Validation of Volumetric Contact Dynamics Models

Mike Boos

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Outline

1. Motivation
2. Model
   - Volumetric model
   - Normal forces
   - Friction forces
3. Experiments
   - Normal forces
   - Friction forces
   - Experimental apparatus
4. Conclusions
1 Motivation

2 Model
   ▪ Volumetric model
   ▪ Normal forces
   ▪ Friction forces

3 Experiments
   ▪ Normal forces
   ▪ Friction forces
   ▪ Experimental apparatus

4 Conclusions
Figure: Dextre at the tip of Canadarm2 [1].
Contact Models

Point contact models

- Small contact patches only
- Simple, convex geometries
- No rolling resistance, spinning friction torque

FEM

- Too complex for real-time

Figure: ISS battery box [1].
Contact Models

Falling ISS battery box:
real-time

Point contact models
- Small contact patches only
- Simple, convex geometries
- No rolling resistance, spinning friction torque

FEM
- Too complex for real-time
1. Experimentally validate the volumetric contact dynamics model for hard-on-hard (metal) contact
2. Demonstrate parameter identification for the model
Motivation

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Conclusions
Figure: The modified Winkler elastic foundation model [1].
Volumetric properties

Figure: The contact surface between two deformable bodies [1].

Volumetric properties

\[ V - \text{volume of interference} \]
\[ J_S - \text{surface-inertia tensor} \]
\[ n - \text{contact normal} \]
\[ J_V - \text{volume-inertia tensor} \]
Normal force

\[ f_n = k_v V (1 + a v_{cn}) \mathbf{n} \]
Rolling resistance torque

\[ \tau_r = k_v a J_s \cdot \omega_t \]
Friction

\[ f_t \quad \text{Friction force} \]

\[ \tau_s \quad \text{Spinning friction torque} \]

7-parameter model

- Bristle stiffness and damping \((\sigma_o, \sigma_1)\)
- Slip-stick effects \((\mu_S, \mu_C, v_S)\)
- Dwell-time dependency \((\tau_{dw})\)
- Viscous damping \((\sigma_2)\)

Figure: Surface asperities (‘bristles’) in contact [1].
The Contensou effect

Translational friction forces tend to ‘cancel out’ as angular velocity increases.

Figure: $v \ll \omega r$ [2]
The Contensou effect

Translational friction forces tend to ‘cancel out’ as angular velocity increases.

Figure: $v \gg \omega r$ [2]
The Contensou effect

Translational friction forces tend to ‘cancel out’ as angular velocity increases.

Figure: $v \simeq \omega r$ [2]
Volumetric contact model

Ball-table simulation: real-time
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Contact geometries

Focus on simple geometric pairs:

- Cylinder-on-plane
Focus on simple geometric pairs:

- Cylinder-on-plane
- Sphere-on-plane
Normal force experiments

Volumetric stiffness

- Increase force on payload quasi-statically
- Measure normal forces and displacements (to calculate volume of interference)

\[ f_N = k_v V \]
Normal force experiments

Volumetric stiffness

- Increase force on payload quasi-statically
- Measure normal forces and displacements (to calculate volume of interference)

Damping

- Drive the payload into contact plate at set velocities
- Measure forces and displacements over time

\[ f_N = k_v V (1 + a v_c n) \]
Translation

Static friction and bristle dynamics

1. Begin with payload at rest
2. Slowly increase force until slipping occurs

Peak force can be used to estimate $\mu_S$:

$$f_t = f_N \mu_S$$

Also, $\sigma_o = \frac{\mu S}{\delta z}$
Coulomb friction and viscous damping

- Drive payload at different constant velocities

\[ f_t \approx f_n (\mu_C + \sigma_2 v_t) \]
Translation

Dwell-time dependency

Static friction: Bonds between surfaces form over time when at rest.

1. Drive payload at a constant velocity
2. Bring to a stop for a set period of time
3. Slowly increase force until slipping occurs
4. Repeat, increasing the dwell time, until no change in peak force detected between iterations
Rotation

- Repeat translation experiments, rotating instead of translating
- Compare parameters for translation and rotation
Combined translation and rotation

Contensou effect

1. Drive at constant tangential velocity with increasing angular velocity
2. Drive at constant angular velocity with increasing tangential velocity
3. Using parameters identified in previous experiments, model the friction forces to compare with observed Contensou effect
Normal force configuration
Friction configuration
Apparatus

![Experimental apparatus image]
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Conclusions

- Volumetric contact dynamics model discussed
- Experimental procedure developed for parameter identification and validation
- Design of experimental apparatus
Y. Gonthier.
*Contact Dynamics Modelling for Robotic Task Simulation.*

*On the Implementation of Coulomb Friction in a Volumetric-Based Model for Contact Dynamics.*
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