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Analysis by Finite Element Method of Impact Modeling on Rigid Body using Multi Bond Graph

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ABSTRACT

The Finite Element Method (FEM) is a numerical approach by which the partial equation can be solved approximately. FEM is a numerical approach for solving engineering problem like stress analysis, heat transfer etc. by using of computer simulation. In FEM we divide a complex problem into smaller and simpler problem that can be solved by existing knowledge of mechanics of materials and by mathematical tool, so the basic idea of FEM is whole domain will be divided into finite elements or called simple elements the shape of elements may be triangular or quadrilateral. 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.

INTRODUCTION

The Finite Element Method (FEM) is a versatile technique for the numerical approximation of solutions of partial differential equations (PDEs). Finite Element Method is considered as one of the well-established and convenient technique for the computer solution of complex problems in different fields of engineering: civil engineering, mechanical engineering, nuclear engineering, biomedical engineering, hydrodynamics, heat conduction, geo-mechanics etc.

The Finite Element Method (FEM) is a numerical approach by which the partial equation can be solved approximately. FEM is a numerical approach for solving engineering problem like stress analysis, heat transfer etc. by using of computer simulation. In FEM we divide a complex problem into smaller and simpler problem that can be solved by existing knowledge of mechanics of materials and by mathematical tool, so the basic idea of FEM is whole domain will be divided into finite elements or called simple elements the shape of elements may be triangular or quadrilateral. The process of dividing the domain (Model) into small elements is called meshing. The elements shares common points called nodes. The behaviour of each elements is well known under all possible support and load applied.

FEM can be done for one, two and three dimensional problems. In FEM, the process of dividing the model into small pieces is called meshing. The structure is discretized into a set of elements joined together at some points called nodes or nodal points and the shape of discretized elements in one, two and three dimensional. The nodes could be the common corners between the elements, or chosen between the boundaries of the elements.

Objective

The words "finite element method" was first used by Clough in his paper in the Proceedings of 2nd ASCE (American Society of Civil Engineering) conference on Electronic Computation in 1960. Clough extended the matrix method of structural analysis, used essentially for frame-like structures, to two-dimensional continuum domains by dividing the domain into triangular elements and obtaining the stiffness matrices of these elements from the strain energy expressions by assuming a linear variation for the displacements over the element. Clough called this method as the finite element method because the domain was divided into elements of finite size. (An element of infinitesimal size is used when a physical statement of some balance law needs to be converted into a mathematical equation, usually a differential equation).

LITERATURE SURVEY

- **E.L. Deladia, M.B. de Rooijband D.J. Schipperb ,**developed a model for the static friction between rubber-like material and rigid asperities has been developed taking into account the viscoelastic behavior of rubber. By using a viscoelastic model leads to an increase of the limiting displacement with respect to time, the static friction force being unaffected.

- **Mark R. Cutkosky, John M. Jourdain and Paul K. Wright,** In this paper, compliant material were tested both under clean, dry conditions and with environmental contamination to determine which materials were most suitable for the contact areas of a robotic hand and to establish accurate models of the materials frictional behaviour. Some of the most promising materials under clean, dry conditions performed unreliably in the presence of oil and water. Contact shape, surface texture and surface porosity each had a strong effect on the ultimate coefficient of friction. The results of these tests revealed that materials that look most promising under clean, dry conditions were often quite sensitive to common environmental conditions such as moisture and oil, making the coefficient of friction hard to predict.

- **Kazuki Namima, Zhongkui Wang and Shinichi Hirai ,** developed a new model to simulate contact and rolling motion between two soft fingers and an object by using Finite Element and Constraint Stabilization Methods. Simulation of the grasping and the rolling motion between soft fingers and an object by using finite element model and Constraint Stabilization Method (CSM) is done.

- **Sadeq H. Bakhy et al ,** 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 γ_{cy}, which ranges from 0 to ½. 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 ,** 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 ,** 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**, 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. A key observation in the approach was that the satisfaction of nonlinear friction force limit constraints was equivalent to positive definiteness of a suitable matrix P containing contact wrenches and friction coefficients, and the remaining constraints were linear constraints on P. The proposed algorithms allow easy accommodation of the various friction models of point contact with Coulomb friction or soft-finger contacts. For the soft-finger contact friction model, a linear and elliptical friction force limit approximation based on earlier experimental results each yield a different structure of the matrix P.

- **Nicholas Xydas, Milind Bhagavat and Imin Kaot** , 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. FEM models were developed for two fingertips with radii of 7.65mm and 17.445mm respectively. Numerical results of normal force versus contact radius are compared with the experimental results of the same fingertips.

METHODOLOGY

When the Finite Element Method is applied to a problem, following tasks are performed in step-by-step manner.

Step1. Discrete and Select element types.
Step2. Select approximate function.
Step3. Define the gradient of the unknown quantity and constitutive relationships.
Step4. Derive element equations.
Step5. Assemble the equation to obtain the global or total equations and introduce boundary conditions.

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.

From the simulated results, it is concluded that bond graph is an algorithmic approach to model soft contact interaction. An effort has been made to integrate the bond graph formulation for dynamic modeling and analysis with the finite element method. Once bond graph structure is defined the derivation of system equations can be carried computationally. It shows the effectiveness and simplicity of the approach**.** For solving system state equations and simulation MATLAB software is used, without any constraint as put by the different software available. Model determines contact area and force distribution over it. It is applicable for all geometries. Dynamics of soft contact interaction is obtained algorithmically. Transient behavior of the soft contact interaction is obtained for different damping coefficient.

The future scope of this work is purposed to be investigated for other important functional aspects, like stiffness in tangential direction, shape recovery properties, energy dissipation and friction. This model will be tested experimentally to find out the effect of rolling sphere on the soft material in three dimensions. Model will also be simulated for the case when contact interface moves.

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