OpenSim plugin to estimate contact forces using static optimization

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This plugin for OpenSim provides a method to simultaneously estimate (external) contact forces and (internal) muscle forces in an inverse dynamic manner from a prescribed motion trajectory. It implements a custom OpenSim model component to represent a simple point-on-plane contact model. Friction effects are considered according to the static and the kinetic regime of Coulomb's law. The contact model is evaluated by a special static optimization procedure that can be run within OpenSim's Analyze Tool.

We developed this approach to analyze physical interactions between human beings and technical artifacts such as manufacturing machines and sports equipment. However, it is also particularly useful to estimate ground reaction forces during gait.

Background information can be found in the following publication:

D. Krüger and S. Wartzack, "A contact model to simulate human–artifact interaction based on force optimization: implementation and application to the analysis of a training machine," *Computer Methods in Biomechanics and Biomedical Engineering*, pp. 1–10, Oct. 2017. DOI: 10.1080/10255842.2017.1393804

If you would like to use our work in your own research please cite that paper!

This distribution contains
- The source code to build the plugin with OpenSim 4.0
- A binary distribution for OpenSim 4.0 (64bit)
- An example model "block_drag" (toy example to demonstrate the transition from static to kinetic friction)

Installation

1. If you want to build the plugin from the source MS Visual Studio 2017 is required.
2. Install the resulting or pre-built `contactForces.dll` into OpenSim's plugins directory. (e.g. `C:\OpenSim 4.0\plugins`)
3. Make sure that the `plugins` folder is in your system's PATH.
4. From within the OpenSim GUI go to: **Tools >User Plugins > contactForces.dll**
5. You should see a message that the plugin has been loaded successfully.

The ContactPointOnPlane model component

To define a contact between two rigid bodies a special force component has to be added to the respective OpenSim model. At present, the plugin features only a simple point-on-plane contact model. Use the OpenSim XML-browser and locate the class `ContactPointOnPlane` to learn about its modeling syntax. As a reference we further included two example models into this distribution. Therefore a brief discussion of the various parameters should get you started:

Parameter	Explanation
isDisabled (bool)	Activate or deactivate the contact.
optimal_force (real number)	The „strength" of the contact. Determines how attractive it is to activate the contact during static optimization. Unit: [N]
static_friction (real number)	The static friction coefficient.
kinetic_friction (real number)	The kinetic friction coefficient.
plane_body (string)	Name of the rigid body the contact plane is attached to.
plane_origin (Vec3)	Station within the plane_body that defines the origin of the contact plane. (The plane is expressed in the normal form.)
plane_normal (Vec3)	Vector within the plane_body that defines the direction of the contact plane's normal.
point_body (string)	Name of the rigid body the contact point is attached to.
point_location (Vec3)	Station within the point_body that defines the contact point.
contact_tolerance (real number)	This parameter defines an upper bound on the distance between the contact point and the contact plane up to which the contact is considered to be engaged in a geometrical sense. Unit: [m] A value of -1 will deactivate this behavior, which means that contact forces can act no matter how far away the contacting bodies are from each other.
contact_transition (real number)	If the point-to-plane distance exceeds the value of contact_tolerance (see above), the contact is gradually weakened to make its activation during static optimization more and more unattractive as the contacting bodies move away from each other. The parameter contact_transition controls how rapidly this happens. Unit: [m]
v_trans (real number)	Transition velocity between the static and the kinetic regime of Coulomb's friction law. Unit: [m/s]

The ContactForceAnalysis

The contact model is evaluated by a special static optimization procedure. In contrast to OpenSim's static optimization algorithm additional constraints are considered, which result from contact mechanics. The static optimization procedure can be run within OpenSim's Analyze Tool by adding an analysis class of the typ `ContactForceAnalysis`. Since this analysis shares most of its configuration options with OpenSim's static optimization algorithm there is only one option worthwhile to discuss:
If the parameter `report_external_forces` is set to <true> the contact forces will be written to the same file format that OpenSim uses to store external force data. This might be useful if you want to input the estimated contact forces e.g. to a subsequent CMC simulation or if you want to visualize the force vectors within the OpenSim GUI.