

# Contact Simulation for Convex Polyhedrons

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## EXTENDED ABSTRACT

### 1 Introduction

Contact interaction is a central problem in many virtual reality and physically based simulations. An approach for simulation of contact interaction between two arbitrary polyhedrons is presented in this paper. This approach treats nondeformable 3D objects with small overlaps at the contact. The presented approach consists of two parts: a collision detection for arbitrary polyhedrons and then a contact force calculation. Collision detection deals with generalized three-dimensional clipping algorithm by Cyrus and Beck [1]. Contact force calculation is based on a point-plane model and computed as a sum of normal viscous-elastic and tangential dry friction forces. Several examples of application of this approach for simulation of multibody system dynamics are given.

### 2 Collision Detection for Polyhedrons

To accelerate computational processes the collision detection is typically divided into so-called far and near collision detection problems. Far collision detection is usually a fast algorithm that should select polyhedrons for the following, usually more time-consuming, near collision detection. On the first stage of the far collision detection circumscribed spheres around polyhedrons are created and its intersection is checked. The polyhedrons that passed through the far collision detection are treated by a near collision detection algorithm.

The well-known in computer graphics generalized three-dimensional clipping algorithm by Cyrus and Beck is used as the near collision detection algorithm. The algorithm deals with two convex polyhedrons and gives as a result clipped edges of one polyhedron that lie within another one and vice-versa, see Fig. 1. For example, the algorithm gives the set of edges  $\{E_1, E_2, E_3\}$  of  $Body_2$  and the empty set of edges for  $Body_1$  in Fig. 1a and  $\{E_1\}$  of  $Body_1$  and  $\{E_2\}$  of  $Body_2$  in Fig. 1b.

### 3 Contact force calculation

After all collisions between the neighboring polyhedron pairs have been detected, the contact forces have to be determined. Let us consider a pair of polyhedrons. Having a set of clipped edges that belong to each polyhedron the algorithm of calculation of contact forces arranges contact points on each edge, see Fig. 1, 2a. The step size between neighboring contact points is a parameter of the

mathematical model that depends on a characteristic dimension of polyhedrons. Then for each contact point the nearest face on another polyhedron from the pair is determined. As soon as pairs of points and planes (faces) are obtained the contact force  $\bar{R}$  can be calculated as a superposition of normal viscous-elastic force  $\bar{N}$ , depending on penetration  $\Delta$  and its derivative, and tangential dry friction force  $\bar{F}_f$ , see Fig. 2b, [2].

Special control procedure keeps position of contact points on an edge during a contacting phase even the length of clipped part of the edge is changed. Such strategy provides smooth changing a resultant vector of contact force between two bodies with time.

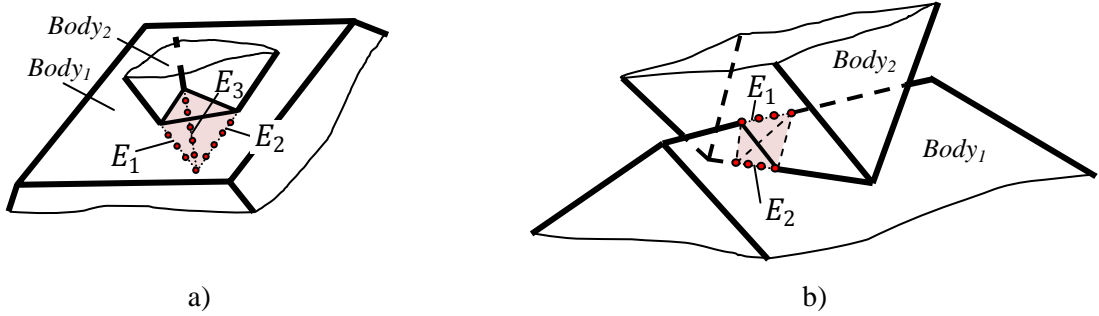


Figure 1: Vertex-face and edge-edge penetration.



Figure 2: Contact points and forces.

The presented approach perfectly manages both basic contact situations: vertex-face and edge-edge penetrations, see Fig. 1. Since the Cyrus and Beck algorithm deals with convex polyhedrons, the presented approach for contact force simulation is also applicable for a case of convex polyhedrons only. However the suggested algorithms can be enlarged for non-convex case if non-convex polyhedrons would be preliminarily divided into convex ones. In practice this strategy works well when a convex decomposition is available with a moderate number of pieces, it breaks down for utterly non-convex objects.

## 4 Applications

Presented approach was implemented in Universal Mechanism software (<http://www.uml-lab.ru>) and widely used for granular media simulation, see Fig. 3a. As well as it was used in real-time simulator for operators of robots, see Fig. 3b, that should manage contact interaction between a robot manipulator and objects to handle with, elements of the robot and a scene, as well as several robots in one scene.

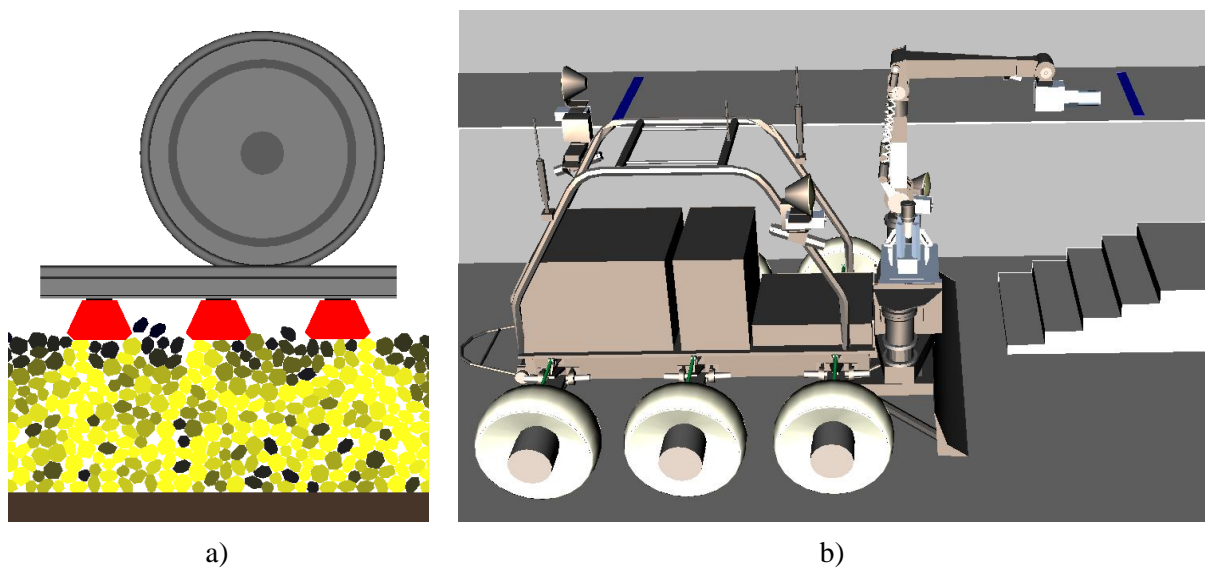


Figure 3: Applications: 2D and 3D cases.

## 5 Conclusions

The proposed approach seems to be a good compromise between accuracy of contact force simulation and required CPU efforts that makes it suitable for problems of multibody system dynamics and physically based simulations. The approach proved its availability for both 2D and 3D applications.

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## References

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- [2] D. Pogorelov, A. Pavlyukov, T. Yudakova, S. Kotov. Contact Interaction in Simulation of Multibody System Dynamics. Sel. *Dynamics, strength and reliability of transport machines*. Bryansk 2001, pp.11-23. (in Russian)