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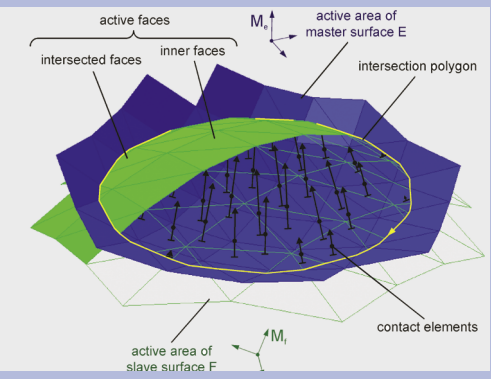
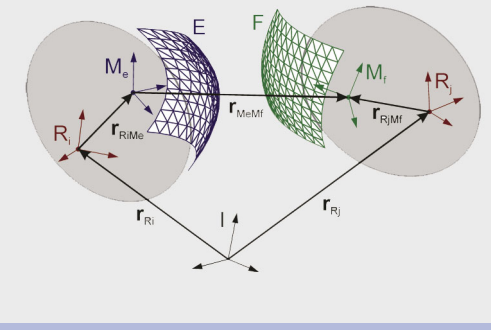
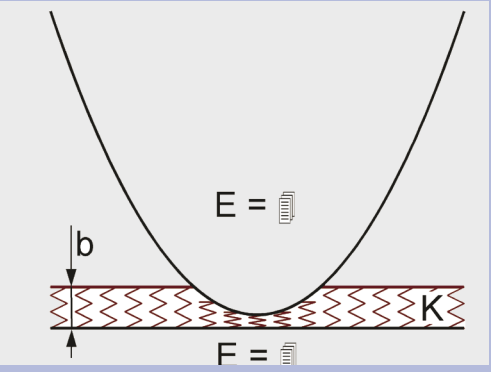
Polygonal Contact Model



Intersection components



Contact pairing kinematics



Elastic foundation model

It is a big challenge to find methods to model the highly complex phenomenon of contacting bodies realistically and efficiently enough for MBS simulation. The Polygonal Contact Model (PCM) is a new algorithm developed at the DLR that enables efficient and robust analysis of elastic contacts between bodies of complicated shape.

SIMPACK is known to be a powerful tool for contact modelling. The classic approach is to consider the problem exclusively in terms of contact points of minimal separation. SIMPACK's corresponding moved markers, in connection with a unilateral spring-damper and non-linear friction force elements, allow very efficient simulation of multi-body systems containing *contact*.

However, this method has reduced reliability for non strictly convex surfaces leading to multi-point contacts, contact point jumps or conforming contacts. PCM addresses this weak point and has been designed to provide a more accurate approximation of the contact forces than the contact point based approach.

PCM is characterised by contact surfaces represented by polygon meshes, a useful feature since most CAD and VR software is equipped with appropriate export filters. Internet libraries are also available providing 3D-meshes of various areas.

As a result of the surface representation PCM's algorithms are closely related to computer graphics. To find out if a given pairing of bodies is in contact, an efficient and exact collision detection submodule has been implemented. The method is based on *bounding volume hierarchies* improving calculation times by approximately four orders of magnitude.

If a collision has been detected, PCM constructs the intersection polygon and the active subdivision surfaces which form the intersection volume. Extensive use of methods corresponding to computer graphics is made. For example, the active polygons are determined by searching along the surfaces using boundary representation data structures known as *doubly connected edge lists*.

The approximation of the contact forces is based on a two-dimensional - but not single plane - discretisation of the contact patch. One of the contacting surfaces is treated as master and the other one as slave. Every active polygon of the master surface results in a contact element. In the following evaluation step, the elements act independently from each other.

The normal force of each contact element is determined due to the *elastic foundation model* which postulates rigid bodies are covered by thin linear-elastic layers. Assuming constant pressure all over the element, the elastic share is proportional to its area, its current penetration and the layer stiffness of the body. A normal damping force, characterised by an aereal damping factor, is calculated. In addition dry friction is approximated by a regularised version of *Coulomb's law*, similar to SIMPACK's non-linear friction force elements.

In various test simulations PCM proved to run robustly and efficiently. No problems were encountered in critical situations such as multiple and multiply bordered contact patches and conforming contacts. The results were plausible and the animations looked realistic. A quantitative verification of the method is still to come.

The most complex test example so far, is a pedestrian/car crash simulation. The car (surface consists of 1240 triangles) moves with constant velocity of 30 km/h. The man (20452 triangles) consists of 15 segments

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parameterised following *Dempster*. His joints are constrained in their angular ranges by force elements representing linear-elastic rotational bumpers. All polygon meshes were taken from free Internet libraries. 27 PCM contact pairings are defined between the car body and the man and also between several man segments.

In the past the contact point approach had led to grave difficulties in surface modelling and robustness of contact kinematics for this application. PCM can solve the problem robustly and efficiently: Using SIMPACK 8.6 the calculation takes less than five minutes on a 1.13 GHz laptop computer. The corresponding real-time factor of 192 appears satisfactory concerning the high complexity of the problem.

PCM is described in detail in the paper „An Algorithm for compliant contact between complexly shaped surfaces in multibody dynamics“ which was presented in July at the „Multibody Dynamics 2003“ conference in Lisbon. You can view some animations on the SIMPACK website www.simpack.com. For more information please contact Gerhard.Hippmann@simpack.de.