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Losowe upakowania układów złożonych z dysków z wykorzystaniem kart graficznych

Praca magisterska
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Praca wykonana pod kierunkiem
dr. hab. Michała Cieśli
z Zakładu Fizyki Statystycznej

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Oświadczenie autora pracy

Świadom odpowiedzialności prawnej oświadczam, że niniejsza praca dyplomowa została napisana przeze mnie samodzielnie i nie zawiera treści uzyskanych w sposób niezgodny z obowiązującymi przepisami.

Oświadczam również, że przedstawiona praca nie była wcześniej przedmiotem procedur związanych z uzyskaniem tytułu zawodowego w wyższej uczelni.

....
Kraków, dnia   Podpis autora pracy

Oświadczenie kierującego pracą

Potwierdzam, że niniejsza praca została przygotowana pod moim kierunkiem i kwalifikuje się do przedstawienia jej w postępowaniu o nadanie tytułu zawodowego.

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Kraków, dnia   Podpis kierującego pracą

Chapter 1

Introduction

TODO make this at the end, when all else is done

Contents

Chapter 2

Problem Overwiev

2.1 Random Sequential Adsorbtion

Random Sequential Adsorbtion is a stochastic process, that can be described as sequential insertion of given shapes onto an empty, limited euclidean space. The shapes are inserted with random position, and in such a way, that if the shape is colliding with an already inserted shape, it is then rejected in the process. The shapes and the space may be defined as having one or more dimensions, with any kind of inserted shape type. The shapes may be generated with random coordinates within given dimensions, as well as random rotation - although this may be optional.[1][2]

2.1.1 Shape Types

The inserted shape that were previously studied include rectangles, squares and other polygons, cubes and hypercubes. Also, the most basic shape usually investigated is a sphere - up to eight dimensions. Other studies involved spheroids, hyperdisks and, what is going to be further investigated in this thesis, disk polymers, or simply two dimensional groups of disks. In case of non spherical shapes, the shape angle can be randomly generated.[3]

2.1.2 Applications

The Random Sequential Adsorbtion can be applied to multiple problems. The process as well as the generated shapes can be used to model a variety of phenomena. These include the ion implantation in semiconductors, structure of the cement paste, particles in cell membranes, protein adsorption and settlement of animal territories.[4] In general, it can be used to model

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[1]G Zhang. "Precise algorithm to generate random sequential adsorption of hard polygons at saturation". In: *Physical Review E* 97 (Mar. 2018). DOI: 10.1103/PhysRevE.97.043311, p. 1.

[2]Jens Feder. "Random sequential adsorption". In: *Journal of Theoretical Biology* 87.2 (1980), pp. 237 –254. ISSN: 0022-5193. DOI: https://doi.org/10.1016/0022-5193(80)90358-6. URL: http://www.sciencedirect.com/science/article/pii/0022519380903586, p. 1.

[3]Zhang, "Precise algorithm to generate random sequential adsorption of hard polygons at saturation", op. cit., p. 1.

[4]Ibid., p. 1.

tightly - but still randomly - packed particles.

A significant example is the Poisson Disk Sampling, which is a process of selection of points in subdomain, in such a way that within a given distance from the selected point, no other are taken. This distribution is used in computer graphics for rendering, texture generation, and more. In ray tracing, it is used to create soft shadow, motion blur and the depth of field. In physics, it can be used for mesh generation, interpolation and process modeling. In some cases, the generated meshes have improved quality and are generated more robustly.[5]

2.1.3   Challenges

While the principle behind RSA algorithms is simple, the execution of it's naive implementations will commonly lead to problems. As the figures are randomly generated and inserted to the area, the probability of rejection of said shape will grow with the saturation of the system. In simpler words, the more figures are already inserted, the more likely it is that a new one will overlap a pre-existing one, which leads to long execution times and uncertain end conditions. The goal of many approaches is to propose an algorithm that will be able to quickly generate shapes within given space, and have clear end conditions signifying a fully saturated state.

2.2   Thesis Goals

This thesis focuses on one particular subset of RSA, namely, the generation of polydisks in two dimensional space. It's goal was to create an algorithm that would take advantage of great degree of parallelization available through using the GPU. A pre-existing algorithm developed by dr. hab. Michał Cieśla enables quick sequential or thread-level parallel generation of polydisks in a 2D area. Such algorithm can be used to simulate the packings of particles on a surface; Which itself is usefull in physics and material research.[6]

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[5]Mohamed S. Ebeida et al. "A Simple Algorithm for Maximal Poisson-Disk Sampling in High Dimensions". In: *Computer Graphics Forum* 31.2pt4 (), pp. 785–794. DOI: 10.1111/j.1467-8659.2012.03059.x. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8659.2012.03059.x. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8659.2012.03059.x, p. 1.
[6]**ciesla**.

Chapter 3

Proposed Algorithm

3.1   Voxel-Based Algorithm

The basic algorithm used in multiple RSA applications involves the use of voxels. The voxels are defined as subspaces of the saturated area, which cover it entirely. After one or more shapes are inserted, the voxels may be removed if within them no more figures can be inserted. Developing an algorithm for "voxel rejection" is the main concern of those undertakings. Only within the non-removed voxels the figures can be generated. After inserting more figures, if the voxels are not rejected or the figures are rejected too commonly - the voxels are split into smaller voxels to be able to further reject them. If all voxels are removed, the system is saturated. An example of such algorithm, using the two dimensional circles as figures is demonstrated below:

3.2   Sequential Algorithm

3.3   Parallel Application

3.3.1   Block Graph

3.4   Implementation

3.4.1   PyCuda

3.4.2   Visualisation

3.4.3   Summary

TODO unfinished, do in near future

Chapter 4

Results Examination

4.1 Performance Evaluation

4.1.1 Parameter Influence over Performance

4.1.2 Shape Influence over Performance

TODO unfinished, do later

Bibliography

Ebeida, Mohamed S. et al. "A Simple Algorithm for Maximal Poisson-Disk Sampling in High Dimensions". In: *Computer Graphics Forum* 31.2pt4 (), pp. 785–794. DOI: 10.1111/j.1467-8659.2012.03059.x. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8659.2012.03059.x. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8659.2012.03059.x.

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