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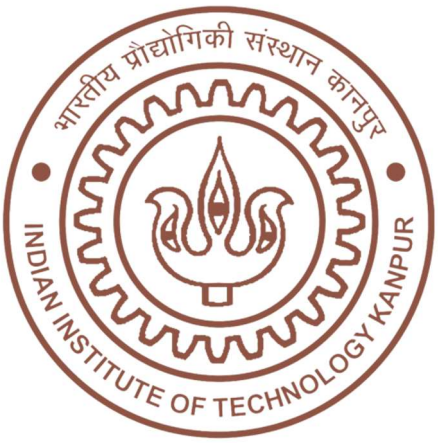

Undergraduate Project-II

Project Report

"Developing DEM Algorithms for Simulating Non-Spherical Particles using the Multi-Sphere Model"

Submitted by:

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Contents

Page No.

Abstract:

This project aims to develop Discrete Element Method Algorithm in C++ for simulating the motion of Non-Spherical Particle using the Multi-Sphere Model where the Non-Spherical Particles are modelled as a combination of Multiple Spherical Particles. The calculation of Forces has been done using Linear Spring Force Model whereas Particle positions and Velocities are updated using Numerical Integration. The method of Quaternions has been used for evaluating forces and torques. As a part of the project various other Methods used for Modelling the Non-Spherical Particles were also examined. In addition to this Parallel Computing Methods were also examined for Speeding Up the Simulations.

1.Introduction

Simulating the Motion of Spherical Particles using DEM does not require the consideration of Orientation of the Particle. Also, we do not require to consider the Rotational Motion of the Particle since the particle is symmetric. However, while simulating the Non-Spherical Particles these aspects should be necessarily considered. There are several methods using which we can model the shape of a Non-Spherical Particle. In this Under Graduate Project I have used the Multi Sphere Model to simulate the Motion of Non-spherical Particles. I have used the Method of Quaternions to simulate the motion of the particle. I have also examined various other methods for simulating the Non-Spherical Particles. Along with this I had also implemented Parallel Computing Methods to parallelize the Translational Motion of the Particle. The Linear Viscous Model has been used for Force Calculation during calculation and Forward Euler Integration has been used for Integration.

In the DEM Implementation for Non Spherical Particles 4 issues should be addressed:-

1. Kinematics of the Particle
2. Method of Representing the Shape of the Particle
3. Calculation of the Contact Force
4. Finding the Contact Plane between particles

Translational Kinematics for the Particle is similar to that for Spherical Particles and Euler Integration is used for updating the values of Position with Time. For Rotational Kinematics of the Particle, Euler Equations have been used for calculating the Angular Acceleration of the Particles and consequently the orientation of the Particle. The Orientation of the Particle is represented using a Quaternion. The overall shape of the Particle is represented using the Multi-Sphere Model.

The Following Classes and Functions are used for simulating the Motion of the Single Particle:-

a. quaternion : This class is used to define various quaternions while calculating the various Forces, Position and Orientation of the Particle. This Class also involves various Member Functions which are used for mathematical operations over quaternions.
b. sphere : This class is used for defining one sphere and its properties such as Position Coordinates.
c. particle : This class is used to define the Non-Spherical Particle using the various spheres defined using the class Sphere. It also defines the various properties of the particle such as Moment of Inertia, Mass, etc.
d. simDom : This class is used to define the boundaries of the Simulation Domain.
e. calculateForce(): This Function is used to Calculate the Collision force acting on the Particle.

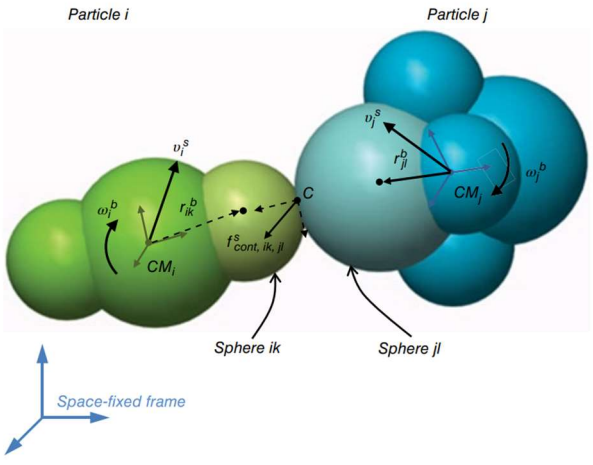

Figure 4.13 Two non-spherical particles *i* and *j* are in contact via their constituent spheres *ik* and *jl*

Figure 1:Non-Spherical Particles represented using the Multi-Sphere Model

2. Algorithm for Simulations

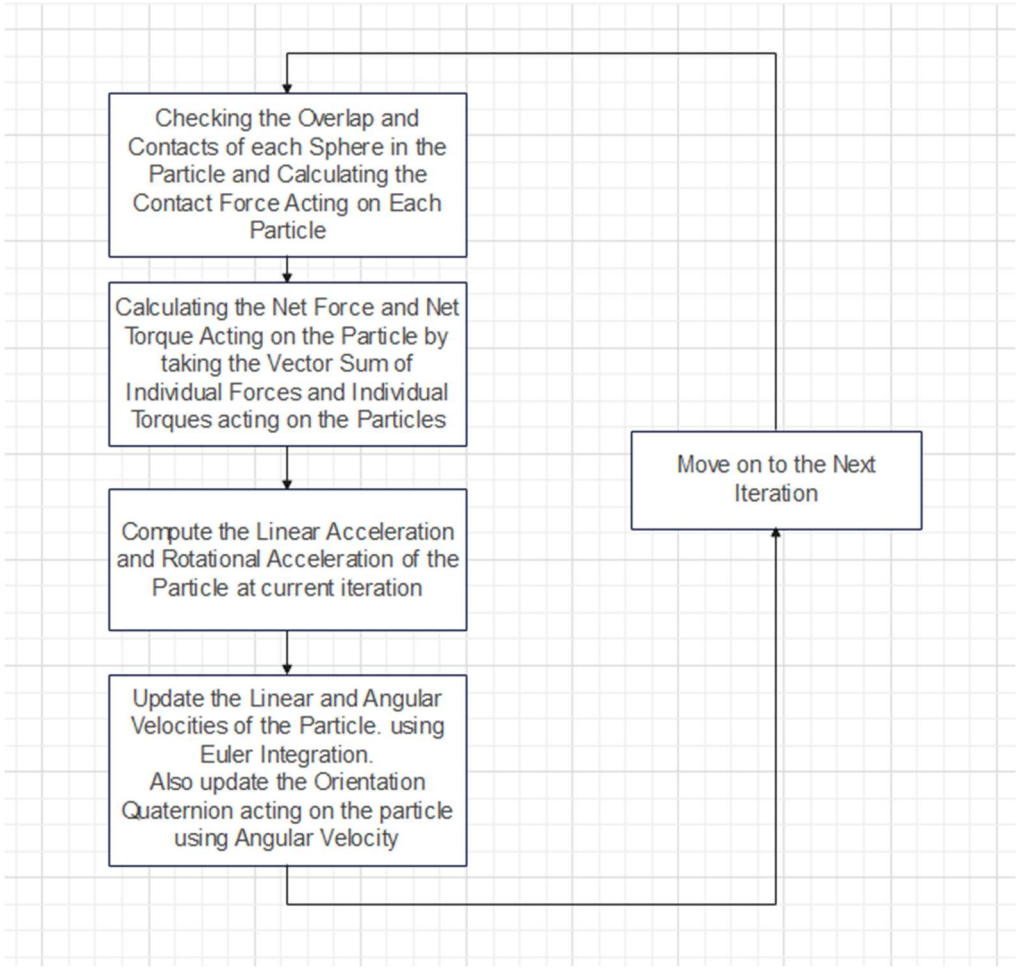

Figure 2: Algorithm used for simulating the Motion of a Single Non Spherical Particle in C++

3. Results

The Following Plots were obtained during the collision of the Particle with the Wall.