Component Design for Constraint Stabilization

The Program flow overview:

Constraint Stabilization will be an algorithm that will be run after every simulation step. The flow of it will be:

1. Gets configuration from the end of the simulation step
2. Check if penetrations exist
   a. If exist
      i. Separate the configurations into islands where each island consists of rigid bodies that are touching or interpenetrating
      ii. Create the constraint based on the contacts in the island
      iii. Calculate the correction needed based on the constraints
      iv. Perform Backtrack line searching to prevent overshoot
      v. Apply changes and check if there are islands remaining, if yes, return to step 2.a.i with the next island, if not return to step 2
   b. If do not exist
      i. Return and continue the simulation with current configuration.

Main library used:

The algorithm is written and tested in Moby, a multi-rigid body simulation software. Among the function Moby provides, this algorithm is going to use:

1. The data structure for storing Polyhedrons and the features (Vertices, Edges or Faces) of them.
2. The Geometry Calculation library, CompGeom that it provides.

The link to the GitHub repository is:

https://github.com/PositronicsLab/Moby

Main Algorithm used:

The main algorithms that used in this projects are modified V-Clip for collision detection, and Solving Linear Complementarity Problems following by Backtrack Line Searching for correcting error.

V-Clip is an algorithm that is presented in [1]. The algorithm is a quick and robust algorithm originally used to determine the closest feature on two polyhedrons, but it also reports penetration when it detects one. The problem with the original algorithm is that the algorithm stops at the pair of feature (either an edge or a vertex from one polyhedron and a face from the other one) when interpenetration is detected, while we want the algorithm to return the deepest penetrating pair of features for our use. The solution will be appending a searching algorithm after V-clip. The searching algorithm is:

1. Find a vertex that is penetrating, it will be the vertex of the pair of feature where V-clip stopped, or one of the ends of the edge if the ending pair of V-clip is an Edge-Face pair.

2. For all the edges that is coincide to the current vertex, check if the distance between the other end of them and the face in the ending-pair is more negative than the current vertex.

3.1 If there is one, update the current vertex to the most negative distanced one and repeat step 2

3.2 if there isn't any, return the current face vertex pair.

Formulating Contact problem as Linear Complementarity Problem is presented in [2]. The problem with this algorithm is the solution to the Linear Complementarity Problem is not reliable and will overshoot if applied directly. That's why a Backtrack Line Searching is used to scale the solution in to a trustworthy value.

User Interface

Since the project is just an algorithm, there is no user interface component in this project; however, Moby does provide visualization for users. The project will be demonstrated using that.

User Interaction with this algorithm:

Due to the fact that the algorithm is running in the background of the simulation, there will be little user interaction with it.

Demonstration Plan:

For demonstration, Moby will be run with and without the algorithm running. The difference between the two cases should be enough to show the effort that the algorithm has done in here.

If smaller components need to be demonstrated, the log generated during the program process should give people a clear grasp about how the algorithm is working in the background

Bibliography

[1] Mirtich, Brian. "V-Clip: Fast and Robust Polyhedral Collision Detection." TOG ACM Trans. Graph. ACM Transactions on Graphics 17.3 (1998): 177-208.

[2] Miha Anitescu and Florian A. Potra, “Formulating Dynamic Multi-Rigid-Body Contact Problem

with Friction as Solvable Linear Complementarity Problems Nonlinear Dynamics”, Pages 231--247, Volume 14,   Year 1997