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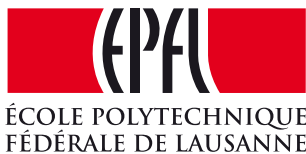
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à la Faculté des Sciences de Base
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École Polytechnique Fédérale de Lausanne

pour l'obtention du grade de Docteur ès Sciences
par

Paolino Paperino

acceptée sur proposition du jury:

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Prof Name Surname, rapporteur
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Prof Name Surname, rapporteur

Lausanne, EPFL, 2011

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Wings are a constraint that makes
it possible to fly.
— Robert Bringhurst

To my parents...

Acknowledgements

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Lausanne, 12 Mars 2011   D. K.

Preface

A preface is not mandatory. It would typically be written by some other person (eg your thesis director).

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Lausanne, 12 Mars 2011   T. D.

Abstract

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Zusammenfassung

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Résumé

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1 Introduction

Limitations

Microscopy: - optical -> video rate but crappy resolution - EM -> rasterscan can slow electron beam fast - AFM -> slow mostly because of bulky mechanics: intertia (mass of the system), toshi ando small piezos (small range) but fast

Using spiral has been shown to be better(demands less BW x,y) but need display of non gridded data (lower res. freq. system)

z is still limiting to go on large scales (x,y)

2 Visualisation of non-gridded data

Most of the current AFM acquisition softwares work the following way: projecting two-dimensional data on a N by M grid. A system of controllers is needed to position the cantilever at the right spot (center of a grid element). With this method, the actual position on the XY plane is unprecise and directly correlated with the efficiency of the position controller. By taking the acquired z-data and assuming that the cantilever was actually on the right spot, we can construct a two-dimensional image of the surface. One can already see the problems induced by this method: limitation by the controllers(speed and precision). Moreover, putting data on a grid forces the scan pattern to be raster. It is simple to project a raster pattern on a 2D grid. Finally, hysteris problems in the piezos is an additional imprecision in the system. We'll see how we can use position sensors on the XY-plane and different scan pattern to solve this problem.

2.1 sensor data

(problem of hyst solved) - graph of hyst - kalman (bit noise)

2.2 experimental setups

- MFP3D: capacity based - Homebuilt - attocube: interferometer

2.3 Image rendering techniques

- OpenGL and heat equations - benchmarking

Current AFMs give discrete data about the cantilever's position; therefore, we'll need to use image processing algorithms to generate images. The process of restoring unknown images is called inpainting. Indeed, it was mainly used to restore missing pieces in old paintings or photos. The principle behind inpainting is to fill a patch with its surroundings. A perfect

example of inpainting is removing an undesirable object from a picture.

We can use these algorithms to generate images from a cloud of points.

2.3.1 Heat equations

The heat equation represents the distribution of heat in a region over time.

$$\frac{\partial u}{\partial t} - \alpha \nabla^2 u = 0 \tag{2.1}$$

α is the thermal diffusity - that is interpreted as a "thermal inertia modulus" - and u is the temperature over space and time (i.e. $u(x, y, z, t)$). A high thermal implies that the heat moves rapidly.

2.3.2 OpenGL

In this section we'll talk about different ways to render 3D models with OpenGL (Open Graphics Library). This library is an API (Application Programming Interface) developed by Silicon Graphics to hide the complexities of interfacing with different 3D accelerators. It is mainly used for 3D modeling in video games and simulations. We've decided to use OpenGL because of it's efficiency to plot 3D models with triangles. Indeed, modern GPUs (graphic processing units) are optimized to render objects from triangles. There are many different methods to plot 3D data with OpenGL, we'll investigate using the "direct mode" and vertex buffer objects.

Triangulation with Delaunay

The first problems we'll face when trying to plot our cloud of points is to know how to generate triangles. Indeed, OpenGL can only render triangles from a triplet of points. An unordered list of points will not be optimized by OpenGL into triangles. TWe'll need sophisticated algorithms to obtain those. The principle behind the Delaunay triangulation is to generate triangles from triplets of point. The goal of the algorithm is to minimize the angles of each triangle. The triangulation is successful if no vertex (i.e. 3-dimensional point) is in the interior of a triangle.

/IMAGE

Triangle.c is a library developped in C by Jonathan Shewchuk [Shewchuk(1996)] to generate Delaunay triangulations. In our case, we'll only use the triangulation program on the first two dimensions of the 3d cloud of points. Indeed, we'll only render triangles on the 2D plane.

The next step is the coloring of the data. We use the z-data to render the color of the image.

Direct mode vs VBO

3 Z axis limitations

4 Results

4.1 Calcite experiment

In this experiment we've observed the dissolution of calcite ($CaCO_3$) with water. This experiment is interesting

4.2 Soft sample

A An appendix

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[Shewchuk(1996)] Jonathan Richard Shewchuk. Triangle: Engineering a 2D Quality Mesh Generator and Delaunay Triangulator. In Ming C. Lin and Dinesh Manocha, editors, *Applied Computational Geometry: Towards Geometric Engineering*, volume 1148 of *Lecture Notes in Computer Science*, pages 203–222. Springer-Verlag, May 1996. From the First ACM Workshop on Applied Computational Geometry.