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CONTACT BETWEEN SPHERES AND GENERAL SURFACES

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ABSTRACT

This work presents a mathematical model to establish the weak form and tangent operator contributions due to contact between spherical surfaces and general surfaces. Normal and friction components are included, such as dissipative actions. The main concern herein is the proper consideration of the kinematics of the spherical surface and its influence on contact forces, including the appropriate description of the spherical motion by gap functions in normal and tangential directions. This leads to the possibility of dealing with complex kinematics of rolling or alternating rolling/sliding of the spherical surface, mapping its motion on another general surface. To achieve that, the model is based on rotational and translational degrees of freedom used to map the motion of contacting surfaces. One may employ such strategy for interactions between spheres and rigid or flexible bodies, modeled using finite element meshes. As examples, parameterizations of rigid and flexible surfaces are proposed and used. Practical applications are shown, with usage of beam and shell finite elements, experiencing contact interactions.

Keywords: contact, finite element method, master-slave, sphere, surface,

1. INTRODUCTION

When analyzing the mechanics of a single flexible body, a model to address kinematics and stresses may be solved by the finite element method. If the body is rigid, its behavior is characterized by only six degrees of freedom and the Newton-Euler equations may be established and time-integrated, among other existing approaches. However, when addressing a system with more than one body, rigid or flexible, the possibility of mechanical interactions emerges and may play a role. To enhance the model to handle mechanical actions between bodies, one may include constraints to the system, which may be enforced by employing equalities or inequalities expressions that characterize the desired mechanical constraint. Examples of equality constraints range from simple displacement impositions to points within a body, to complex joints, used in the context of multibody rigid/flexible dynamics, such as presented in [1], [5], [16] and [18]. Some examples of scenarios that may be represented using joints in a multi-body model are arms of a robot connected with spherical joints, bodies connected with hinges, translational joints, and many others.

Another kind of mechanical constraint is the contact between bodies. It may be described as a constraint that prevents a body of penetrating inside the other bodies' volumes. This is usually mathematically-translated as an inequality (see e.g.: [34]), with the aid of the definition of kinematic quantities to measure the distance between bodies, which are usually defined as measures for the "gap". The gap has to be evaluated and monitored along time-evolution, and in case of penetration detection, the constraint plays a role and is included in model equations, to avoid penetrations. Even the idea being quite simple, the way the contact models are established and enforced by numerical approaches may be quite complicated. One can easily feel that numerical contact models are non-trivial, due to the high number of distinct models that exist when dealing with different physical scenarios. A "best" contact model was not elected by scientific community for all kinds of bodies, geometries and related problem-scales of usual interest.

As examples of distinct strategies to address contact, one may refer to classical master-slave techniques. In this context, the surface of one body is elected as the "master", and the surface of the other body as the "slave". Slave surface is discretized using points that are monitored along simulation evolution, named "slave points". Base ideas from such strategy may be found in [34]. When evaluating the gap between each slave point and master surface, one needs to solve a minimum distance problem. The master surface is