“Modeling of Dynamics of Contact between a Rigid Body and a Soft Body using Multibond Graph Approach

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ABSTRACT

The deformation effect of soft material of robotic fingertips is a useful feature in general robotic application. Moreover, soft material contact mechanics plays an important role in grasping stability as well as safe object handling during manipulation. The estimation of grasping forces requires knowledge of contact characteristics, including relationship between normal force and contact area, and pressure distribution profile at the finger-object interface. The development of forces and moments at the contact interface due to the change in the contact area also needs to be analyzed. A bond graph model is developed to study the dynamics of soft contact interaction between a rigid sphere and a soft material. The model is applicable for all geometries. Sphere of different weights are thrown on the soft material and corresponding deformation of the soft material are obtained. The soft material is discritized into a number of elements with T nodes with the help of finite element method. Also mass and stiffness on each node is determined. The model determines contact area and distribution of forces over the contact nodes. Mathematical model is developed by Bond Graph approach from which the system equations are derived. MATLAB code is generated algorithmically from the bond graph. System equations are solved using one of the ordinary differential equation solvers available in MATLAB. The model is verified through simulation.

INTRODUCTION

Contact is a phenomenon in which two bodies touches each other and transmits forces to one another in the region of contact. When two bodies contact with each other, contact may be a point contact and an area contact. Where a point contact or line contact is an ideal approach for example when two rigid spheres or a rigid cylinder with a plane comes in contact with each other, but area contact is a realistic approach. Area contact occurs when one of the two bodies is deformable or soft. Contact mechanics deals with deformation, distribution of contact forces over contact area, state of stresses within the contacting bodies. Contact between two bodies may be static contact or dynamic contact. Impact, rolling and sliding contacts are dynamic in a sense that contact area and distribution of forces change dynamically.

In this work, concern is for impact contacts. Impact may be defined as a sudden change in the momentum of each contacting body, without a corresponding change in position [1]. The contact stresses resulting from the impact of two bodies are another area of interest in the study of impact. For spherical surfaces, Hertz theory is used to obtain the force deformation relation needed to calculate the duration of impact and the maximum indentation. This approach has been extended to the cases where contained plastic deformation occurs, generally with the assumption of a material having a yield point. Numerical models of the contact zone are also used when Hertz theory is not applicable.

Objectives

The objective of this work is to represent an impact model between rigid body and a soft body. This objective can be accomplished by developing the integrated bond graph model of rigid body, soft body and contact interface. Bond graph for rigid body can be understood by rigid body mechanics. Stiffness and mass matrix are determined from ABAQUS Software which can be used as C and I field respectively in the bond graph. Contact interface can be determined with help of assumptions for model explained in section by penalty approach with an additional damper at each contacting node. The next objective is to observe that how contact area changes when an impact force comes in to action. In this work, a rigid
body under the action of gravity is dropped on a soft surface. So next objective would be and also to observe that how many times the rigid body bounces and the time for attaining the stable equilibrium.

**LITERATURE SURVEY**

- **Hertz** first studied contact mechanics [1], based on contact between two linear elastic materials. Hertz’s model can be used to predict the elasticity at each contact as well as the pressure distribution across each contact patch. He also determined the contact area or contact radius and also how contact area relates with normal forces.

- **K. L. Jhonson, K. Kendall and A. D. Roberts** [2], added surface energy which is caused by forces of attraction (adhesion) between solid surfaces when they are dry and clean. Adhesion forces are in significance when normal load on the bodies are low and has a low significance when normal loads are high.

- **B. V. Derjaguin, V. M. Muller, And Yu. P. Toporov** [3], developed a strict theory of the mutual influence of the contact deformation and the molecular attraction of a ball to a plane. The van der Waals' forces are capable of increasing the area of elastic contact.

- **Sadeq H. Bakhy et al** [4], proposed contact-mechanics model for anthropomorphic hemi-cylindrical soft fingers is proposed as a power-law equation. That is, the half width of contact of a soft finger is proportional to the normal force raised to the power $\gamma_{cy}$, which ranges from 0 to $\frac{1}{2}$. They concluded that hemi-cylindrical shape fingertips are preferable over spherical shape fingertips for prosthetic application.

- **Anil Kumar Narwal, Anand Vaz and K.D. Gupta** [5], developed a model for rigid disc rolling on a soft material and studied there dynamics, they were also able to determine the contact forces at the time when disc is placed on the material and also when rolling of disc occurs.

- **Anil Kumar Narwal, Anand Vaz and K.D. Gupta** [6], developed a model for rigid non-circular body is kept on a soft material. A general contact algorithm is presented in this paper. The approach facilitates the determination of the contact area, and also the distribution of forces at the contact interface, during dynamic contact interaction.

- **M. Buss, H. Hashimoto, and J. B. Moore** [7], a grasping force optimization method for dexterous robotic hands was developed. The methods may also be applied to walking robots or multiple robot arms with closed kinematic chains. The proposed algorithms were based on gradient flows on the smooth manifold of linearly constrained positive definite matrices.

- **Nicholas Xydas, Milind Bhagavat and Imin Kao** [8], employed nonlinear finite element analysis to study the soft-finger contact mechanics also the influence of friction over the contact area was investigated using FEM analysis.

**METHODOLOGY**

Methodology of this thesis work can be summarized as given below:

- A patch of soft material in cuboid shape is modelled in part module of ABAQUS which can be used as underlay for rigid body(sphere).
- General mechanical properties of silicon rubber are assigned to soft material with the assumption of linear stiffness as
- Soft material is meshed in to eight node brick elements.
- Stiffness and mass matrices are obtained in text file from ABAQUS.

**CONCLUSIONS AND FUTURE SCOPES**

A crucial problem in robot grasping is the choice of grasping forces so as to avoid, or minimize, the risk of slippage. The existence of uncontrollable grasp force is the main issue and characteristic of the grasp force analyses in enveloping grasp. Modeling of contact interaction is one of the most important subjects in dexterous manipulation because grasping and manipulation are dictated by contact behavior. Since the next generation of robots will interact with people directly, the interest on the implementation of artificial systems to replicate the manipulating ability of the human hand is growing among researchers. The soft fingers are the interface between the robot
and the environment; therefore dexterous manipulation skills are necessary for robot in everyday life. The soft-finger model gives rise to more realistic analysis in robotics. The fingers are made soft by introducing linear mass, spring, and damper effects in them.

REFERENCES