeling

cpu-gpu coupled computation

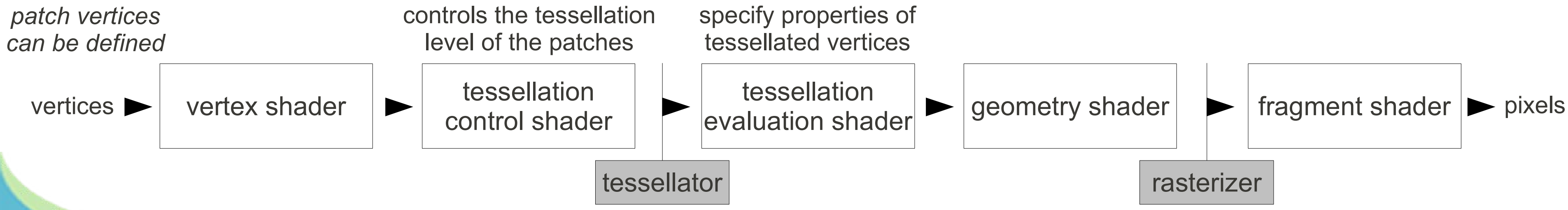
The GPU offers *massive parallelism*



generate the terrain *heightmap*

tessellate the terrain *triangles*

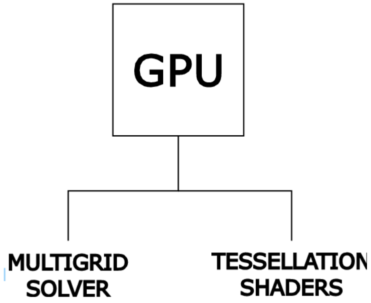
footnote


patch vertices can be defined
controls the tessellation level of the patches
specify properties of tessellated vertices
vertices
vertex shader
tessellation control shader
tessellation evaluation shader
geometry shader
fragment shader
pixels
tessellator
rasterizer

terrain modeling

cpu-gpu coupled computation

The GPU offers <span>massive parallelism</span>



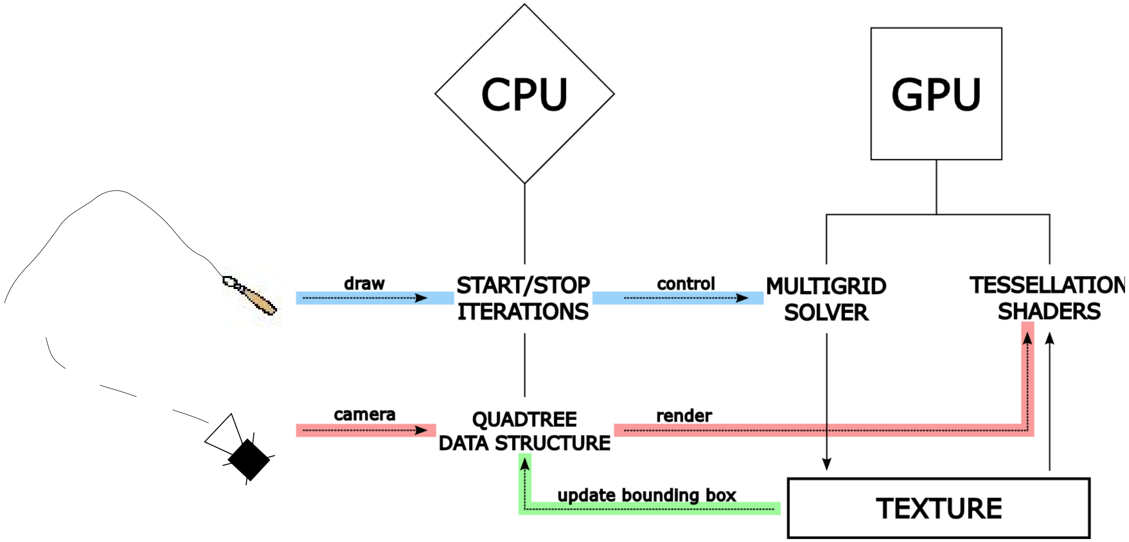
generate the terrain *heightmap*

tessellate the terrain *triangles*

terrain modeling

cpu-gpu coupled computation

The coupled solution favors balancing



the terrain is in *different resolutions* in each unit

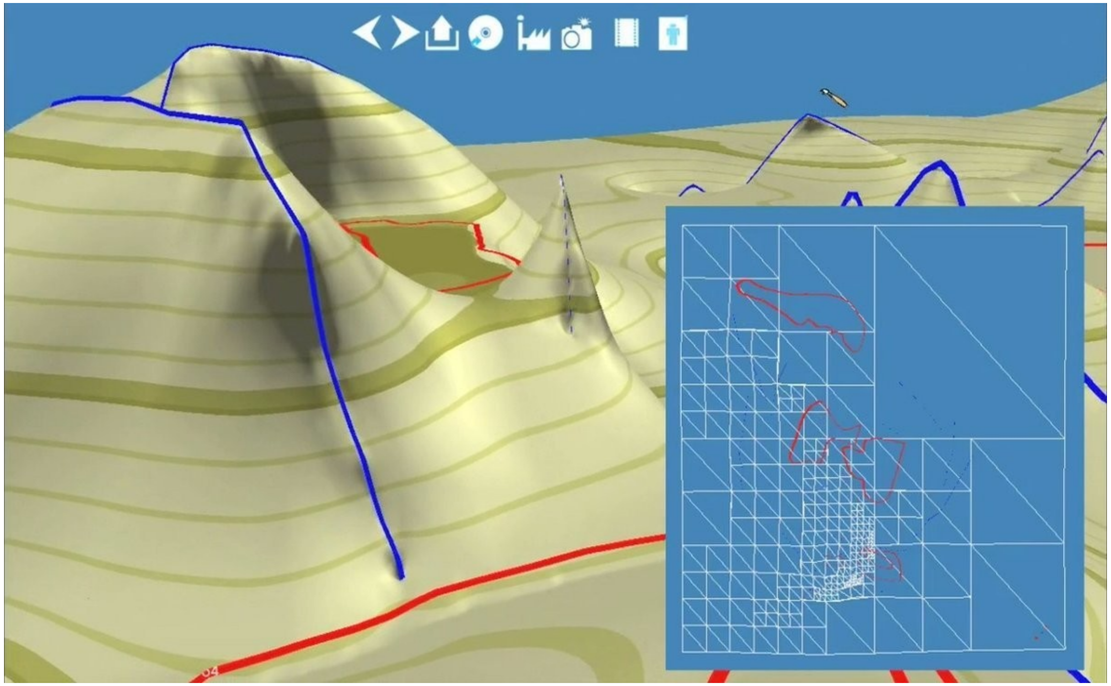
terrain modeling

the quadtree data structure

the quadtree represents the terrain in the CPU

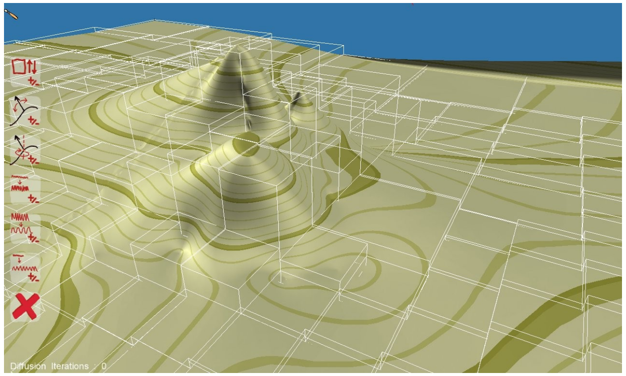
Controls the quad patches to be sent to the GPU

Each quad patch corresponds to a quadtree leaf node

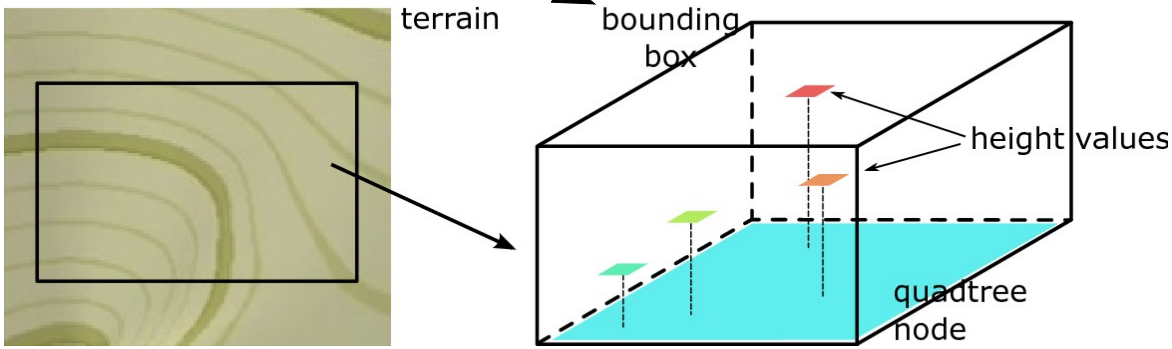


terrain modeling

the quadtree data structure



Each quadtree node has the maximum and minimum value inside the node

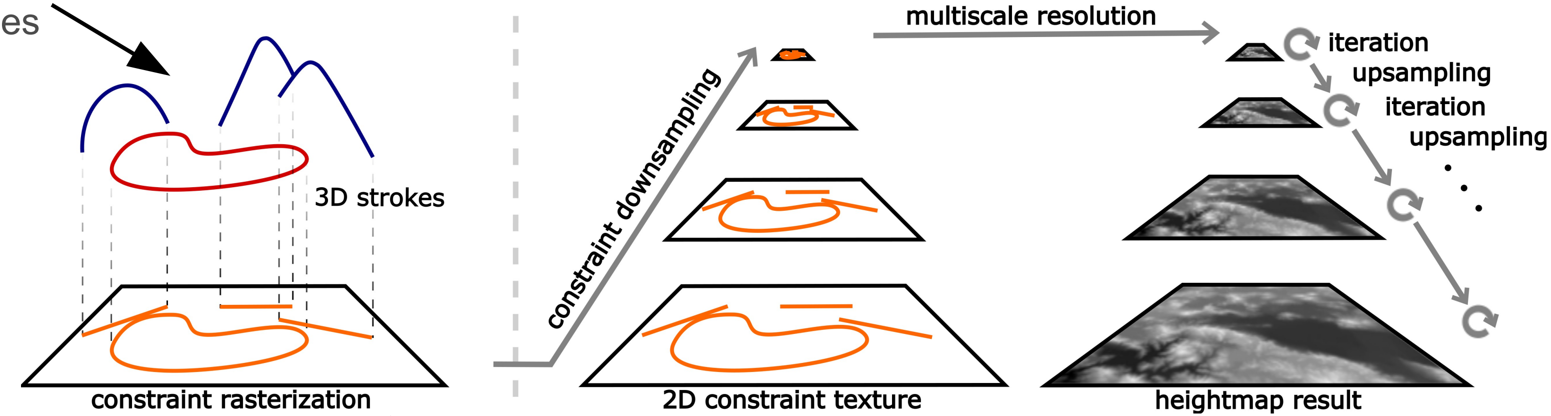


terrain modeling

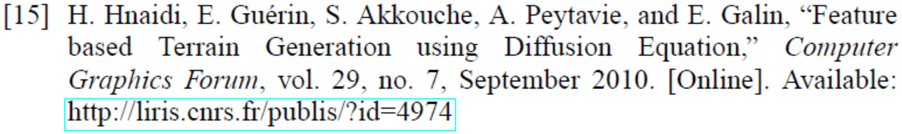
the multigrid solver

Solver generates the terrain:
curve → heightmap

landscape primitives



rasterized to the ground plane

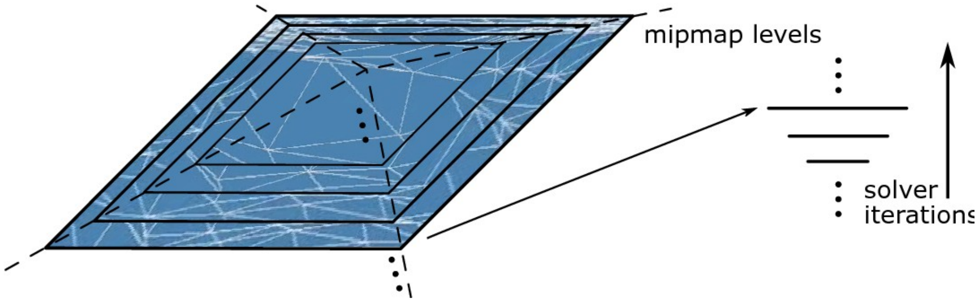


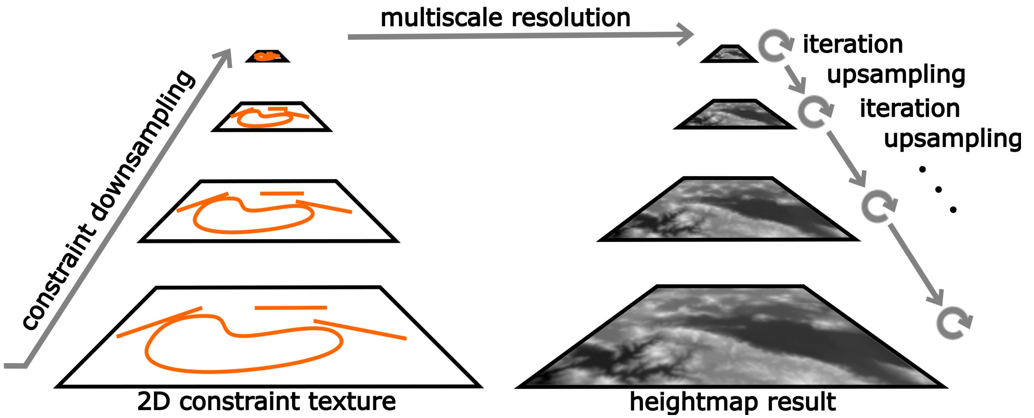
[15] H. Hnaidi, E. Guérin, S. Akkouche, A. Peytavie, and E. Galin, "Feature based Terrain Generation using Diffusion Equation," *Computer Graphics Forum*, vol. 29, no. 7, September 2010. [Online]. Available: http://liris.cnrs.fr/publis/?id=4974

terrain modeling

the multigrid solver

The terrain in multiresolution is stored in a mipmap texture

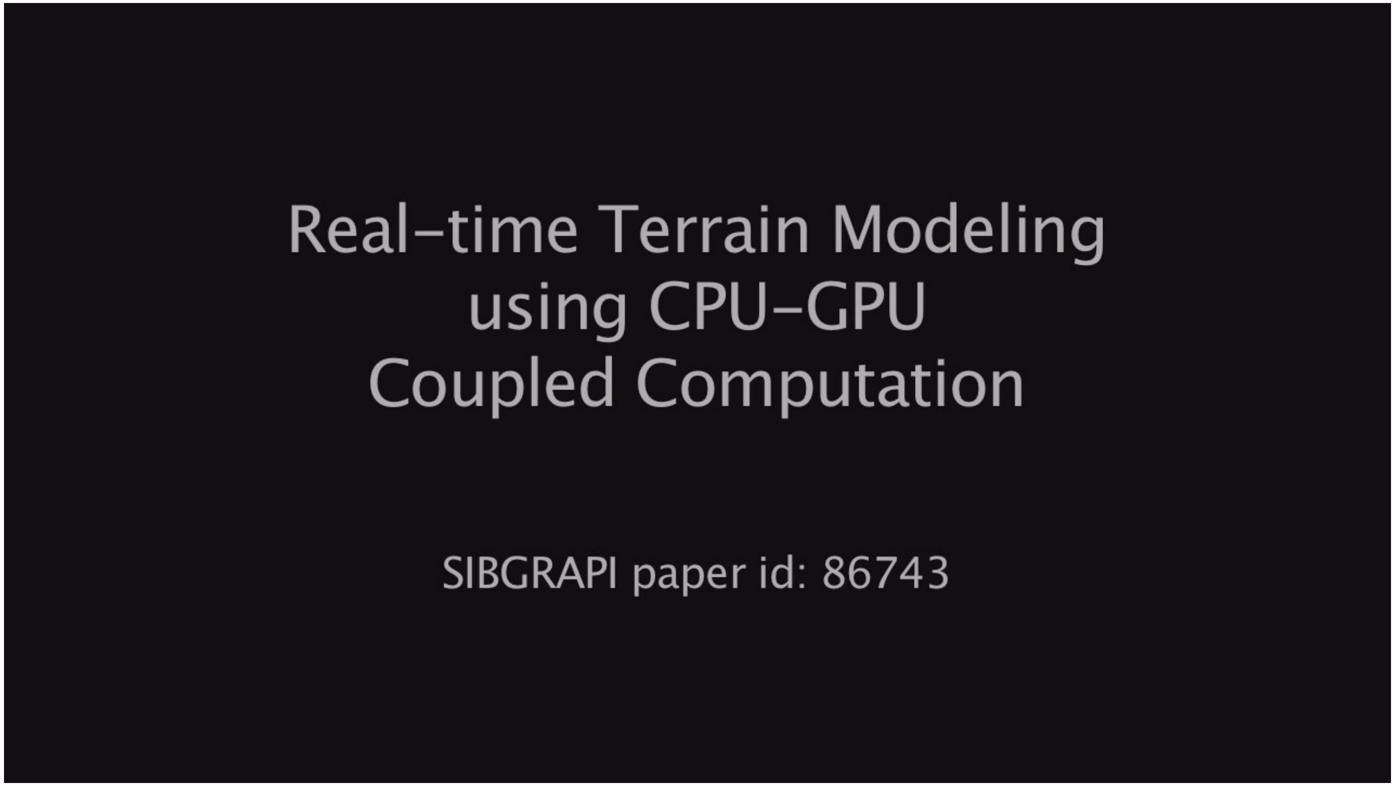




results
&
conclusions

results

video



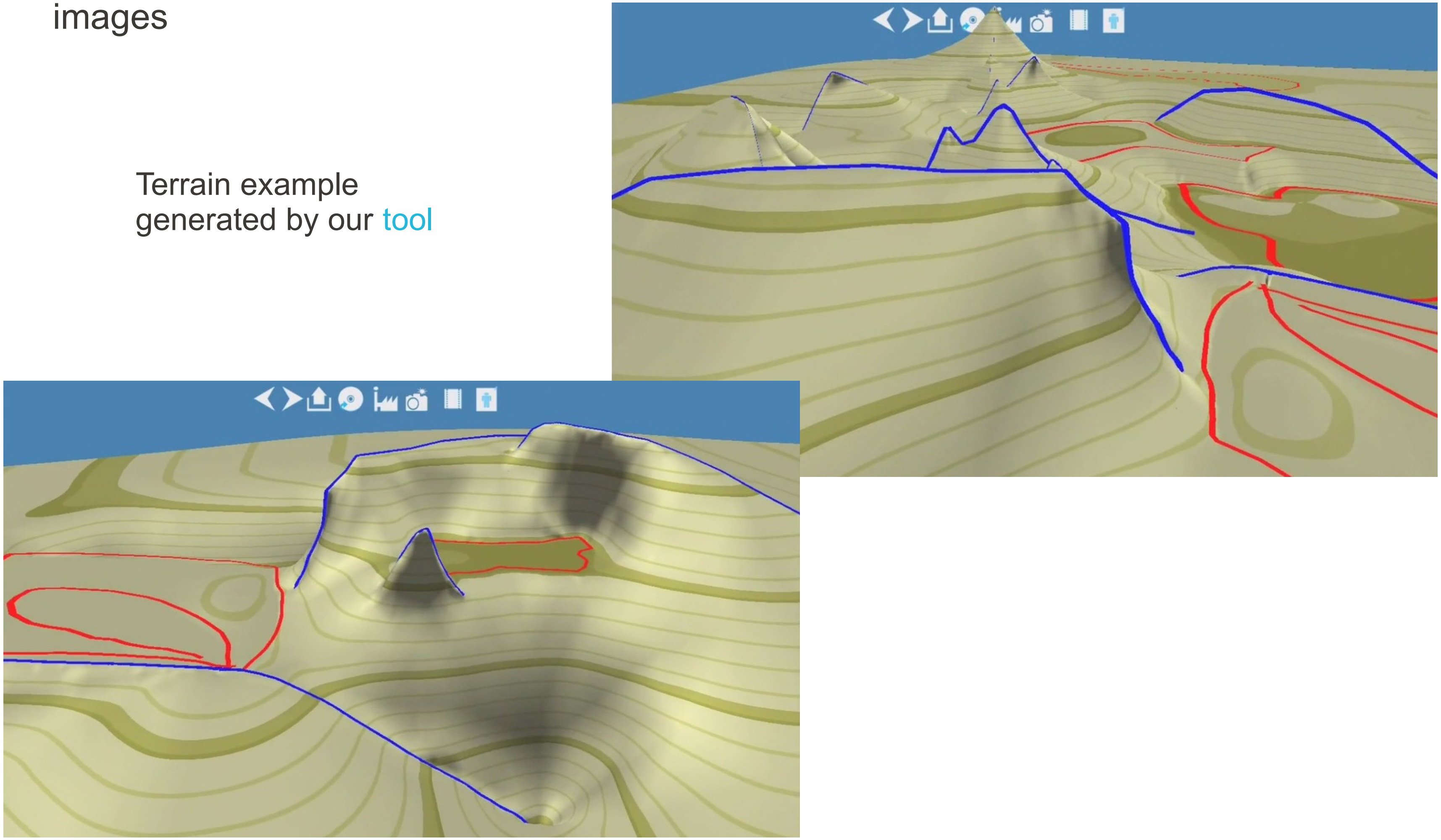
Real–time Terrain Modeling
using CPU–GPU
Coupled Computation

SIBGRAPI paper id: 86743

results

images

Terrain example generated by our tool

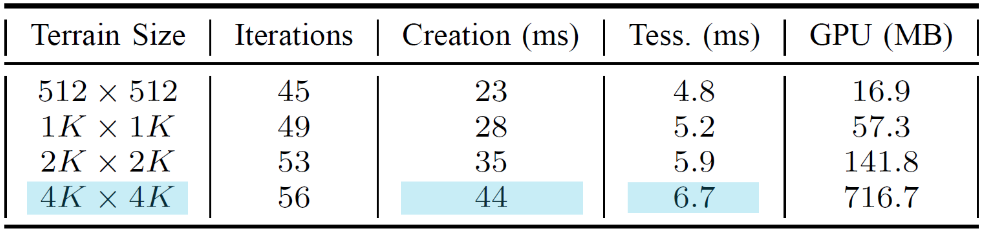


results

timings

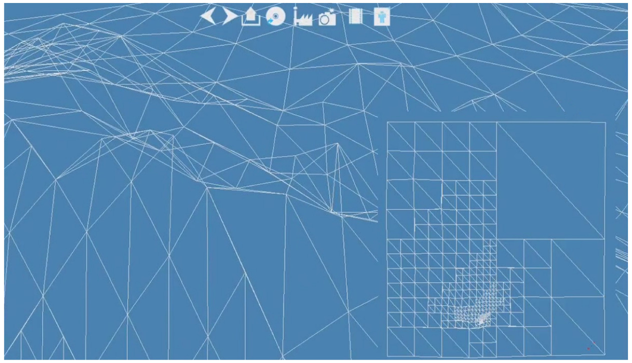
Real-time: 50 ms for a 16 MiP heightmap

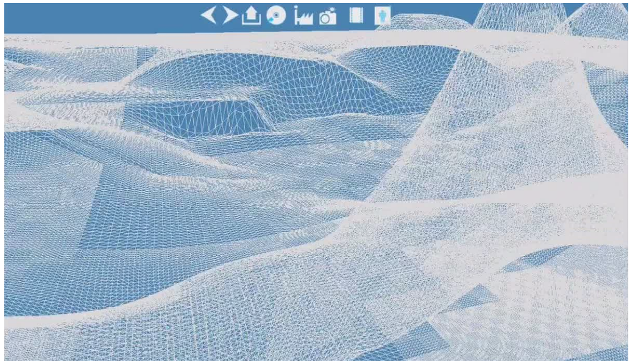
Two orders of magnitude faster than Gain et al.'s approach



Terrain Size	Iterations	Creation (ms)	Tess. (ms)	GPU (MB)
512×512	45	23	4.8	16.9
$1K \times 1K$	49	28	5.2	57.3
$2K \times 2K$	53	35	5.9	141.8
$4K \times 4K$	56	44	6.7	716.7

TABLE I
TERRAIN MODELING COMPUTATIONAL TIMINGS AND GPU MEMORY CONSUMPTION AT DIFFERENT RESOLUTIONS.





conclusions

summary

- Real-time terrain modeling tool
    - Drawing and visualization of terrain primitives at the same time
- CPU-GPU coupled computation
    - Balanced level-of-detail visualization
- Natural and intuitive interaction
    - Pull and push the terrain surface by sketching
    - Use both camera and click events for interaction

conclusions

future work

The multigrid solver can be further improved

- Initial iterations can be done in the CPU

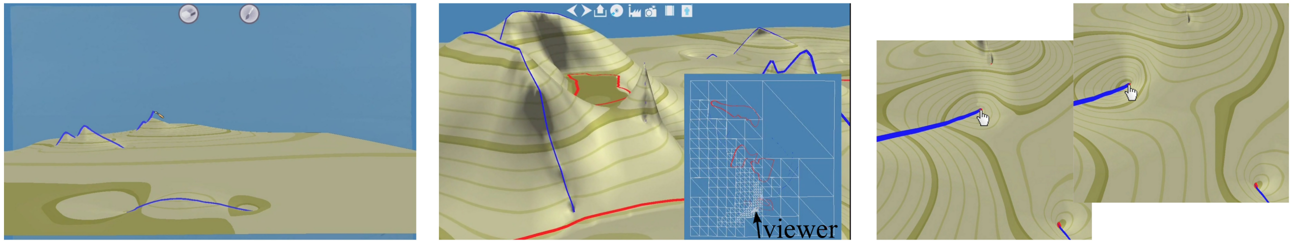
Explore texture filtering in the tessellation evaluation shader

- Anisotropic filtering for geometry

Normal and fractal texture painting

- More realistic results

Extend the idea to general surfaces



thank you

Adrien Bernhardt[1] adrien.bernhardt@inrialpes.fr
Andre Maximo[2] andmax@impa.br
Luiz Velho[2] lvelho@impa.br
Houssam Hnaidi[3] houssam.hnaidi@liris.cnrs.fr
Marie-Paulie Cani[1] marie-paule.cani@inrialpes.fr

[1] INRIA, Grenoble Univ., France [2] IMPA, Brazil [3] LIRIS, CNRS, Univ. Lyon 1, France

http://www-evasion.imag.fr/Membres/Adrien.Bernhardt