Geometric packing for rock accumulation analysis

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1 Introduction

The discovery of new environmentally friendly materials is a priority in Chile in order to become a developed country. Some examples of possible applications for these new materials are insulating materials, tunnels stabilization, mining waste formation and shapes among others. However the design of these new materials by trial and error is time consuming and expensive. Therefore the development of computer based tools to predict the properties of putative materials is essential to accelerate their discovery.

In terms from reservoir engineering standpoint [2], research in new alloying materials has been carried out in Chile. One of the researches studies that needs further analysis is on porosity, the measuring of space available for hydrocarbons storage. Research on this topic has not been carried out extensively yet and further investigations would be on the creation of alloys in Chile.

The problem of porosity can be solved using the packing perspective. That is to say, the packing problem is an optimization problem that intends to organize the content of a container as densely as possible. There is extensive research on circle [4] and sphere packing and for square-like or rectangular-like shapes some research has also been done [8]. On the contrary, research in convex polygon shapes is very novel and unexplored [5]. We propose to develop an algorithm to design new materials by optimizing the packing problem with variables like porosity using only convex polygonal shapes.

2 Related work

The packing algorithm is an optimization problem that tries to pack objects together into reduced spaces. There are two main aspects to be considered: (i) the objects to be packed and (ii) the containers. In terms of the objects, there are algorithms for the variety of shapes to be packed like rectangles, squares, circles, convex shape polygons and irregular shape polygons. The irregular shape polygon refers to both convex and concave polygons. In this section we will briefly describe some of packing algorithms that have been developed will be described.

2.1 Rectangular-like shape packing algorithms

One of the heuristics is the Bottom-Left (BL) algorithm, which takes a new rectangle and starts at the top-right corner, the item is slid as far as possible to the bottom and then as far as possible into the left corner. These steps are done until the item remains in the same position it was when the new loop started [8].

The second heuristic is the Bottom-left-fill (BLF) algorithm that consists of placing the rectangle into the lowest available position of the object and left-justifying it [8].

2.2 Circle packing algorithm

A circle packing is an algorithm that subdivides a finite space into a configuration of circles with a specified pattern of tangencies. This iterative algorithm was suggested by William Thurston in 1978 [12], since then many algorithms and implementations about this matter have been done. Some of the most recent implementations are ones that use local properties to accelerate the convergence of the algorithm (2003) [4], the polynomial time circle packing (1993) [10] and most recently one that uses a technique of alternating between estimations of circle radii and locations of the circle centers (2017) [11].

2.3 Convex polygon packing algorithm

There is one simple technique that simulates where the next convex polygon should be placed [6]. It uses three steps it first generates where a new polygon should be placed. Second, it calculates the ”Minkowski addition” [1] of the new polygon another P and Q, and checks if the intersection of these new regions is a position where the generated polygon touches the two previous P and Q polygons. Thirdly, it checks if the new position overlaps any existing polygon.

2.4 Irregular shape packing algorithm

Packing irregular shape polygons is an NP-complete problem, so there is a lot of research on these topics. This problem is commonly noted as the nesting problem and it refers to nesting objects in the most time and space efficient way. In the next section [3] are listed the newest algorithms that solved the nesting problem with some restrictions. Most of them use the NFP polygon, this NFP polygon is a polygon derived by combining two polygons overlapping one over the other. This NFP is used to determine the best position to insert the next polygon. An excellent approach of this problem was made by [7], they used the neighbourhood technique by swapping pieces of the layout for a denser packing.

3 Problem

The problem is how to simulate rock accumulation. In previous investigations, researchers have used Voronoi diagrams for rock accumulation analysis. Therefore, for the mesh creation they used a Voronoi generation library [9], but these meshes need the initial points of the diagram and are currently made by hand.

We aim to produce a more automatized creation of the meshes, that is to say, design and implement a packing algorithm that simulates the rock accumulation process. The convex polygons will be arranged in a way that the probability of choosing a polygon is the same as a normal distribution, that is to say, we are packing polygons by a Gaussian function over the size of the polygons, also it can be a function over other variables like weight, rock properties among others.

So for that purpose we have two approaches. For the first one we will design and implement an algorithm that uses the convex polygon packing algorithm form [5], this will use the Minkowski addition for deciding which position is the best to minimize or maximize the property that was chosen as the parameter like size. The second approach is to use an approach with an irregular shape packing algorithm [7], this uses the NFP to determine the best position of the next polygon to be placed, also swapping operations over the polygons for better results.

4 Research questions

Is there an algorithm that can be adapted to Chilean research investigations?

Could irregular shape packing algorithms generate a more realistic mesh than convex shape packing algorithms?

Does adding normal distribution choices to geometric packing make a more realistic mesh?

5 Hypothesis

The irregular shape algorithm will generate better modeling results than the convex polygon approach.

6 Main aim

In this investigation we will implement a geometric packing algorithm for convex-like shape polygons, with the size and shape of the polygons chosen by a normal distribution function.

7 Specific aims

- Design and implement a general way to make a choice for the next polygon to be inserted. Add a Gaussian function that makes the election of the next inserted polygon with a preset measure like the size of the polygon.
- Design an algorithm using the [5] approach.
- Design an algorithm using the [7] approach.
- Make software to analyze the results and to simulate posterior investigations.
- Compare the results of the two algorithms.

8 Methodology

8.1 Research

To better approach how packing works in real life, there will be an ongoing dialogue with experts in civil engineering and mechanical engineering. To refine what types of physical variables will be working afterwards, for example, the size, and roundness, among others.

8.2 Packing algorithm framework

First we need to decide on the next inserted polygon, for that a Gaussian function is going to be performed to choose this polygon. Also this decision could be implemented with latest research on probabilistic programs. A probabilistic program may be implemented with probabilistic programming languages, this will be considered as an alternative.

For the packing algorithm there are some proven techniques that will be implemented which are advancing front packing with the locus approach [5], the algorithm that takes advantage of locality using neighbourhood and swapping neighbours approach. [7].

8.3 Experimentation

The algorithm will be compared with different variables that are considered relevant in the study of rock accumulation. For example, which algorithm gives a denser packed mesh. Also the running times of the algorithms that will be implemented will be tested, along with testing different rock sizes or changing the normal distribution of the input. For further and better experimentation the new meshing algorithm will be compared with data on real-life rock accumulations.

8.4 Technologies

For the implementation of the algorithms will be implemented in C++ or Python and desirable in Scala. The provided framework from a previous thesis is written in C++.

9 Expected results

New meshing algorithms based on packing convex shape polygons.

A software that provides a useful and interactive interface for the analysis of rock accumulation. With the selection of the polygon which will be packed and the details of the probability of each polygon. Also two packing algorithms will be available for academic use.

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