Independent Study Report
Topic: Granular Dynamic Solver

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Abstract
The purpose of this project is to find a method to reduce the error between models and objects. We choose to use spheres to model the object. Our method contains two parts, the judgment part and the slice part. The code of judging part is finished by the weight equation, which contains the weird degree, the value of modification, and the volume ratio as factors. The workflow of slicing parts contains four steps, and the purpose of these steps is to create two spheres that can model the target mesh. Also, we include some examples that show the performance of our algorithm.

Introduction
A granular Dynamic Solver is an algorithm using spheres to model the object. The algorithm can output the position of spheres points and the radius of spheres after the customers input the object file and the expected number of spheres. Because the sphere model is friendly for force analysis. The main purpose of this project is to find a method to reduce the error between models and objects. Firstly, the report will discuss the method used for constructing the algorithm. Then, the report will show the results of some tests.

Method
The algorithm succeeds in the modeling by executing the iterations of the code of judging part and the code of slicing part. By slicing the object several times, we can get many meshes, and we can use the spheres to represent the meshes. The first part will introduce the judging algorithm, and the second part will discuss the slice part.

The code of judging part is finished by the weight equation, which contains the weird degree, the value of modification, and the volume ratio as factors.The corporation of all these factors makes the judgment comprehensive. The ratio of the shortest and the longest distance from the surface to the outer sphere center represents the Weird degree, and the value of modification can be calculated by taking the difference between the longest and the shortest distance from the surface to the outer sphere center being divided by the radius of the outer sphere. The ratio of the volume of the mesh and the volume of the whole object represents the volume ratio. With the weight equation, the algorithm can decide the worst mesh in each iteration and recommend it to the slice code to separate the mesh into two parts. It means that the meshes from objects will be more and more friendly for using spheres to model after every iteration.

The workflow of slicing parts contains four steps. Finding the outer sphere of all convex points is the first step. First take any point A in the point set, then traverse the point to find the farthest point B, recorded as the farthest distance S1. Then take B as a starting point to find the farthest C, recorded as S2, and if S2S1, repeat step 3 until the farthest distance is found. Finally, the point with the longest distance is used as the middle perpendicular line, the midpoint of BC is E, and the circle is made with BC as the diameter, if all points are in the circle, BC is the diameter of the circumscribed circle, and E is the center of the circle. Otherwise, take the farthest point outside the circle as point A and repeat step 2.Then, we can get the longest axis of the object through the center of the sphere.

On the axis, we can set several pairs of points to represent the center of the two new spheres. The combination of the pairs of spheres will all have the same volume as the original object, which means if the spheres overlap, the overlapping part will not be involved in the volume computing. By comparing the sum of distances between the convex points and the new sphere's surface, we can choose the smallest pair of points to represent the two new spheres. The slicing surface is based on these new spheres. If two spheres contact, then the slicing surface is the contacting surface. If they do not, the distance from the slicing surface to the two center points will be the same as the ratio of radius. With the slicing surface, the mesh can be separated from one part to two parts.

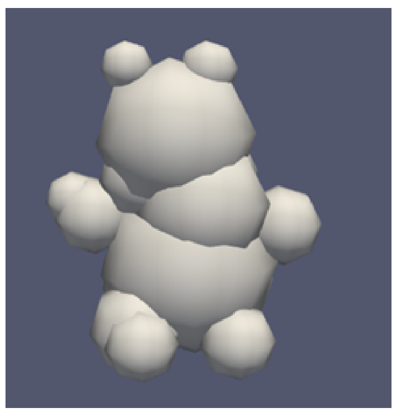
Result:

These are some examples we had tried using our algorithm. The first example is a mesh in bear shape. The second one is a football mesh.

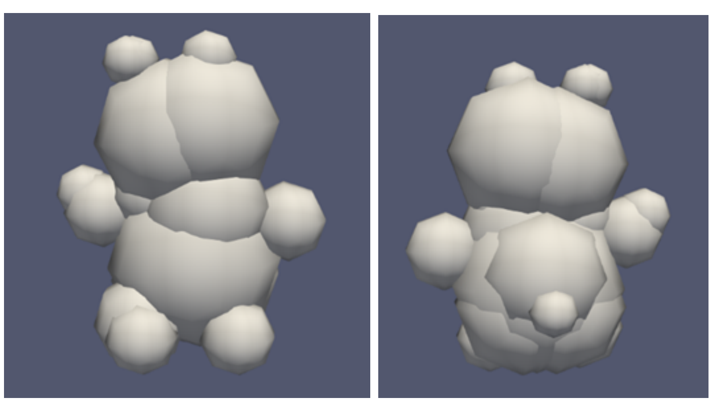
1. **The bear:**

The original object:

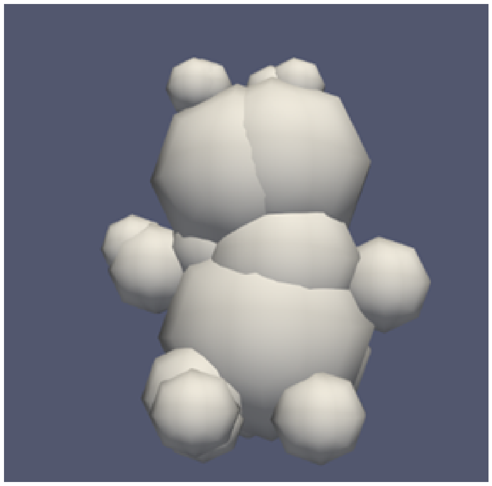
First iteration:

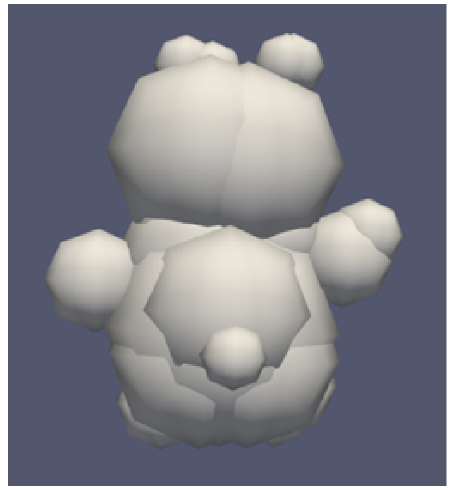


Third iteration:



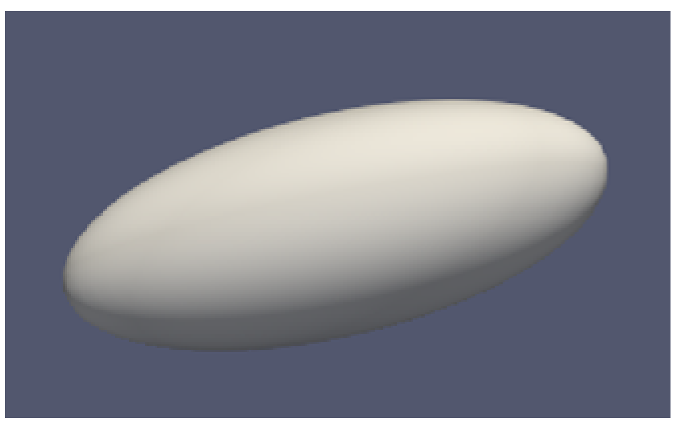
Fifth iteration:



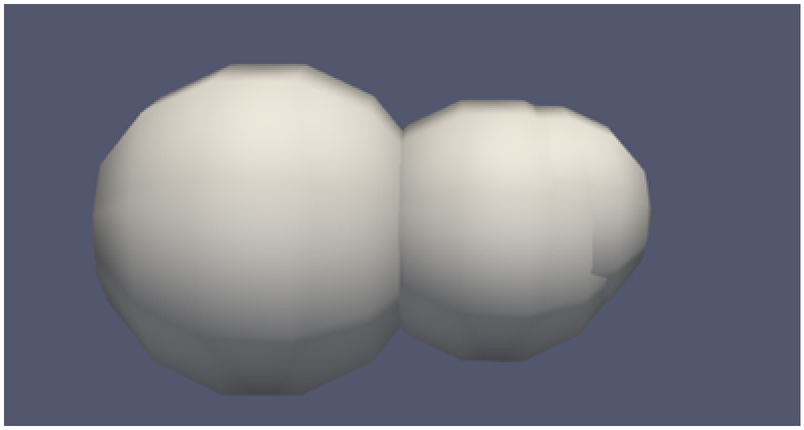


2. <u>The football:</u>

The original object:



Third iteration:



Improvement

Our algorithm basically has two parts, the judgment part, and the slicing part. The way we judge is not precise enough, and the criteria we use are not good enough. Also, we assign a weight for each criterion manually, which is not satisfactory. We should do some calculations to decide the weight for each criterion or give different weights for different input mesh. For the slicing part, we can develop a more comprehensive algorithm that can apply to any mesh with any shape.