

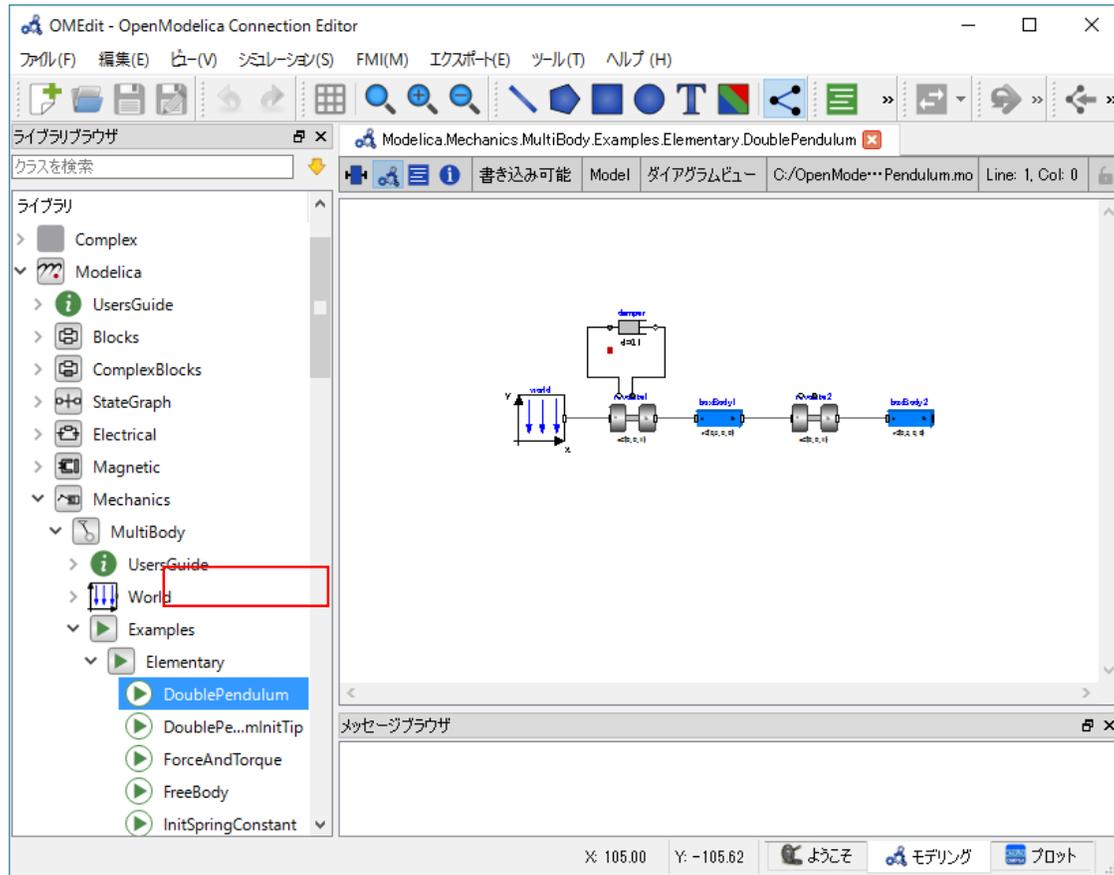
# OpenModelica Modelica Standard Library MultiBody ライブラリについて

- OpenModelica
- MultiBodyライブラリのモデルの概要（コネクタ、基本的なモデル）
- MultiBodyライブラリの可視化方法
- MultiBodyの例題モデルの動画

オープンCAE合同勉強会@東京2016

finback

# OpenModelica



OpenModelica Connection Editor (OMEdit)

## OpenModelica Ver.1.9.6

( <https://www.openmodelica.org/> )

- Modelica 言語を使用した微分代数方程式ソルバーである。
- Open Source Modelica Consortium (OSMC)によって開発がサポートされている。

ライセンス OSMC-PL

(<https://www.openmodelica.org/useresources/license> )

## Modelica Standard Library (MSL) – Ver.3.2.1

- 制御系、電気系、機構系、流体系、熱流体系などを含む Modelica 言語で記述されたライブラリである。
- Open Modelica Ver.1.9.6 に同梱されている。

### Licensed by the Modelica Association under the Modelica License 2

Copyright © 1998-2016, ABB, AIT, T. Bödrich, DLR, Dassault Systèmes AB, Fraunhofer, A. Haumer, ITI, C. Kral, Modelon, TU Hamburg-Harburg, Politecnico di Milano, XRG Simulation.

*This Modelica package is free software and the use is completely at your own risk; it can be redistributed and/or modified under the terms of the Modelica License 2. For license conditions (including the disclaimer of warranty) see [Modelica.UsersGuide.ModelicaLicense2](https://www.modelica.org/licenses/ModelicaLicense2) or visit <https://www.modelica.org/licenses/ModelicaLicense2>.*

# OpenModelica

## MultiBodyライブラリ

- 3次元力学的コンポーネントを提供するパッケージである。
- 適切な大きさと色を持ったアニメーションの情報を持つ。
- Modelica Standard Library の一部として配布されている。

## Modelica3D

- Modelica のための 3次元可視化ライブラリ
- プラットフォーム非依存
- light weight
- OpenModelica に同梱されている。
- 使用方法は以下に記述がある。

<https://www.openmodelica.org/doc/OpenModelicaUsersGuide/latest/modelica3d.html>

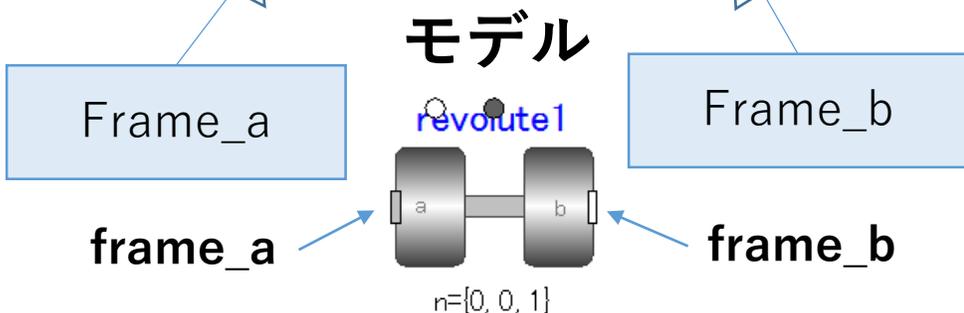
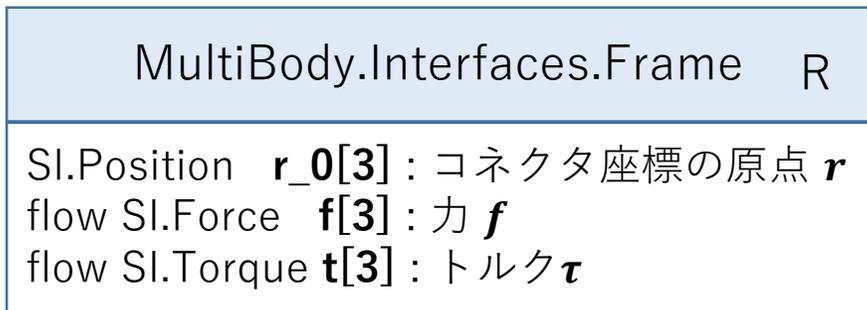
# MultiBodyライブラリのモデルの概要

- コネクタ
- 基本的なモデル

# コネクタ

固有のコネクタ座標系を持つ

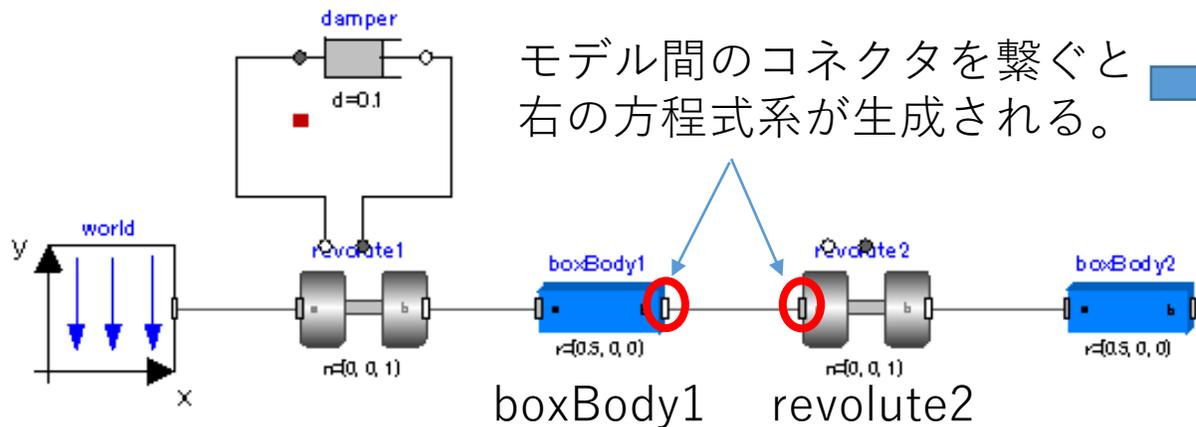
## オリエンテーションオブジェクト



- ワールド座標系 基準座標系
- コネクタ座標系 コネクタに固定された座標系
- $\mathbf{r}_0[3]$  はワールド座標系
- $\mathbf{f}[3], \mathbf{t}[3], \mathbf{w}[3]$  はコネクタ座標系

$$\begin{aligned} \mathbf{r}^a &= \text{frame\_a.r}_0 \\ \mathbf{R}^a &= \text{frame\_a.R} \\ \mathbf{f}^a &= \text{frame\_a.f} \\ \boldsymbol{\tau}^a &= \text{frame\_a.t} \\ \boldsymbol{\omega}^a &= \text{frame\_a.R.w} \end{aligned}$$

## コネクタの接続による方程式の生成



## モデル間の方程式

変数 (値が一致する)

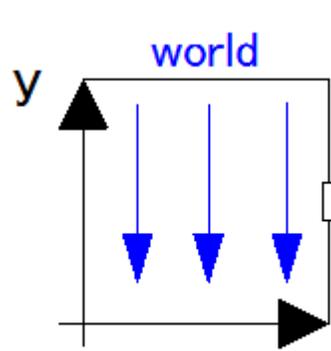
$$\begin{aligned} \text{boxBody1.r}^b &= \text{revolute2.r}^a \\ \text{boxBody1.R}^b &= \text{revolute2.R}^a \end{aligned}$$

フロー変数 (和がゼロになる)

$$\begin{aligned} 0 &= \text{boxBody1.f} + \text{revolute2.f} \\ 0 &= \text{boxBody1.t} + \text{revolute2.t} \end{aligned}$$

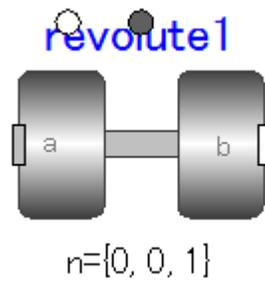
$$\begin{aligned} \mathbf{r}^b &= \text{frame\_b.r}_0 \\ \mathbf{R}^b &= \text{frame\_b.R} \\ \mathbf{f}^b &= \text{frame\_b.f} \\ \boldsymbol{\tau}^b &= \text{frame\_b.t} \\ \boldsymbol{\omega}^b &= \text{frame\_b.R.w} \end{aligned}$$

# 基本的なモデル – モデル内の方程式が実装されている。



**World**  
ワールド座標の原点を規定する。

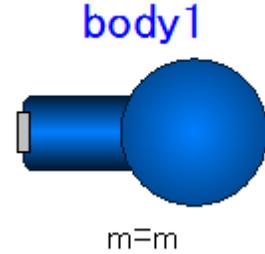
```
root(frame_b.R)
rb = 0
Rb = nullRotation()
```



**Joints.Revolute**  
軸回転ジョイント

```
branch(frame_a.R, frame_b.R)
rb = ra
Rrel = planarRotation(n, φ)
Rb = absRotation(Ra, Rrel)
ω = φ
0 = nT · τb
0 = fa + resolve1(Rrel, fb)
0 = τa + resolve1(Rrel, τb)
```

角速度  
n: 軸方向ベクトル



**Parts.Body**  
物体

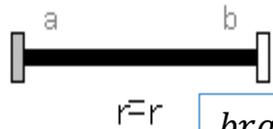
```
potentialRoot(frame_a.R)
if isRoot(frame_a.R) then
  0 = Q.constraint(p)
  ωa = Q.angVel2(p, ṗ)
  Ra = Frames.from_(p)
else
  ωa = angVel2(Ra, Ṙa)
  p = Q.nullRotation()
end if
v = ṙa
g = grav(ra + resolve1(Ra, rCM))
a = resolve2(Ra, v̇ - g)
fa = m · (a + ω̇a × rCM + ωa × (ωa × rCM))
τa = Iω̇a + ωa × Iωa + rCM × fa
```

m: 質量  
I: inertia tensor  
r<sup>CM</sup>: 重心  
p: quaternion  
v: 速度  
a: 加速度  
g: 重力加速度

運動量保存則  
角運動量保存則

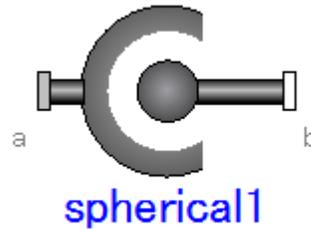
**fixedTranslation1**

**Parts.FixedTranslation**  
コネクタ座標の固定移動を表す。



```
branch(frame_a.R, frame_b.R)
rb = ra + resolve1(Ra, rab)
Rb = Ra
0 = fa + fb
0 = τa + τb +a rab × fb
```

frame\_a のコネクタ座標で見たベクトル  
 ${}^a r^{ab} = \vec{ab}$



**Joints.Spherical**  
球回転ジョイント

```
rb = ra
Rrel = relRotation(Ra, Rb)
0 = fa + resolve1(Rrel, fb)
τa = 0
τb = 0
```

Otter M., Elmquist H., and Mattsson S.E.: **The New Modelica MultiBody Library.**

Modelica 2003 Conference, Linköping, Sweden, pp. 311-330, Nov. 3-4, 2003.

[https://www.modelica.org/events/Conference2003/papers/h37\\_Otter\\_multibody.pdf](https://www.modelica.org/events/Conference2003/papers/h37_Otter_multibody.pdf) より

## モデル内の方程式で使用されている関数

Modelica.Mechanics.MultiBody.Frames, Modelica.Mechanics.MultiBody.Frames.Quaternionsなどに定義されている。次のように内容を確認できる。

The screenshot shows the OMEdit - OpenModelica Connection Editor interface. The left sidebar displays a library tree with 'resolve1' highlighted under 'Frames'. The main editor shows the source code for the 'resolve1' function, which takes an orientation 'R' and a vector 'v2' in frame 2 as input and returns a vector 'v1' in frame 1. The code includes an algorithm section with the transformation  $v_1 := \text{transpose}(R.T) * v_2$  and an annotation for derivatives. The right pane shows the function's documentation: 'Transform vector from frame 2 to frame 1'. A blue arrow points from the 'resolve1' function call in the code to the documentation. Another blue arrow points from the 'resolve1' entry in the library tree to the function name in the code. A third blue arrow points from the mathematical equation  $v_1 = \text{resolve1}(R, v_2) \equiv (R.T)^T v_2$  to the 'resolve1' function name in the code. The bottom status bar shows coordinates and system icons.

```
124 function resolve1 "Transform vector from frame 2 to frame 1"
125   extends Modelica.Icons.Function;
126   input Orientation R "Orientation object to rotate frame 1 into frame 2";
127   input Real v2[3] "Vector in frame 2";
128   output Real v1[3] "Vector in frame 1";
129   algorithm
130     v1 := transpose(R.T)*v2;
131     annotation (derivative(noDerivative=R) = Internal.resolve1_der,
132                 InlineAfterIndexReduction=true);
133   end resolve1;
134
```

**Modelica.Mechanics.MultiBody.Frames.resolve1**  
Transform vector from frame 2 to frame 1

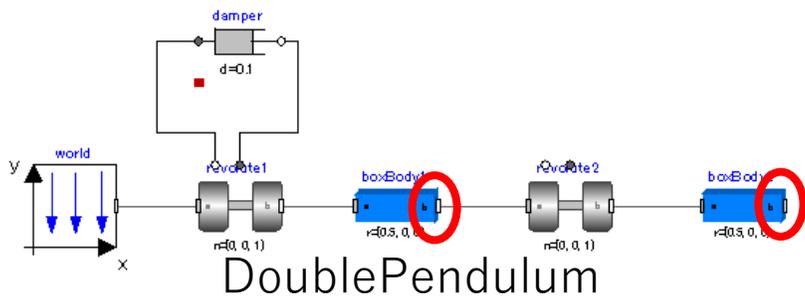
座標系 2 のベクトルを  
座標系 1 のベクトルに変換する

$$v_1 = \text{resolve1}(R, v_2) \equiv (R.T)^T v_2$$

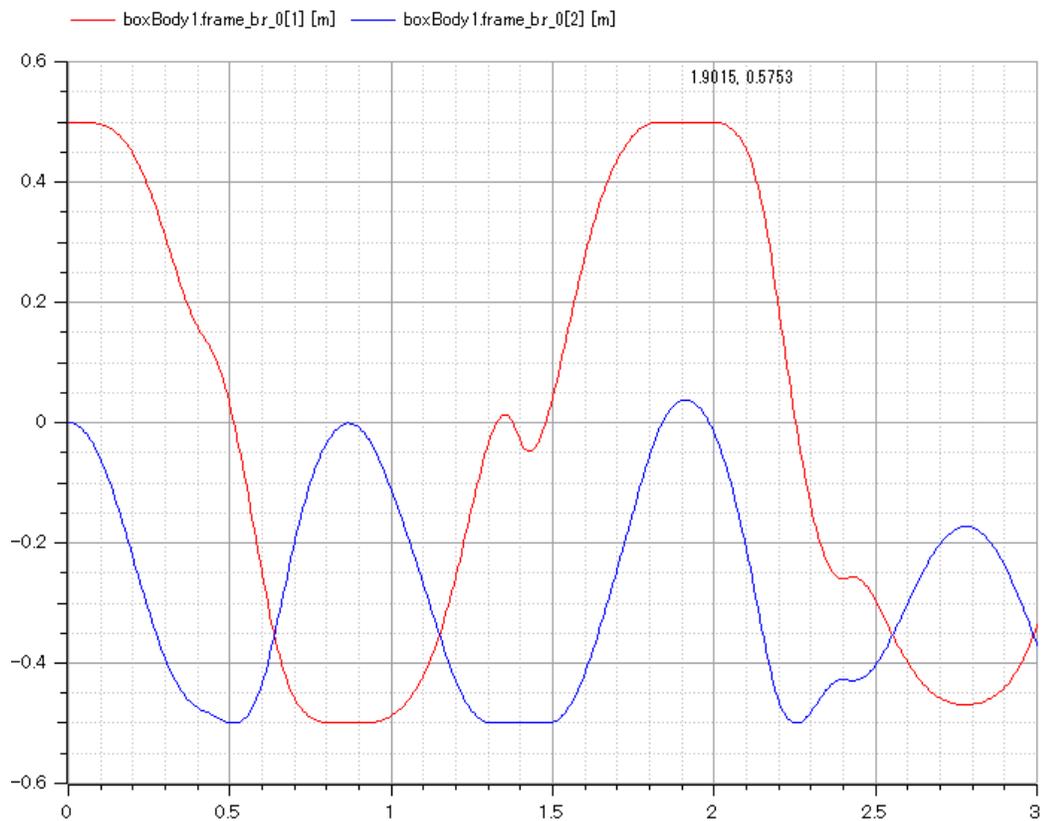
Modelica.Mechanics.MultiBody.Frames.resolve1

メッセージブラウザ  
[Modelica.Mechanics.MultiBody.Visualizers: 1986:8-1987:83]: PartialModelicaServices is partial, name lookup is not allowed in partial classes.  
[3] 02:54:57 変換 エラー  
[ModelicaServices: 653:5-654:81]: PartialModelicaServices is partial, name lookup is not allowed in partial classes.

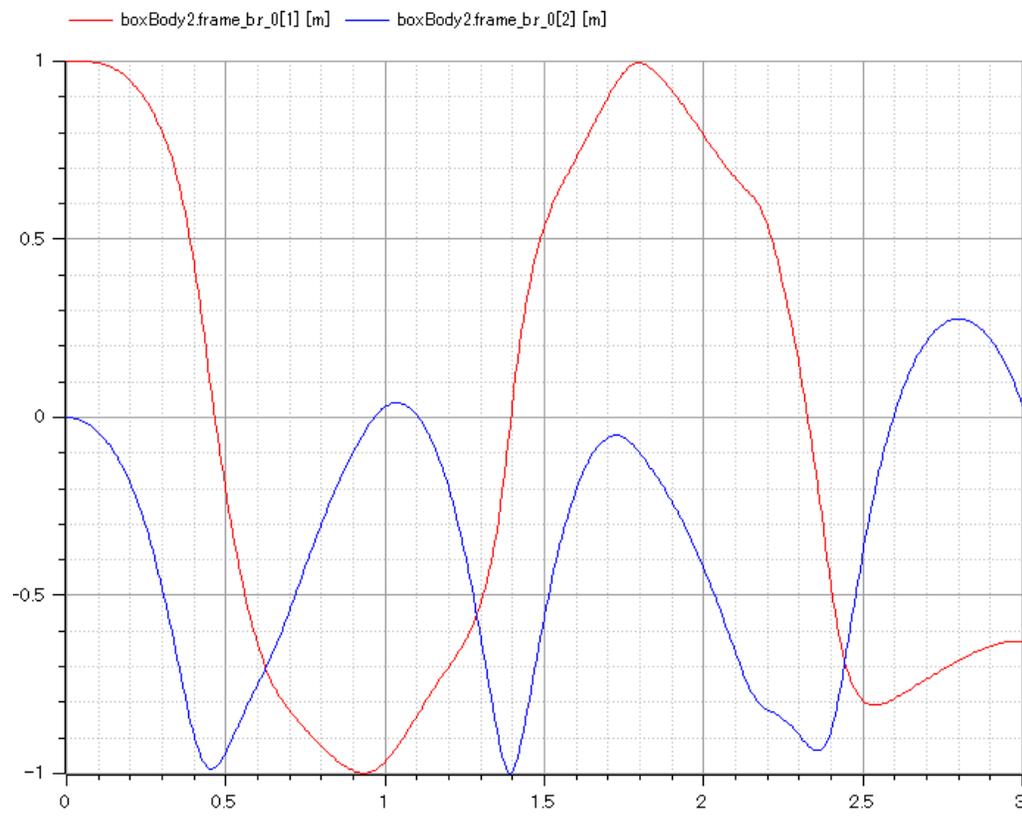
**root()**, **branch()**, **potentialRoot()** などのオペレータの内容は、ModelicaReference.Operators.Connections に記載されている。



モデル内の方程式とモデル間の方程式を連立する。



boxBody1.frame\_b.r\_0  
(boxBoxy1のコネクタframe\_bの座標)



boxBody2.frame\_b.r\_0  
(boxBoxy2のコネクタframe\_bの座標)

DoublePendulumの計算結果

# MultiBodyライブラリの3D可視化方法

# Modelica3Dによる3D可視化の手順

## 使用した環境 Windows 10

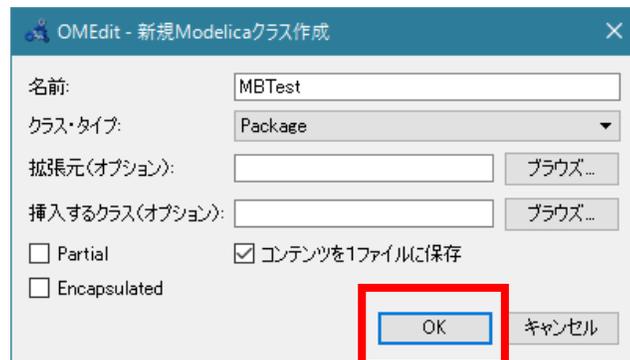
OpenModelica Ver.1.9.6 Windows版 ( <https://www.openmodelica.org/> )

Python 2.7.11 32bit版 (Anaconda 4.0.0 (32-bit)でインストールしたもの)

PyGTK 2.24.32 Anaconda を使用して以下のようにインストールしたもの

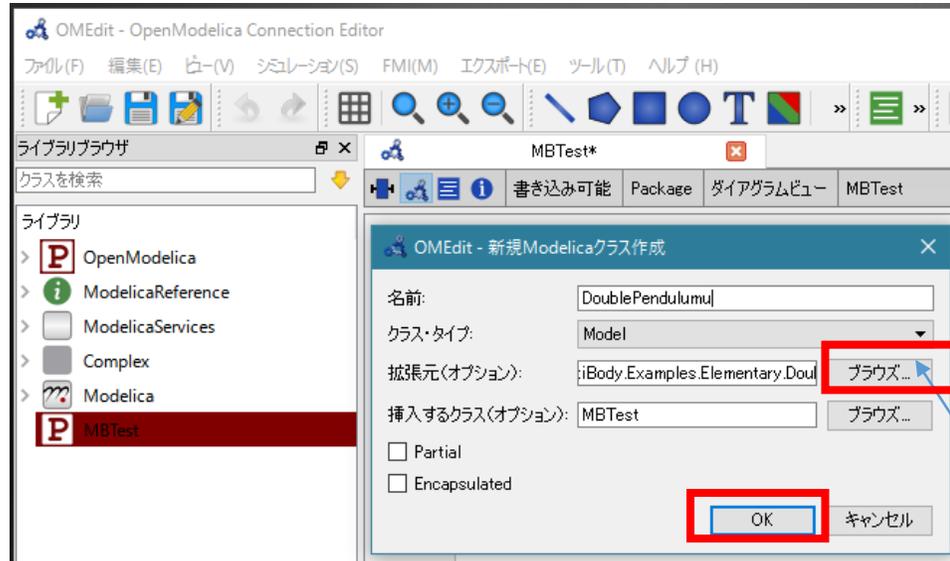
```
conda install --channel https://conda.anaconda.org/mike pygtk-ai
```

- ① OpenModelica Connection Editor (OMEdit) で  
ファイル>Modelicaクラス新規作成でパッケージを作成する



名前: MBTest  
クラスタイプ: Package

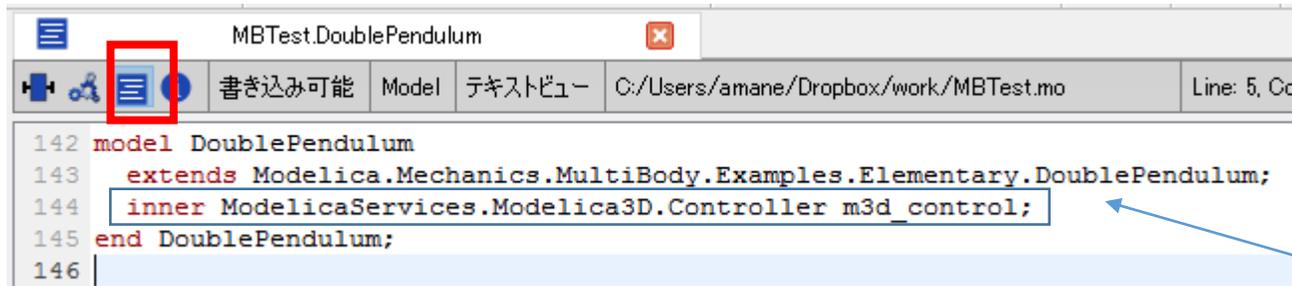
## ②MBTestを右クリックして、Modelicaクラス新規作成



名前：DoublePendulum  
クラス・タイプ：Model

Modelica.Mechanics.MultiBody.Examples.  
Elementary.DoublePendulumを選択する。

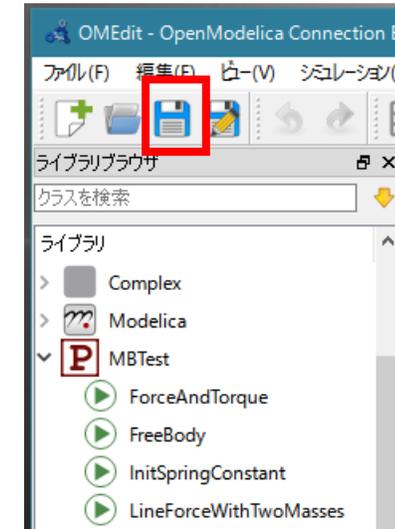
## ③テキストビューに切り替えて以下を挿入する。



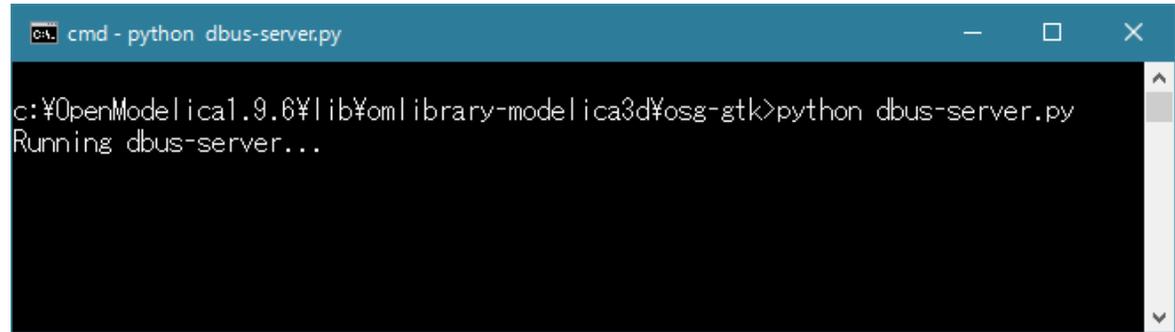
```
inner ModelicaServices.Modelica3D.Controller m3d_control;
```

## ④

②③の手順を繰り返して  
MBTestパッケージに  
MultiBodyライブラリの  
モデルを追加し保存する。



- ⑤ コマンドプロンプトでカレントディレクトリを  
c:¥OpenModelica1.9.6¥lib¥omlibrary-modelica3d¥osg-gtk  
にして  
python dbus-server.py  
を実行する。

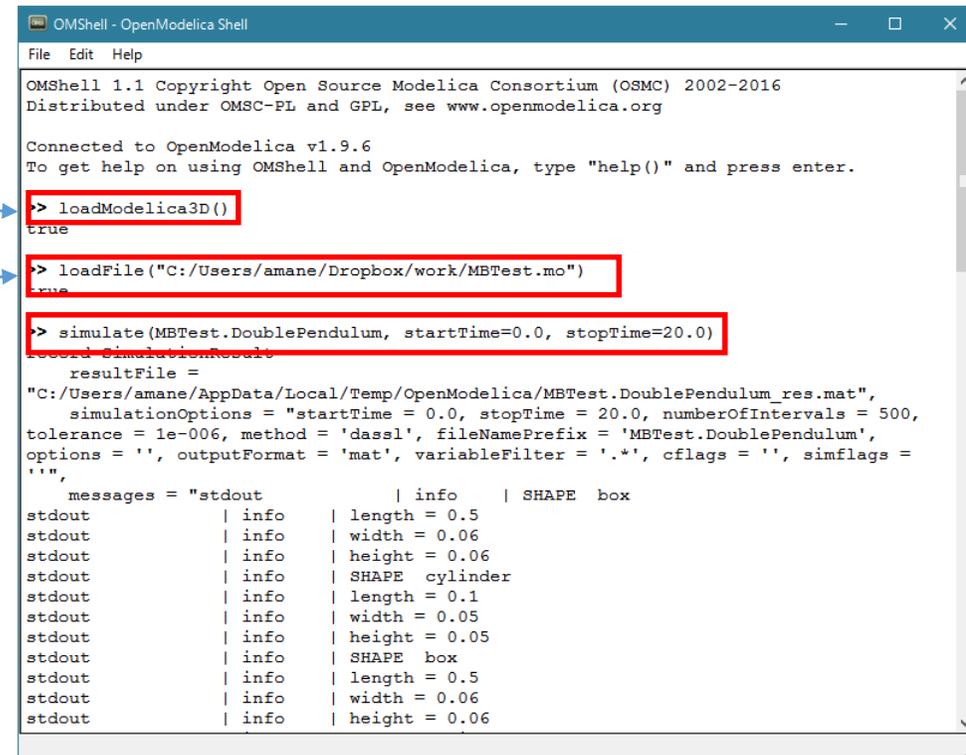


```
cmd - python dbus-server.py
c:¥OpenModelica1.9.6¥lib¥omlibrary-modelica3d¥osg-gtk>python dbus-server.py
Running dbus-server...
```

- ⑥ OpenModelica Shell (OMShell)を起動して  
以下を実行する。

loadModelica3D()

- ⑦ File>OpenでMBTest.moを開く。



```
OMShell - OpenModelica Shell
File Edit Help
OMShell 1.1 Copyright Open Source Modelica Consortium (OSMC) 2002-2016
Distributed under OSMC-PL and GPL, see www.openmodelica.org

Connected to OpenModelica v1.9.6
To get help on using OMShell and OpenModelica, type "help()" and press enter.

> loadModelica3D()
true

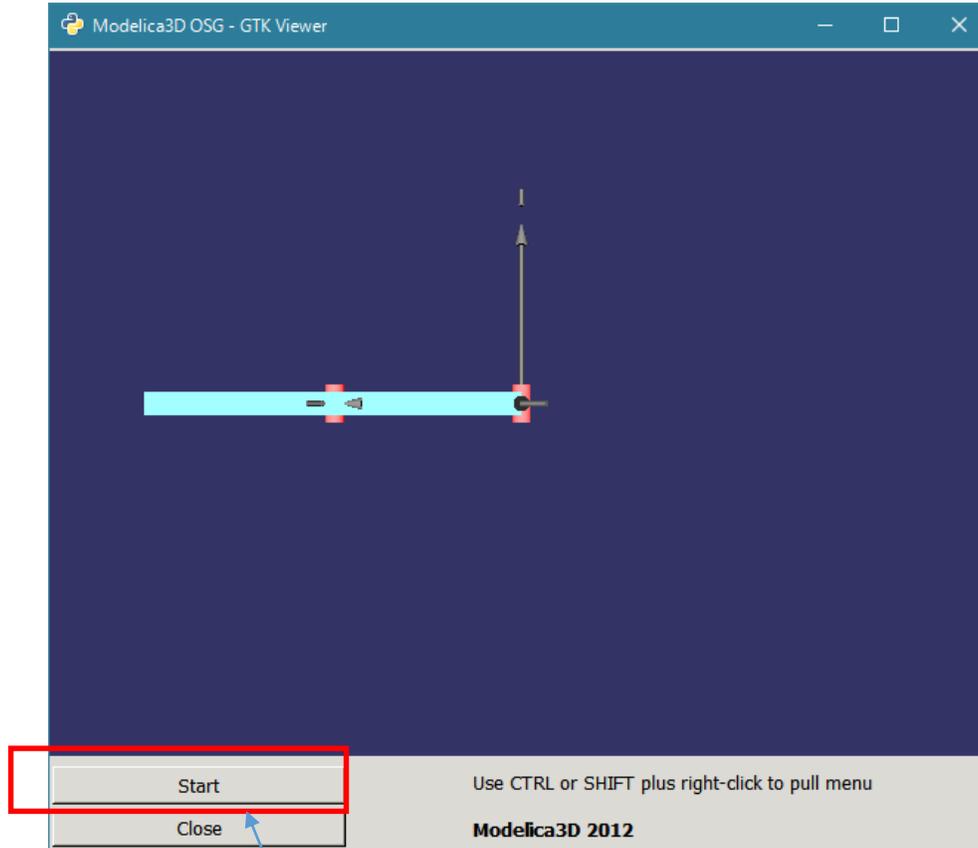
> loadFile("C:/Users/amane/Dropbox/work/MBTest.mo")
true

> simulate(MBTest.DoublePendulum, startTime=0.0, stopTime=20.0)
Record SimulationResult
  resultFile =
"C:/Users/amane/AppData/Local/Temp/OpenModelica/MBTest.DoublePendulum_res.mat",
  simulationOptions = "startTime = 0.0, stopTime = 20.0, numberOfIntervals = 500,
tolerance = 1e-006, method = 'dassl', fileNamePrefix = 'MBTest.DoublePendulum',
options = '', outputFormat = 'mat', variableFilter = '.*', cflags = '', simflags =
'',
  messages = "stdout          | info      | SHAPE box
stdout          | info      | length = 0.5
stdout          | info      | width = 0.06
stdout          | info      | height = 0.06
stdout          | info      | SHAPE cylinder
stdout          | info      | length = 0.1
stdout          | info      | width = 0.05
stdout          | info      | height = 0.05
stdout          | info      | SHAPE box
stdout          | info      | length = 0.5
stdout          | info      | width = 0.06
stdout          | info      | height = 0.06
```

- ⑧ simulate(MBTest.DoublePendulum, startTime=0.0, stopTime=20.0)

startTime=..., stopTime =...  
はオプション。

⑦ビューアが表示される。

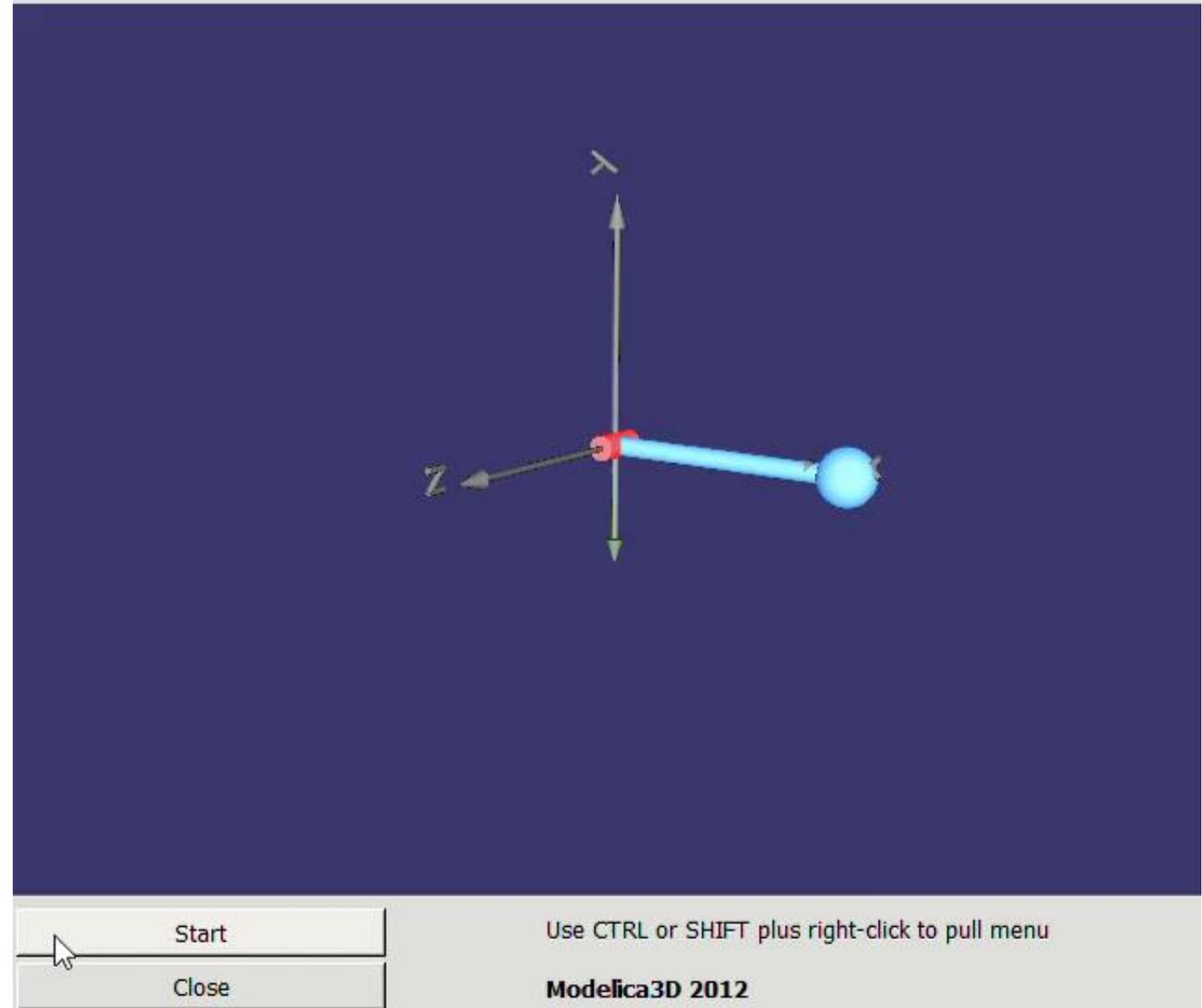
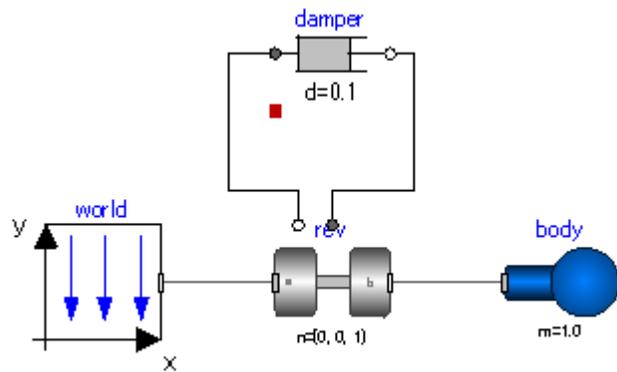


[start]ボタンをクリックする。  
3Dアニメーションがスタートする。

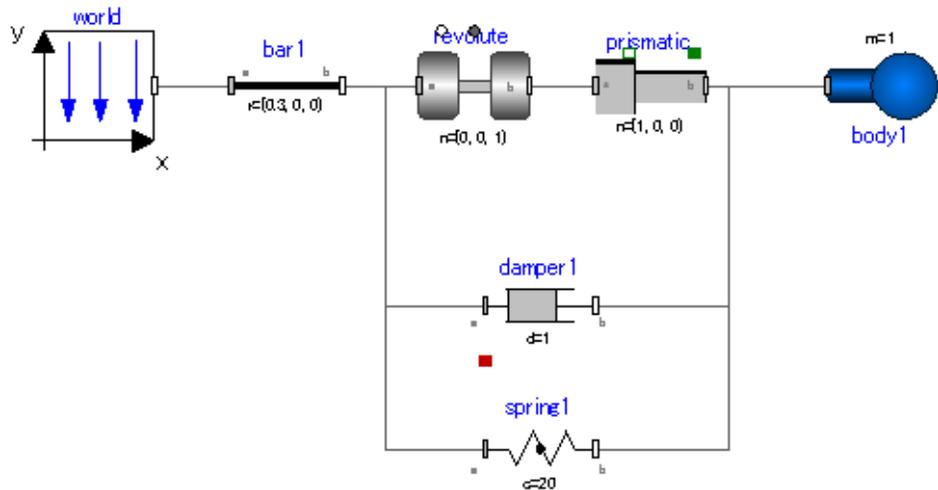
[Close]ボタンを押すと  
dbus-server.py  
も終了するので、別のモデルの  
シミュレーションを続けて実行  
するときは、⑤を実行してから  
simulate(...) を入力する。

MultiBodyライブラリ例題モデルの動画

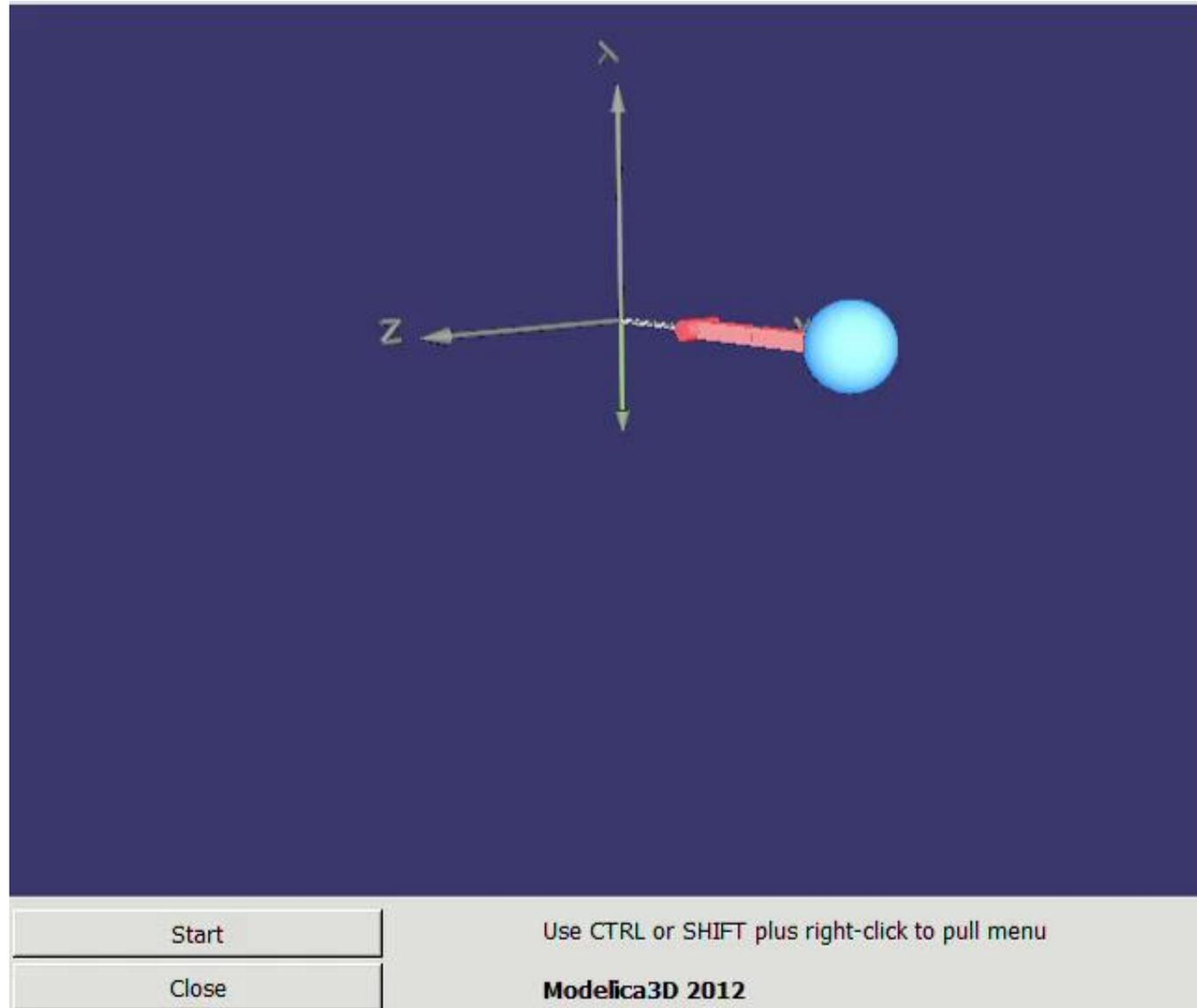
# Modelica.Mechanics.MultiBody.Examples.Elementary.Pendulum



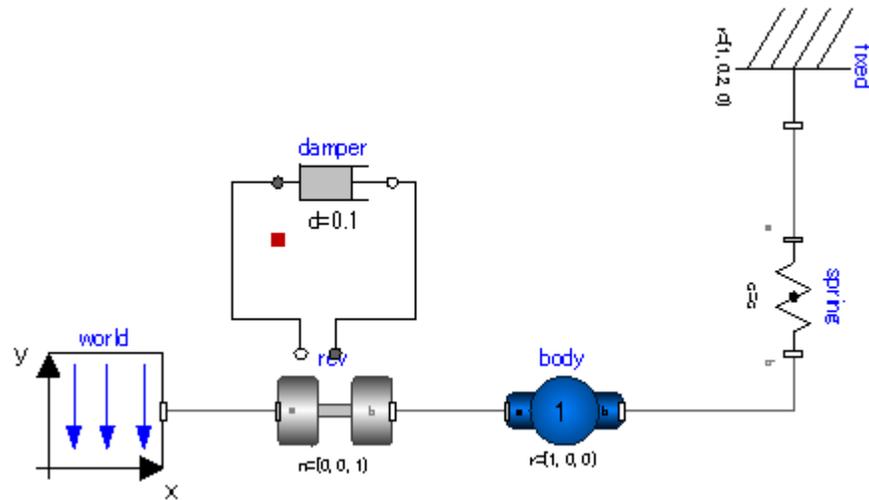
# Modelica.Mechanics.MultiBody.Examples.Elementary. PendulumWithSpringDamper



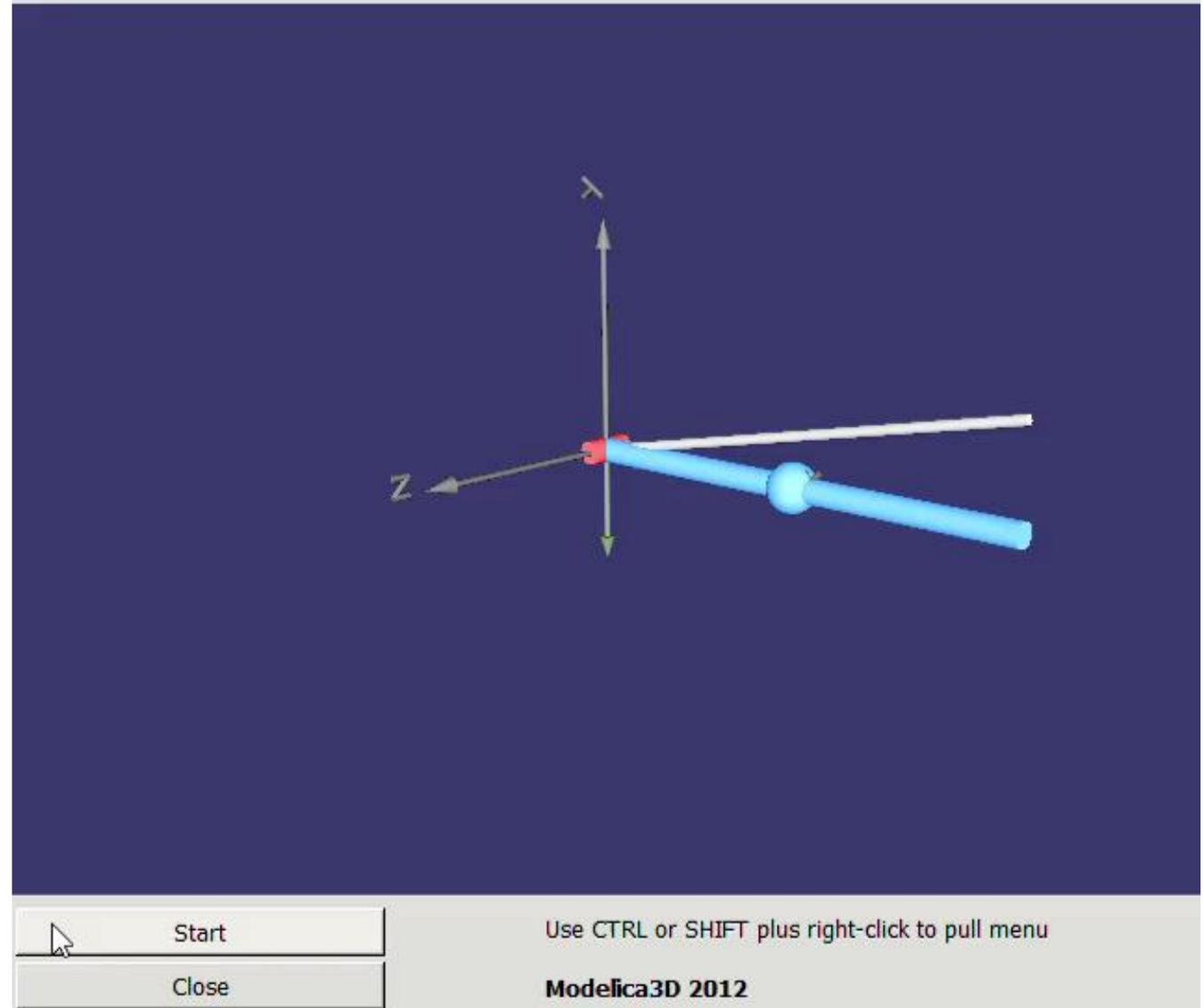
Spring が表示されない！！



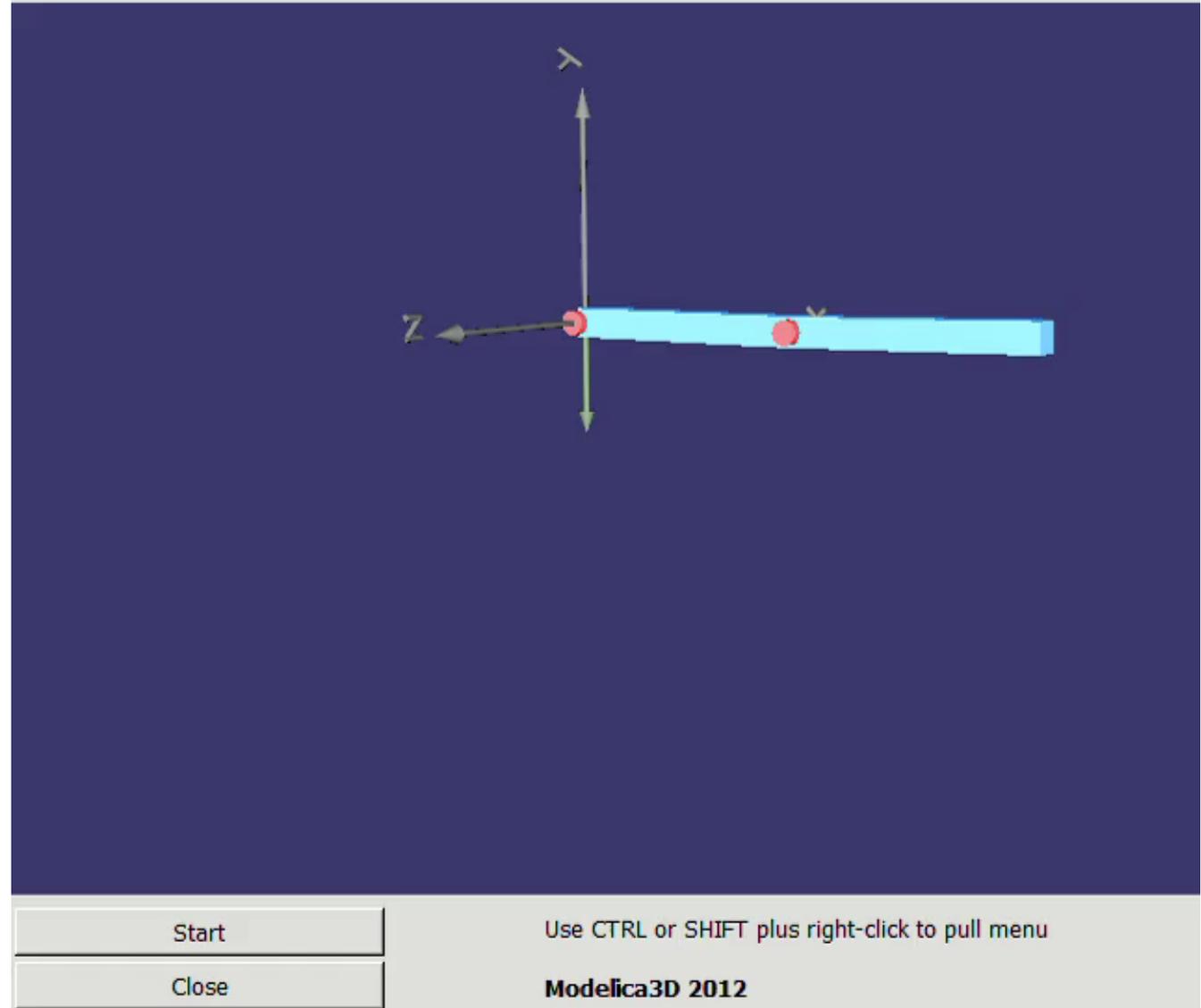
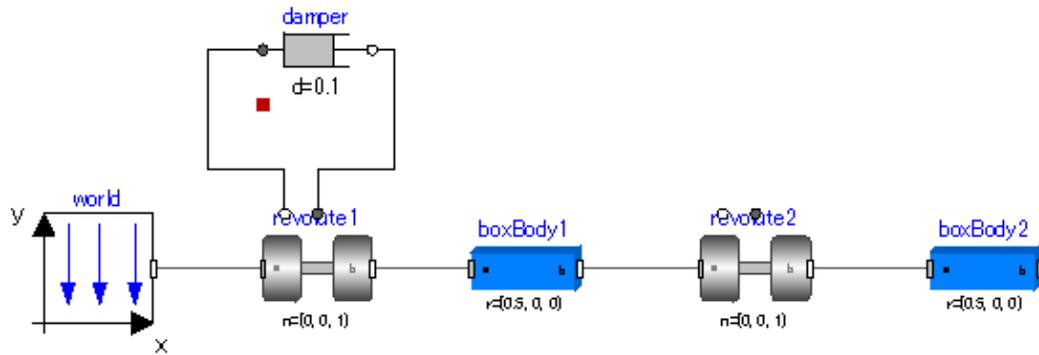
# Modelica.Mechanics.MultiBody.Examples.Elementary. InitSpringConstant



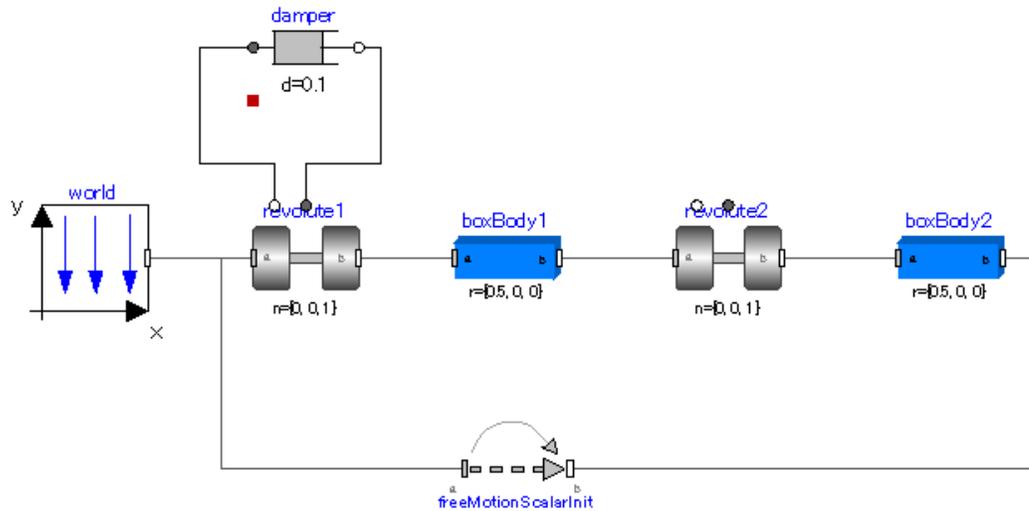
ばねと重力が釣り合うところで止まっているモデル。  
動かないのが正解??



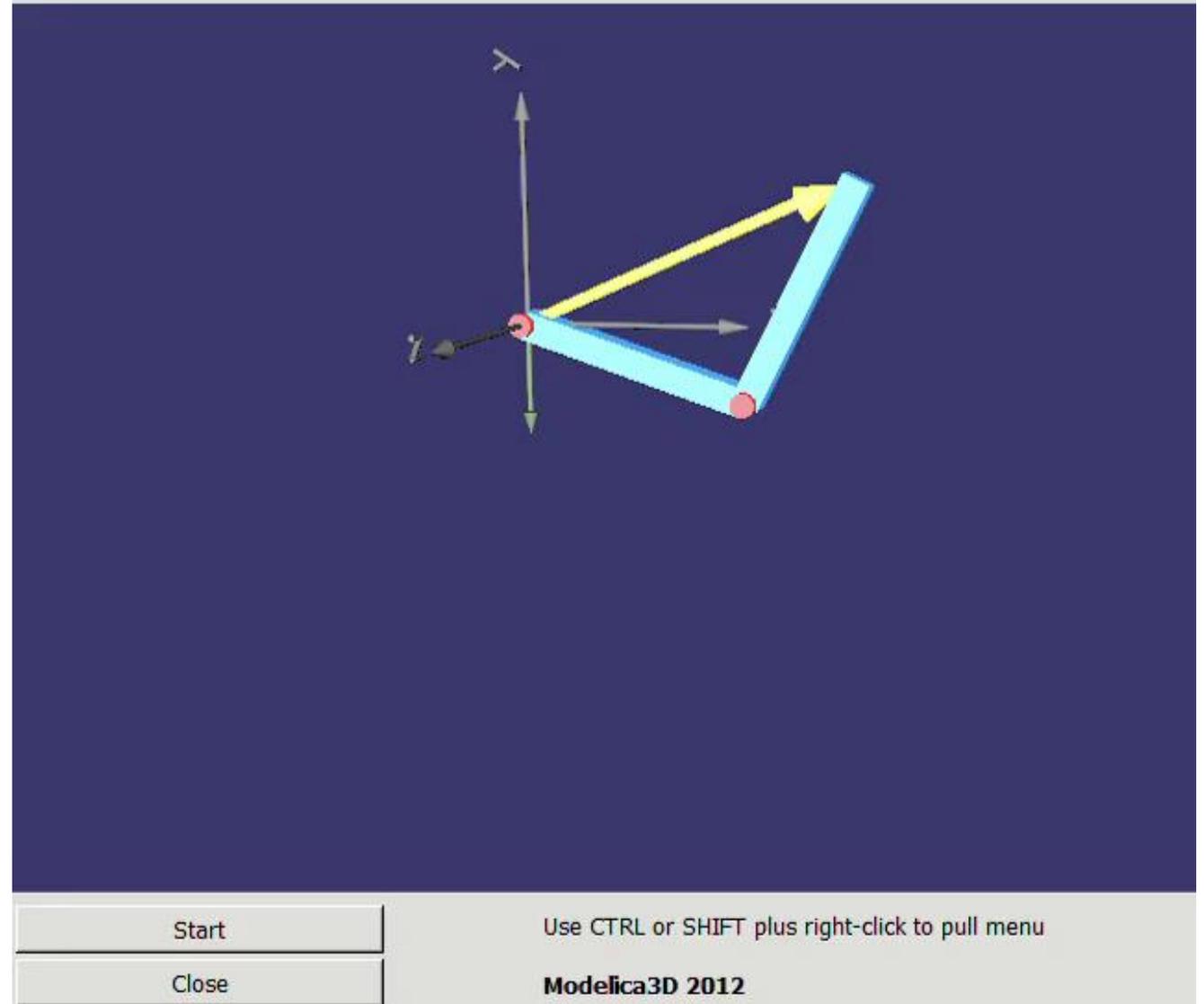
# Modelica.Mechanics.MultiBody.Examples.Elementary. DoublePendulum



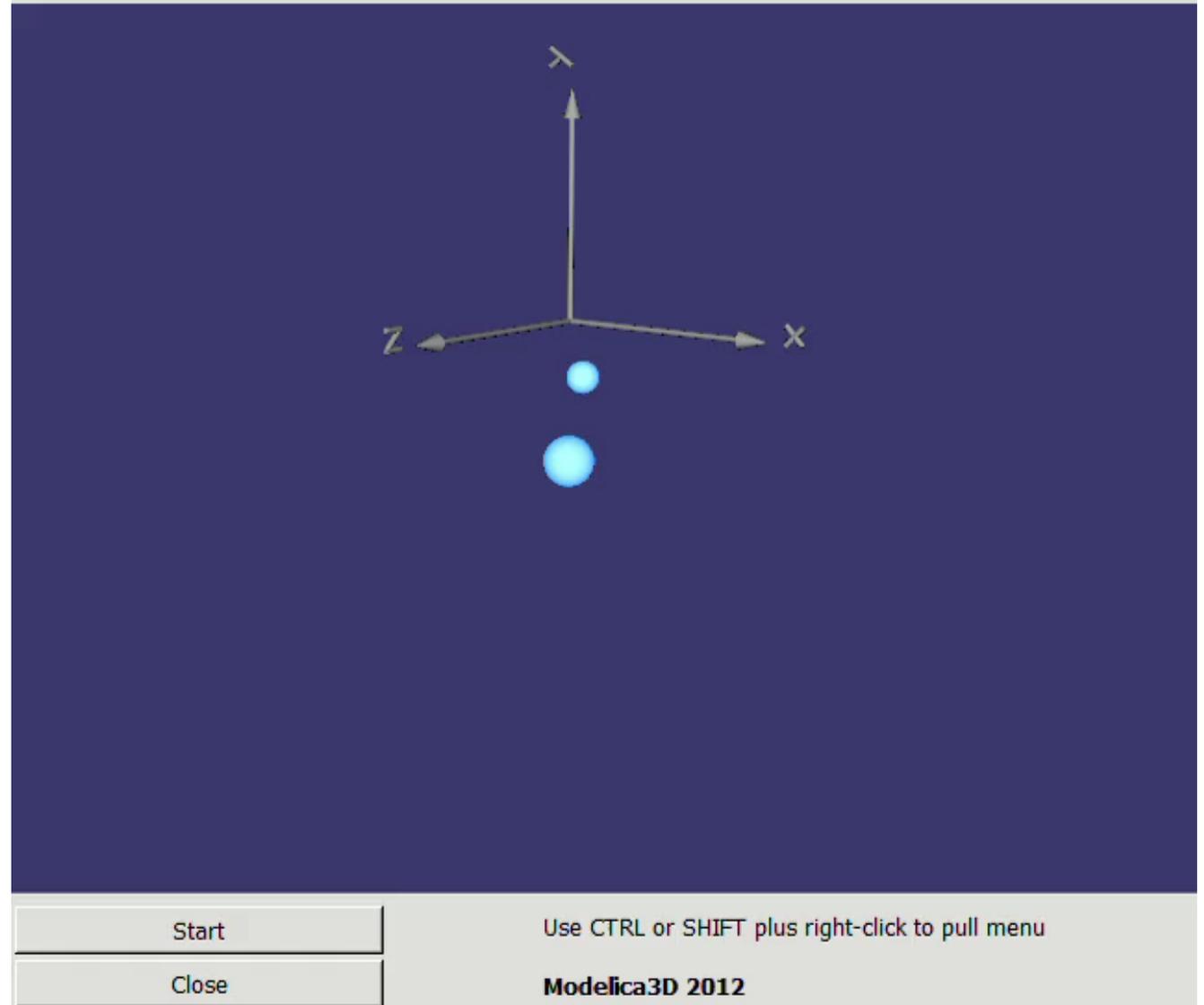
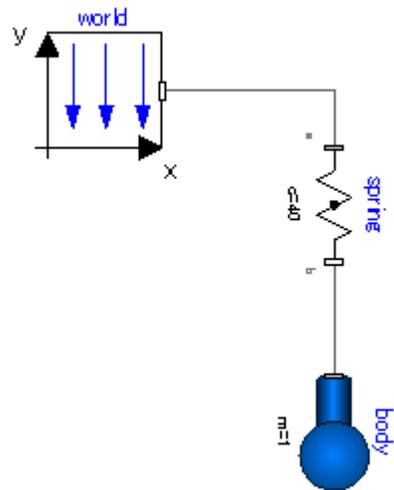
# Modelica.Mechanics.MultiBody.Examples.Elementary. DoublePendulumInitTip



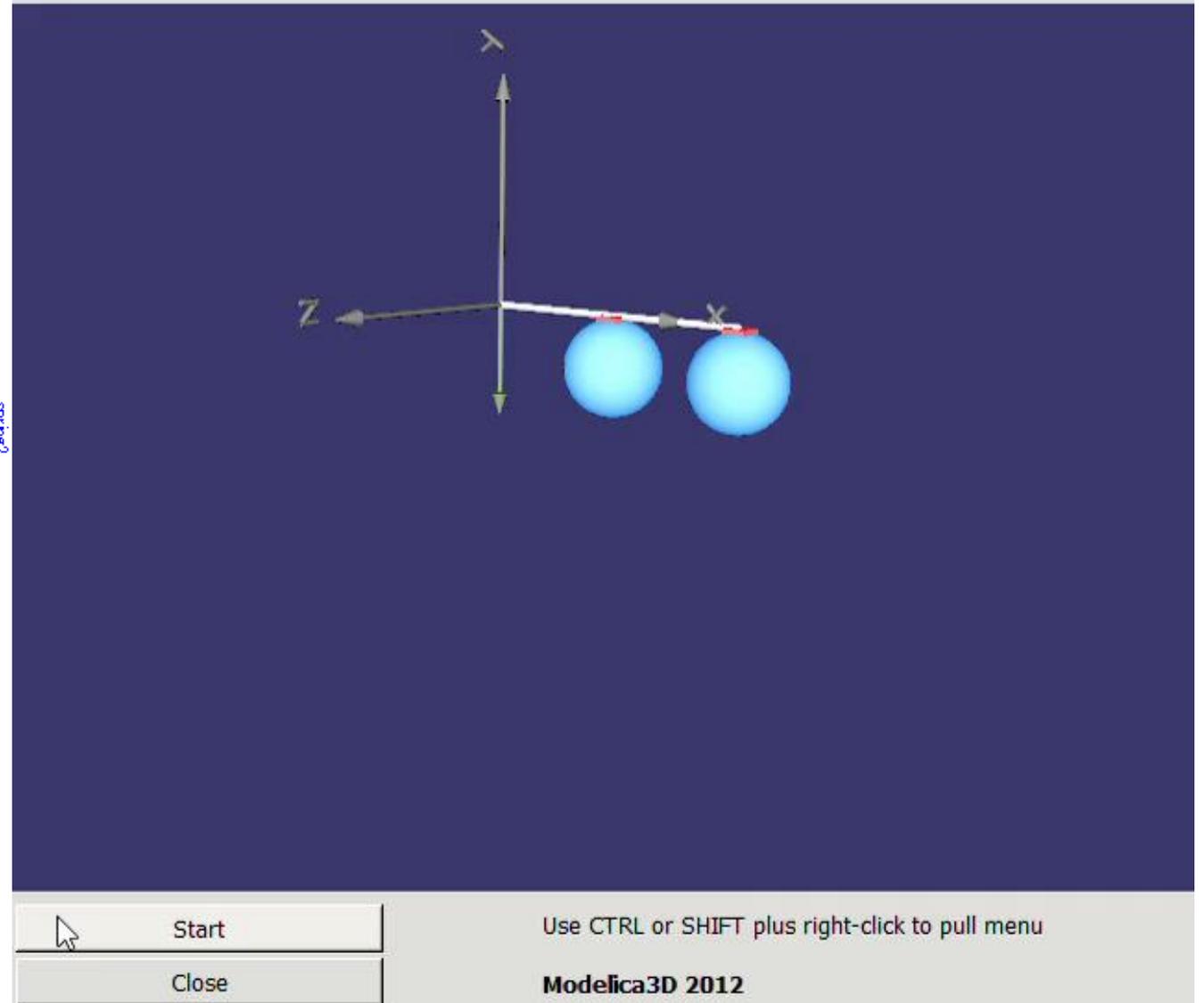
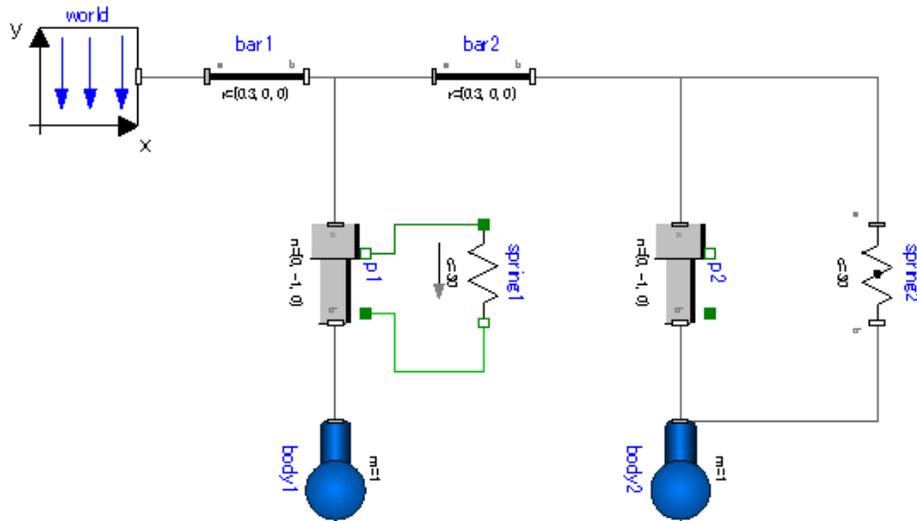
初期位置設定付き  
矢印の頭が変！！



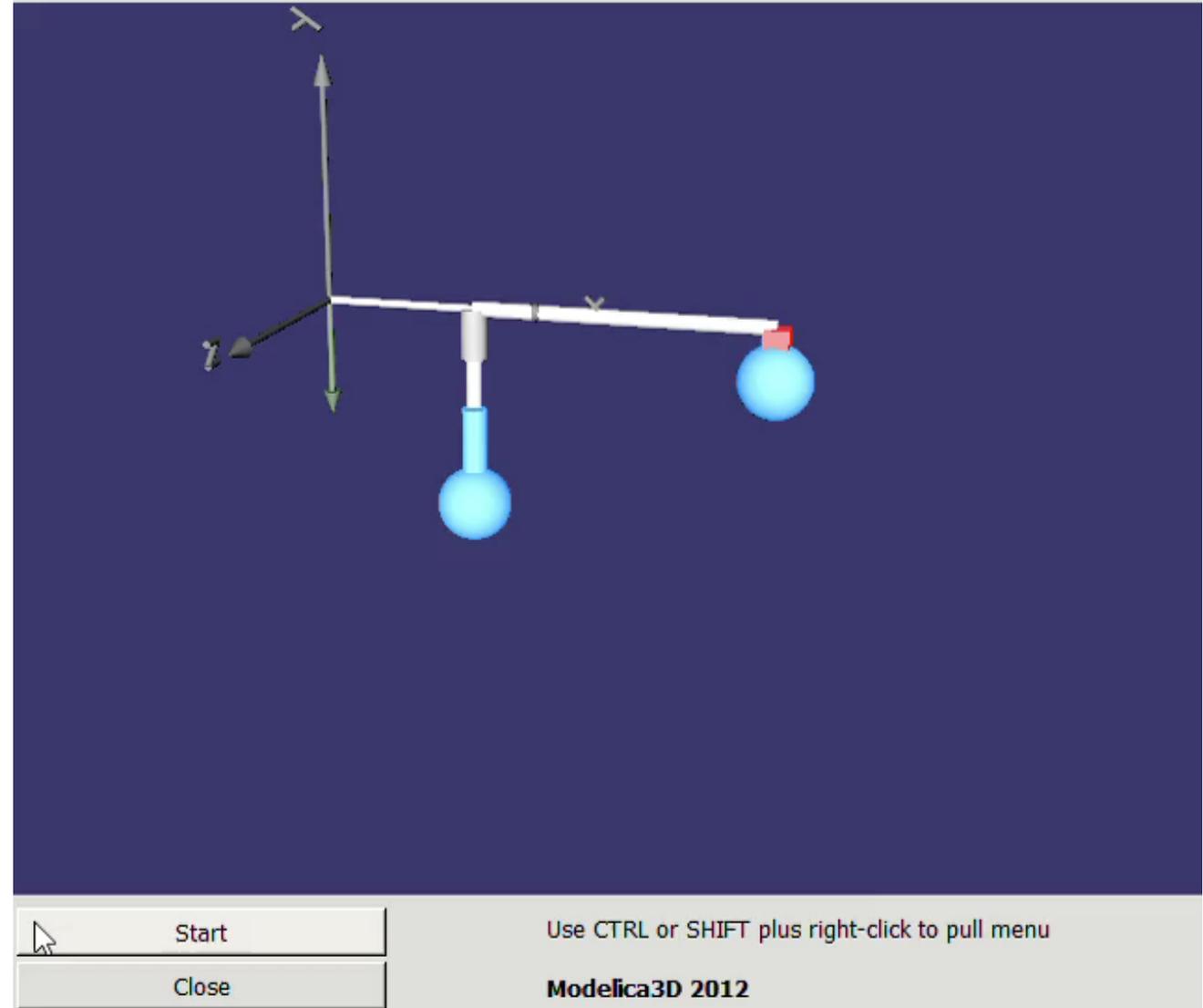
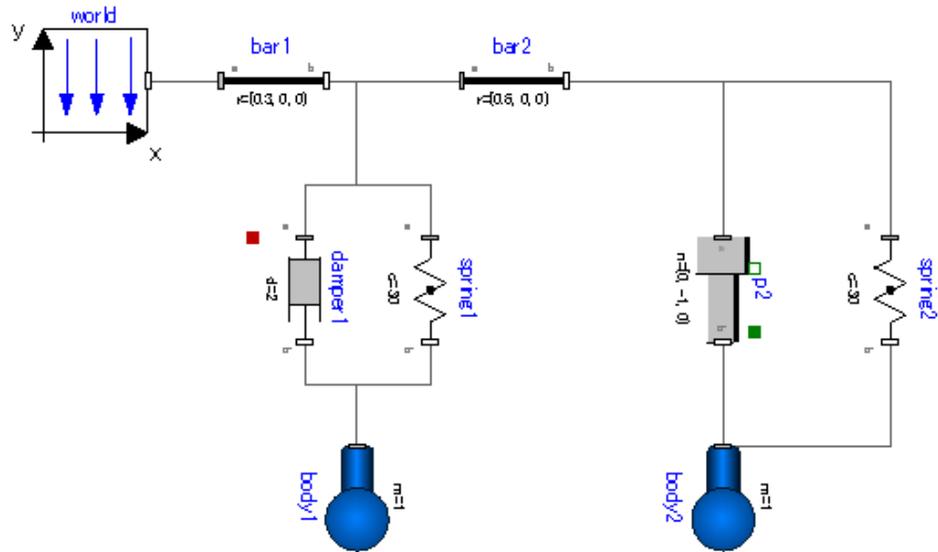
# Modelica.Mechanics.MultiBody.Examples.Elementary. SpringWithMass



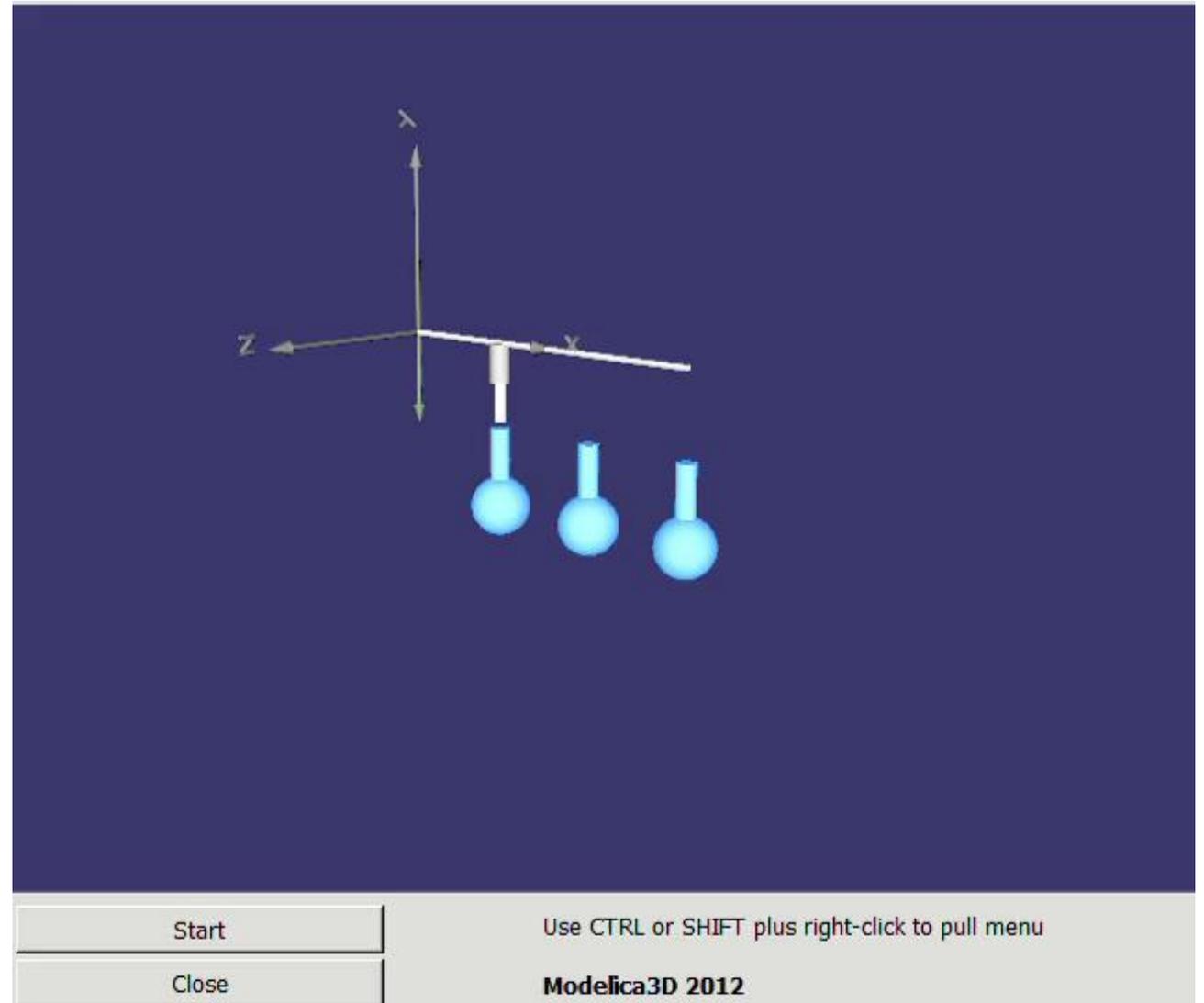
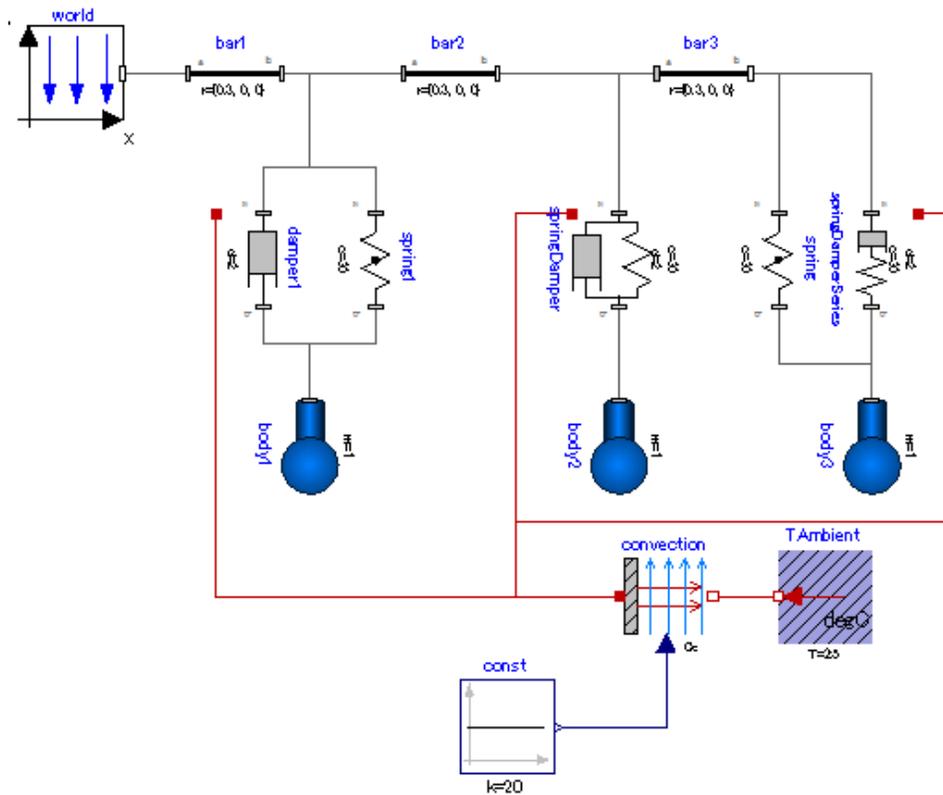
# Modelica.Mechanics.MultiBody.Examples.Elementary. SpringMassSystem



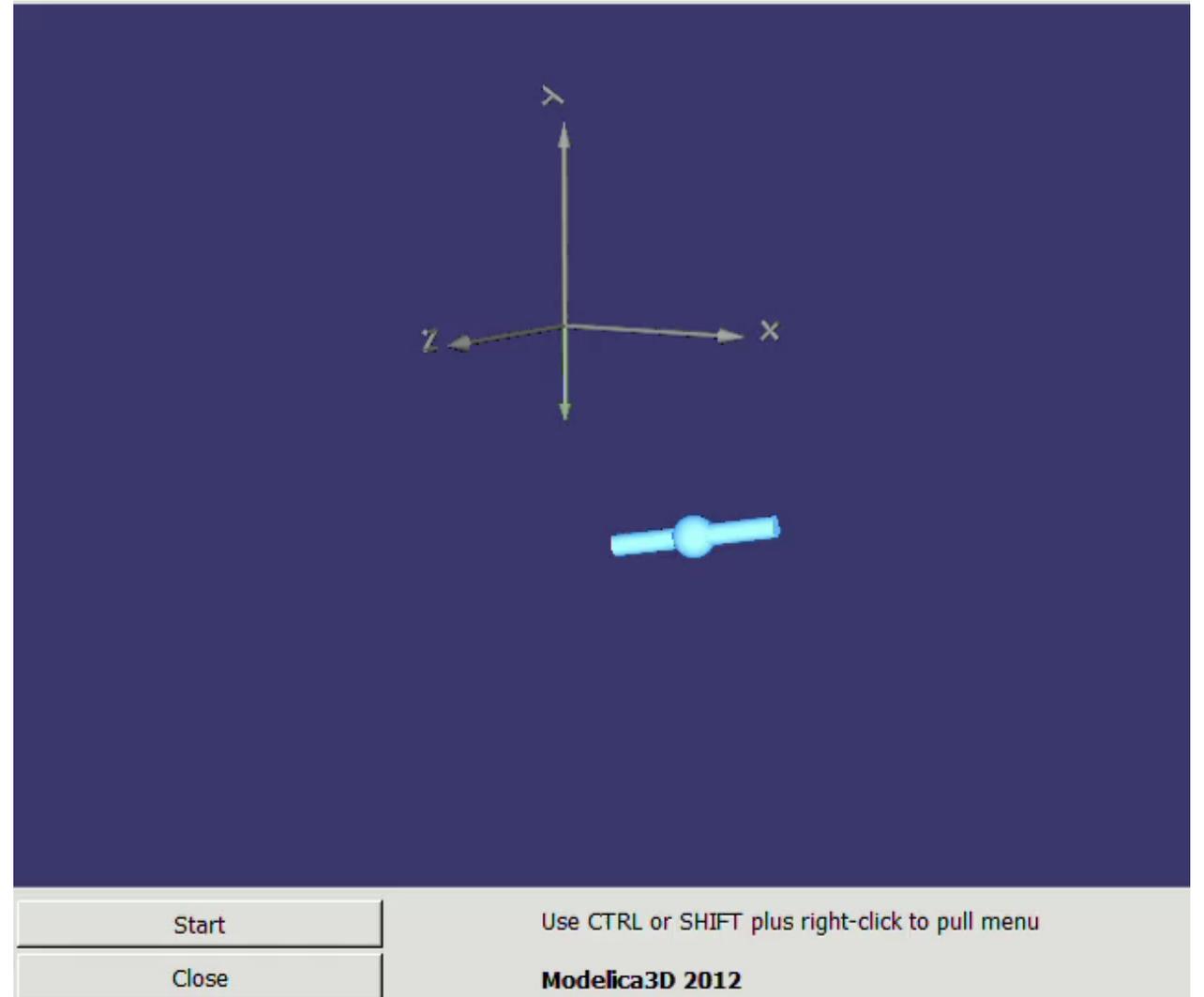
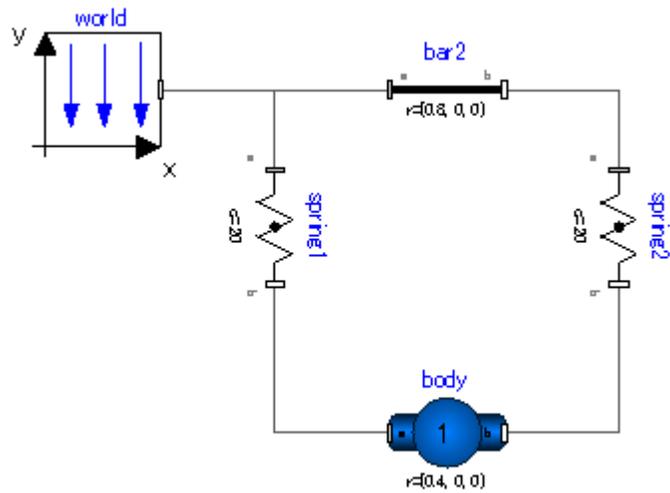
# Modelica.Mechanics.MultiBody.Examples.Elementary. SpringDamperSystem



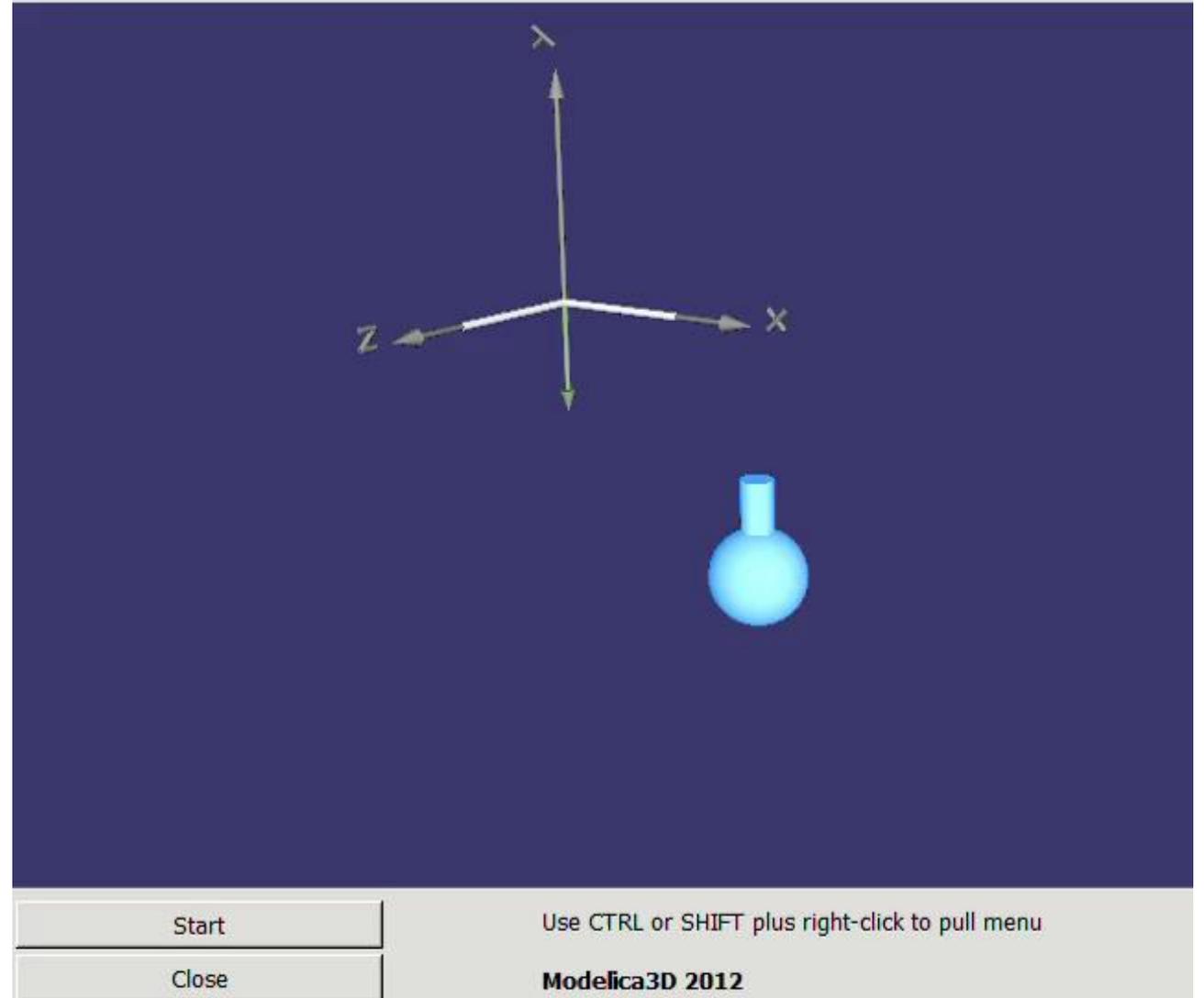
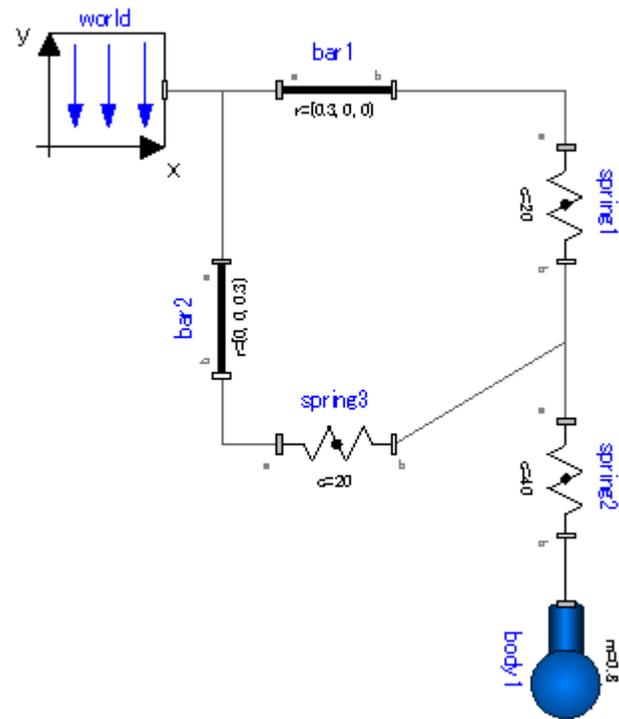
# Modelica.Mechanics.MultiBody.Examples.Elementary. HeatLosses



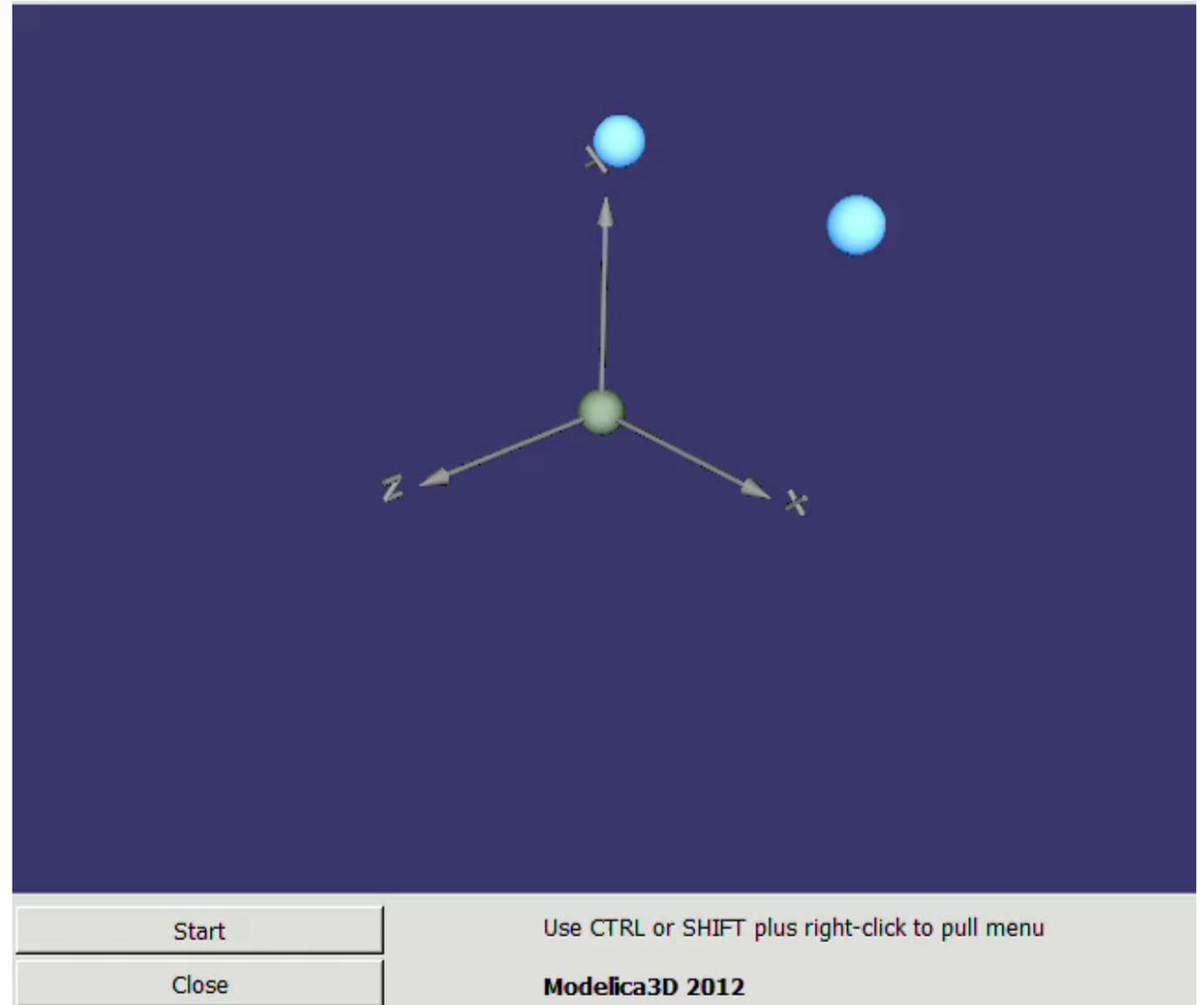
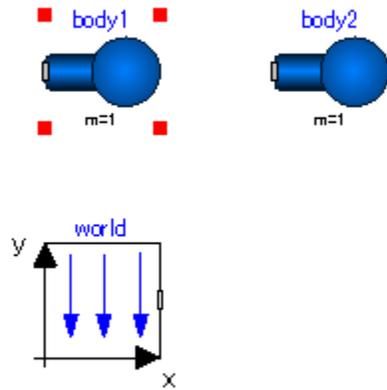
# Modelica.Mechanics.MultiBody.Examples.Elementary.FreeBody



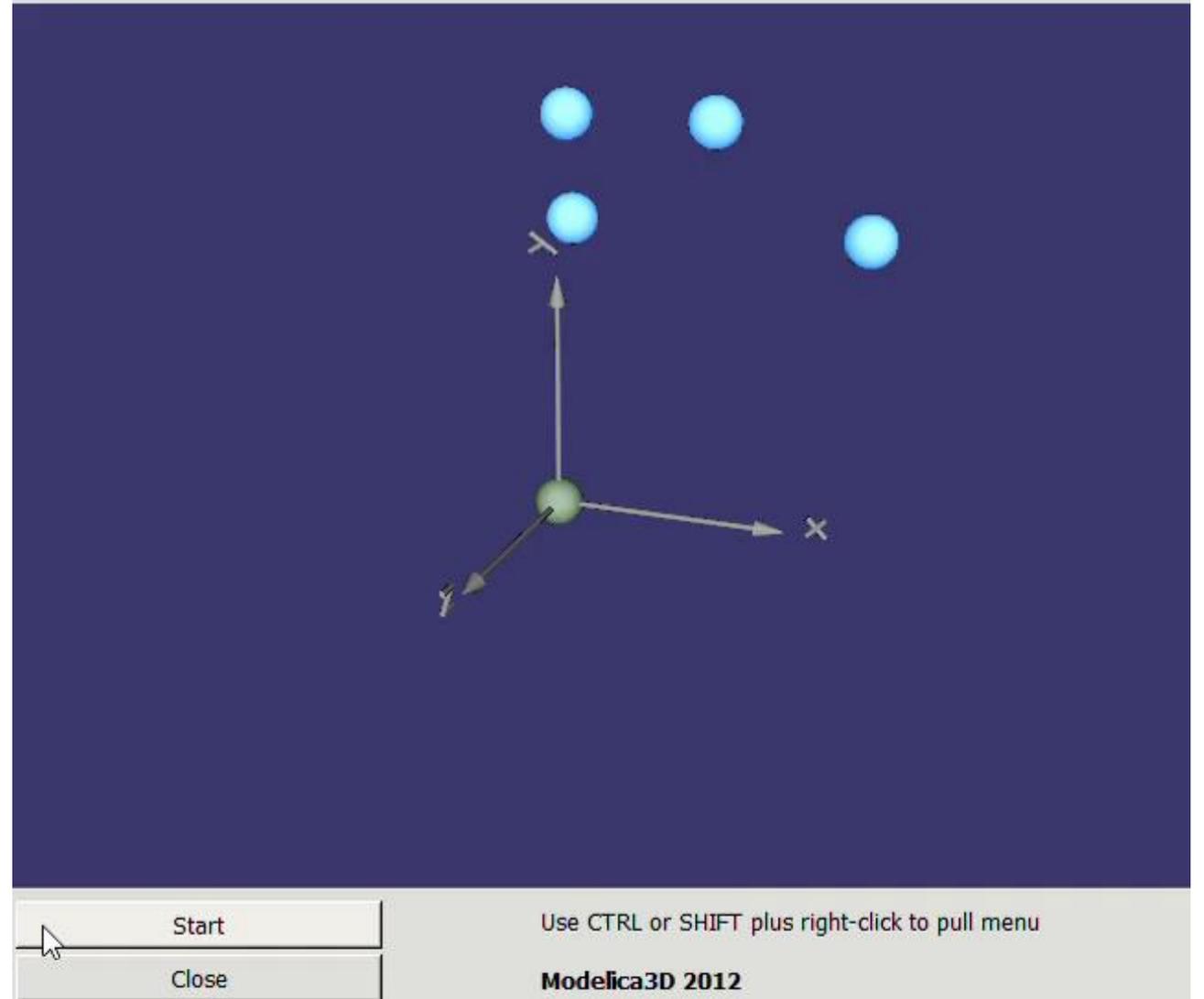
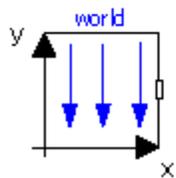
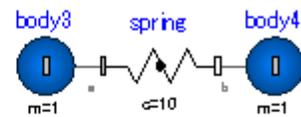
# Modelica.Mechanics.MultiBody.Examples.Elementary. ThreeSprings



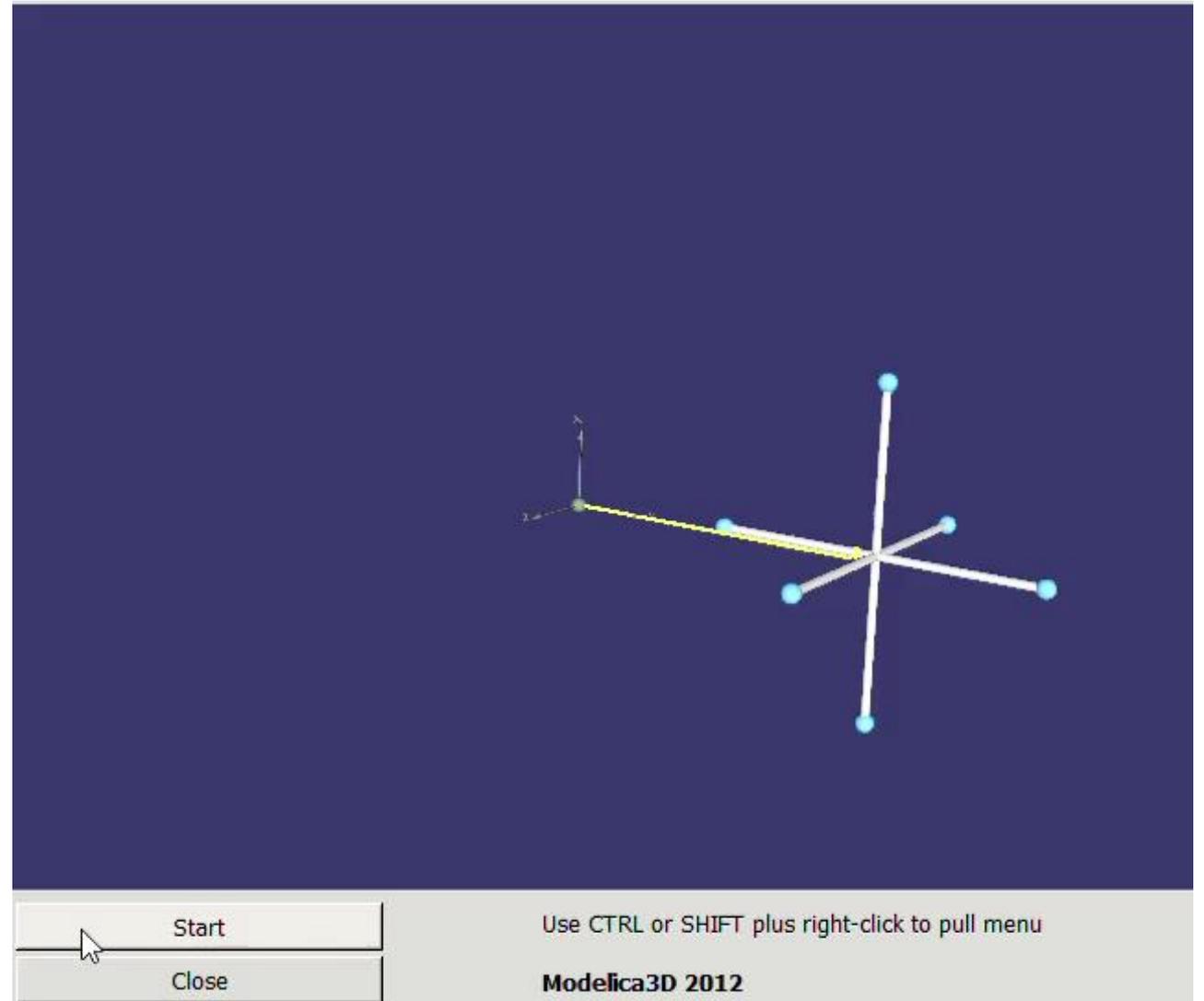
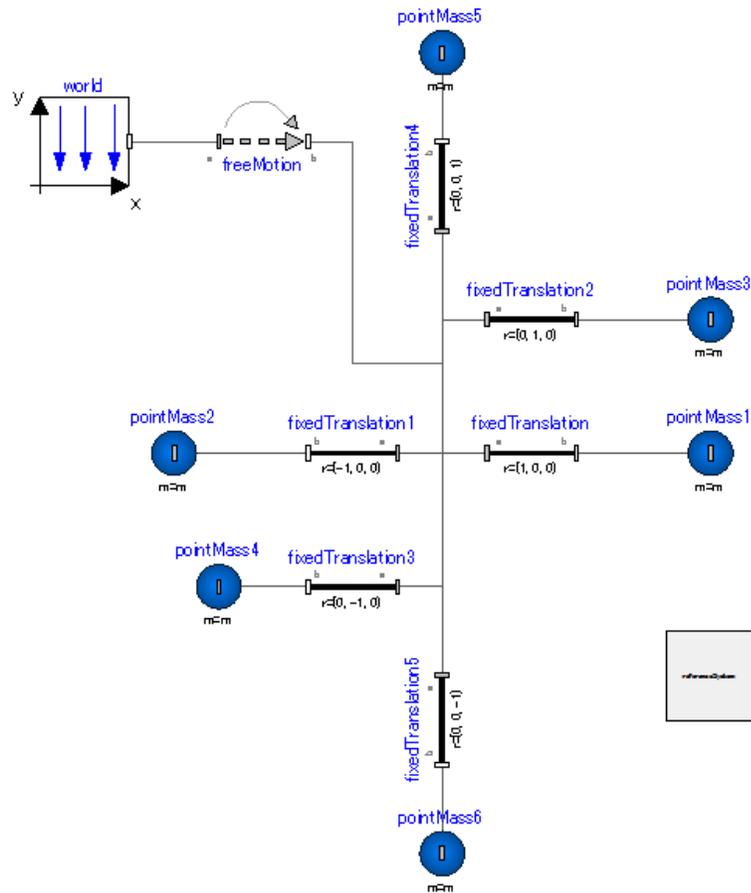
# Modelica.Mechanics.MultiBody.Examples.Elementary. PointGravity



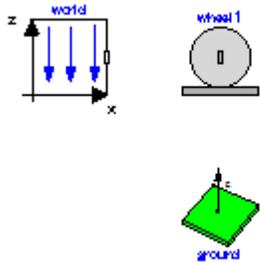
# Modelica.Mechanics.MultiBody.Examples.Elementary. PointGravityWithPointMasses



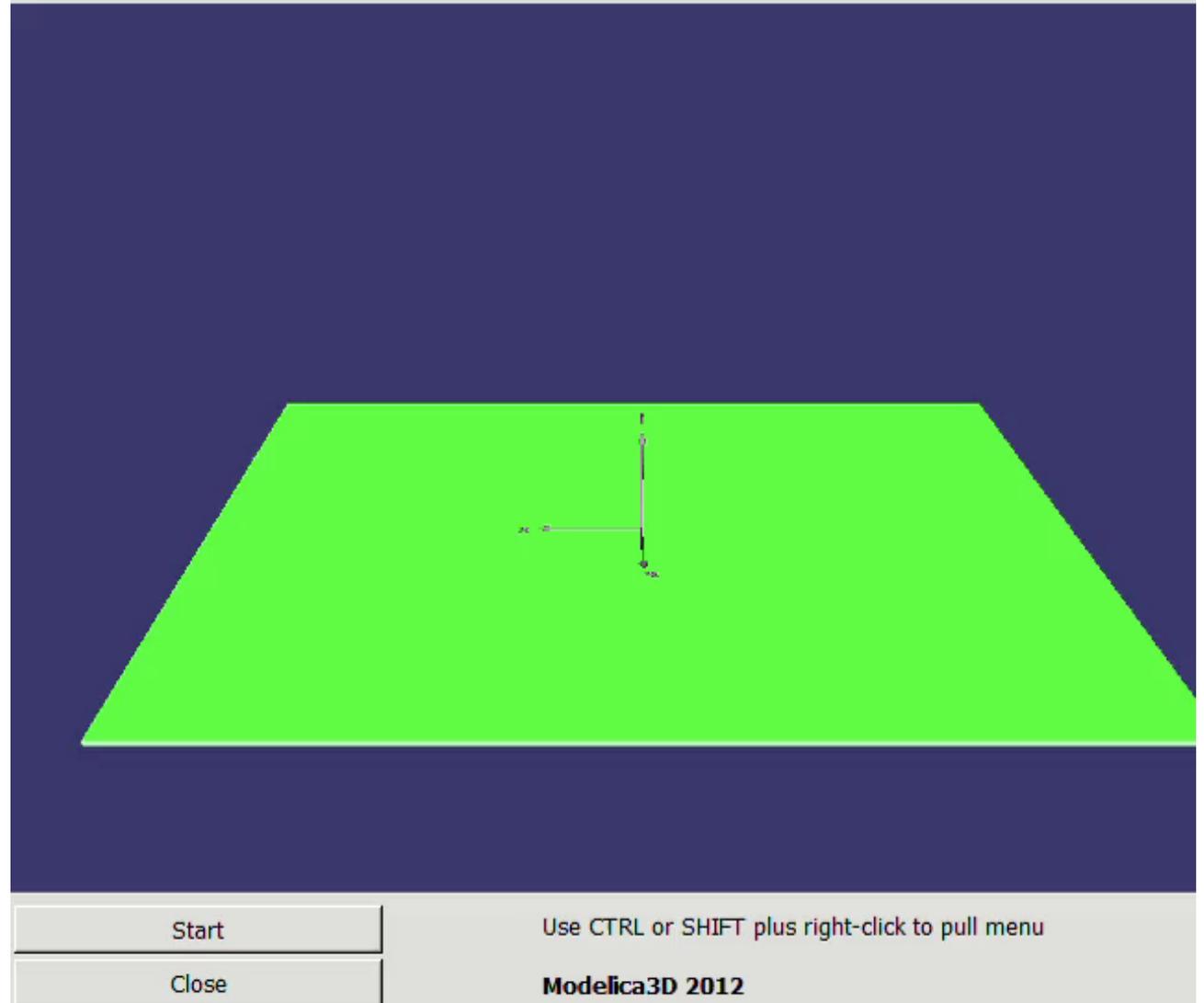
# Modelica.Mechanics.MultiBody.Examples.Elementary. PointGravityWithPointMasses2



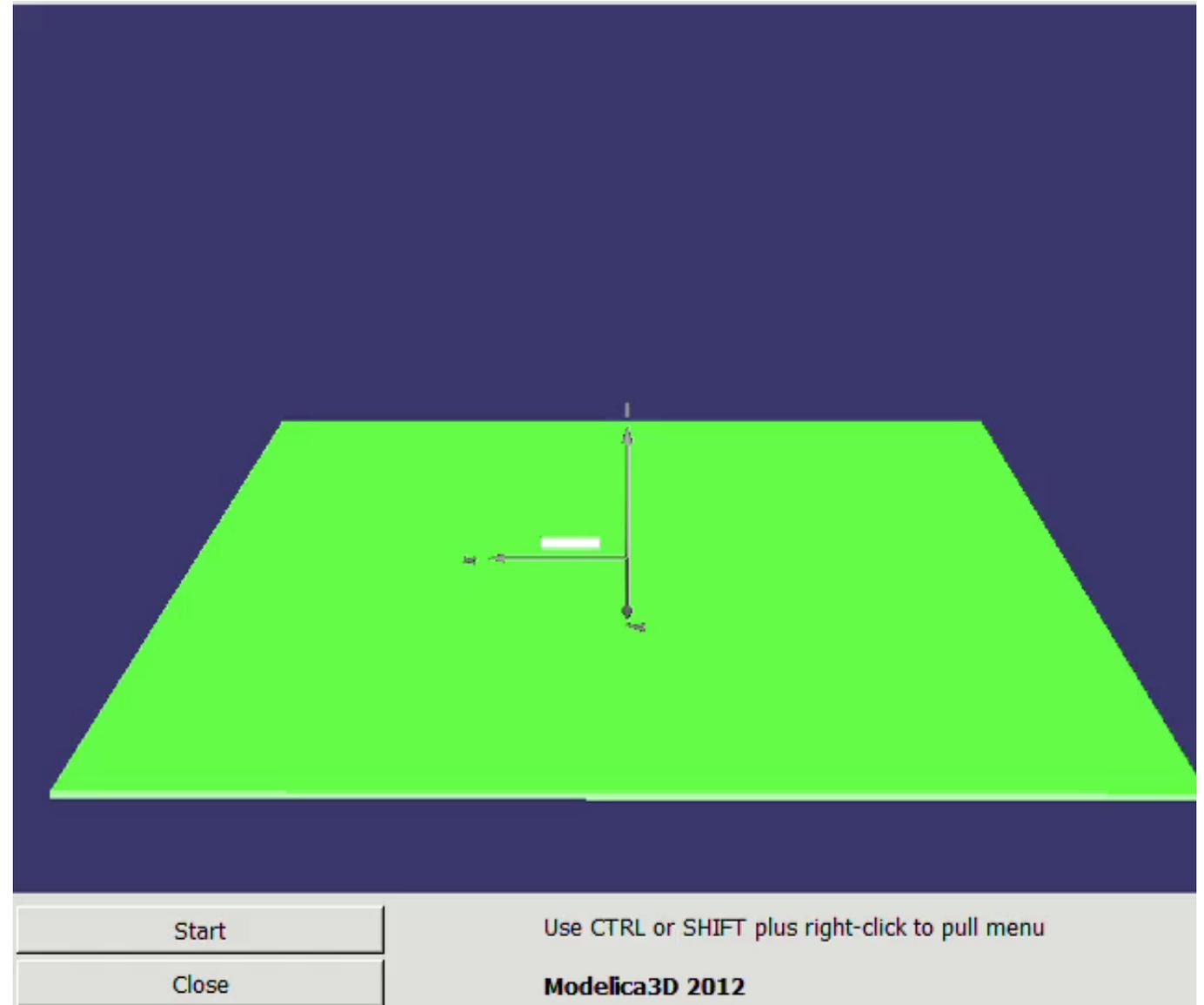
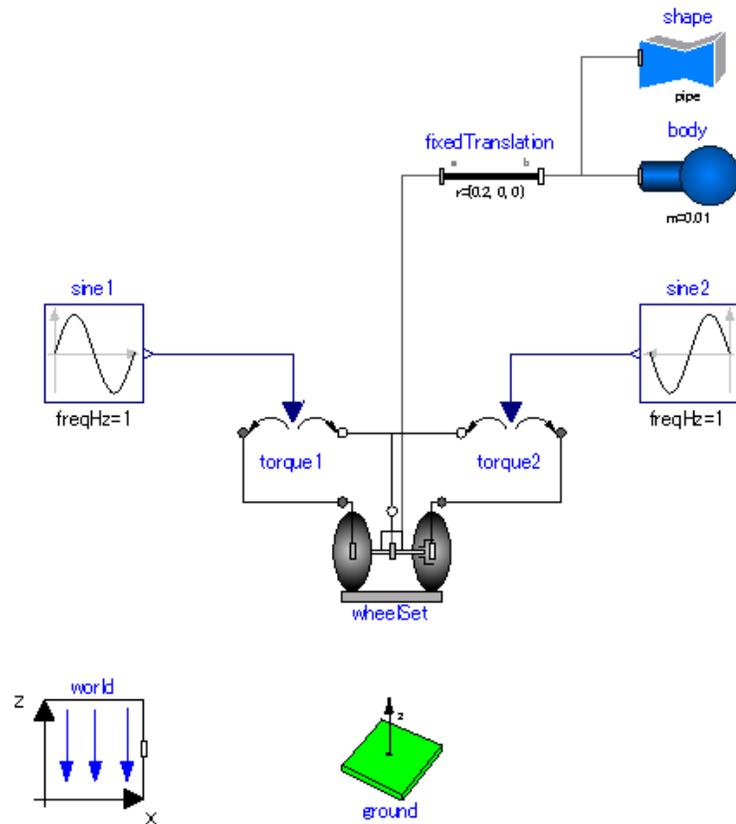
# Modelica.Mechanics.MultiBody.Examples.Elementary. RollingWheel



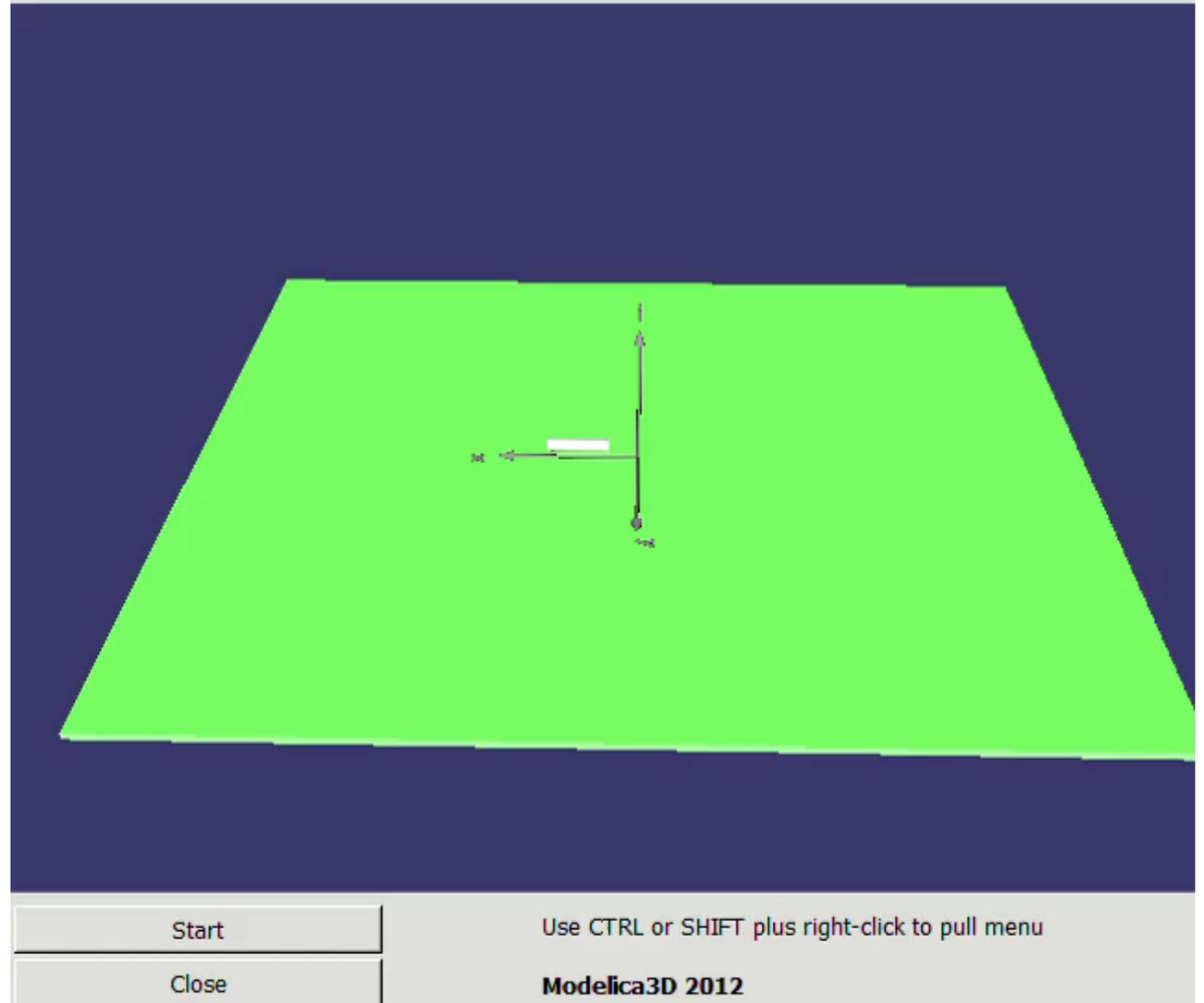
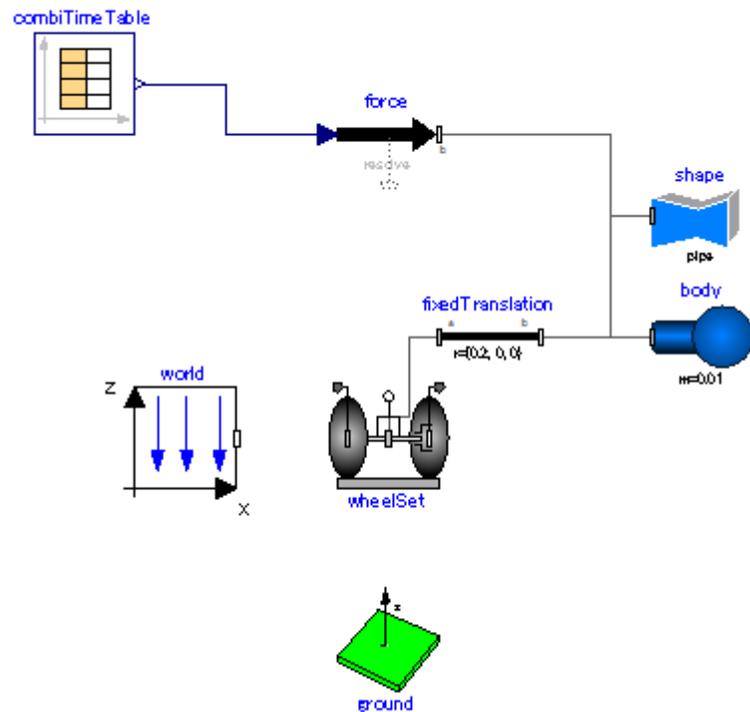
Wheel が表示されないので変化なし！！



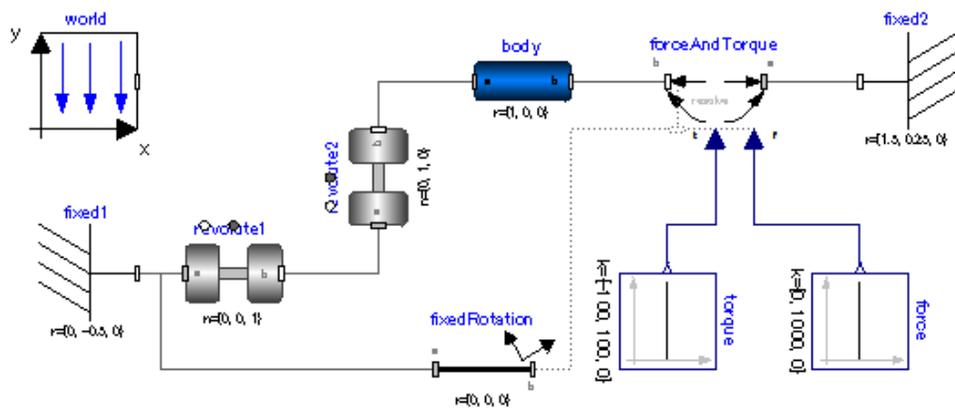
# Modelica.Mechanics.MultiBody.Examples.Elementary. RollingWheelSetDriving



# Modelica.Mechanics.MultiBody.Examples.Elementary. RollingWheelSetPulling



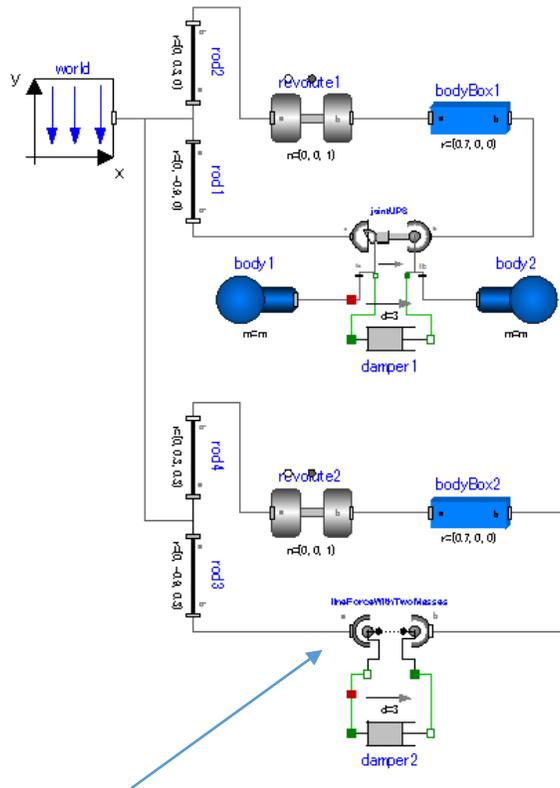
# Modelica.Mechanics.MultiBody.Examples.Elementary. ForceAndTorque



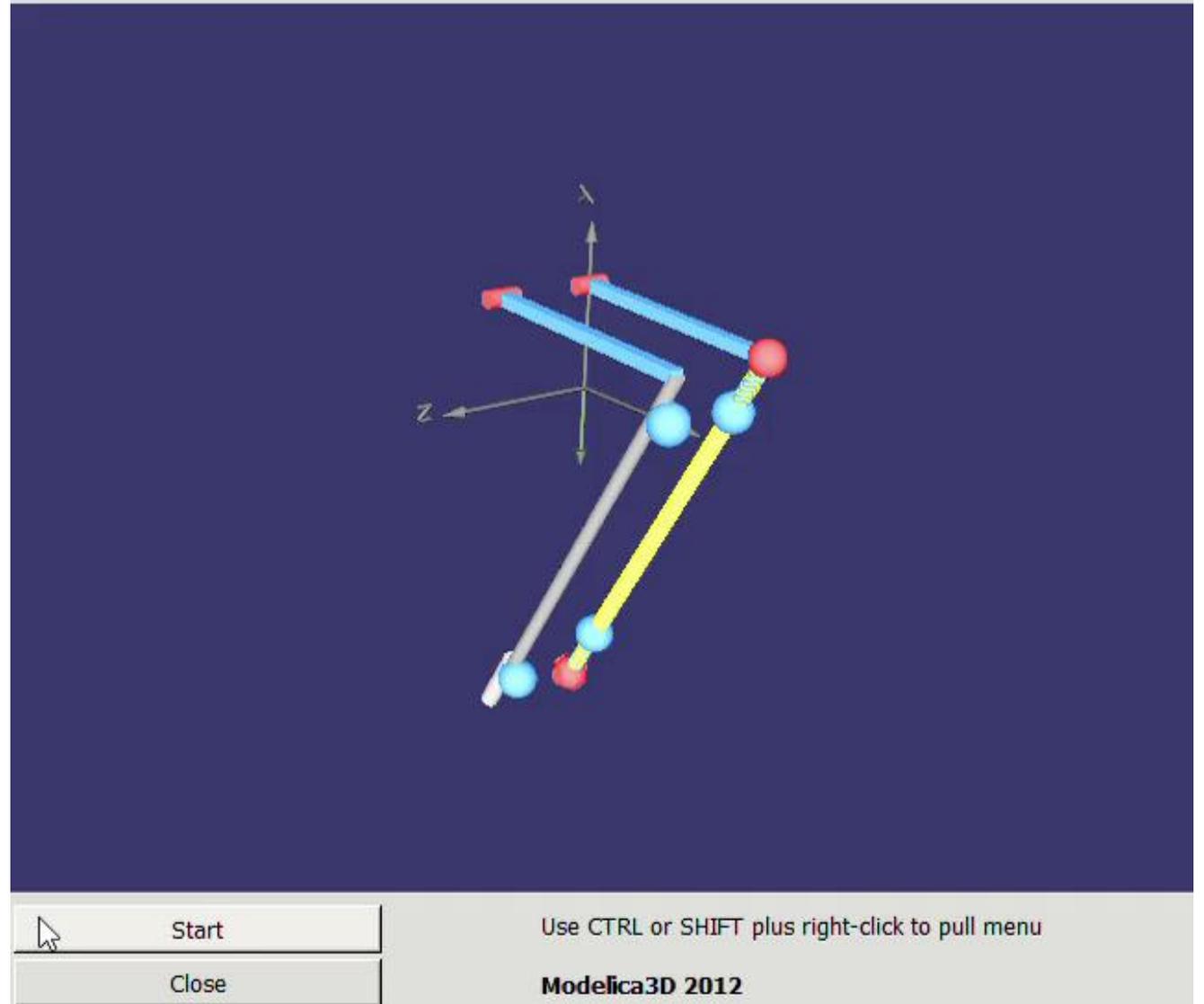
矢印がうまく表示できない。



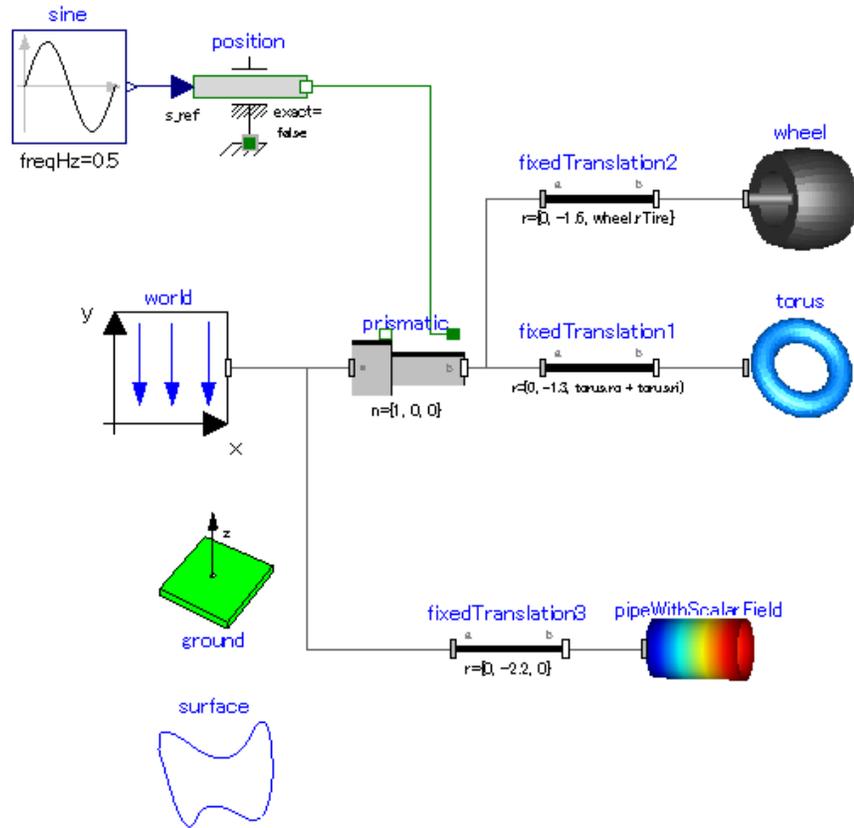
# Modelica.Mechanics.MultiBody.Examples.Elementary. LineForceWithTwoMasses



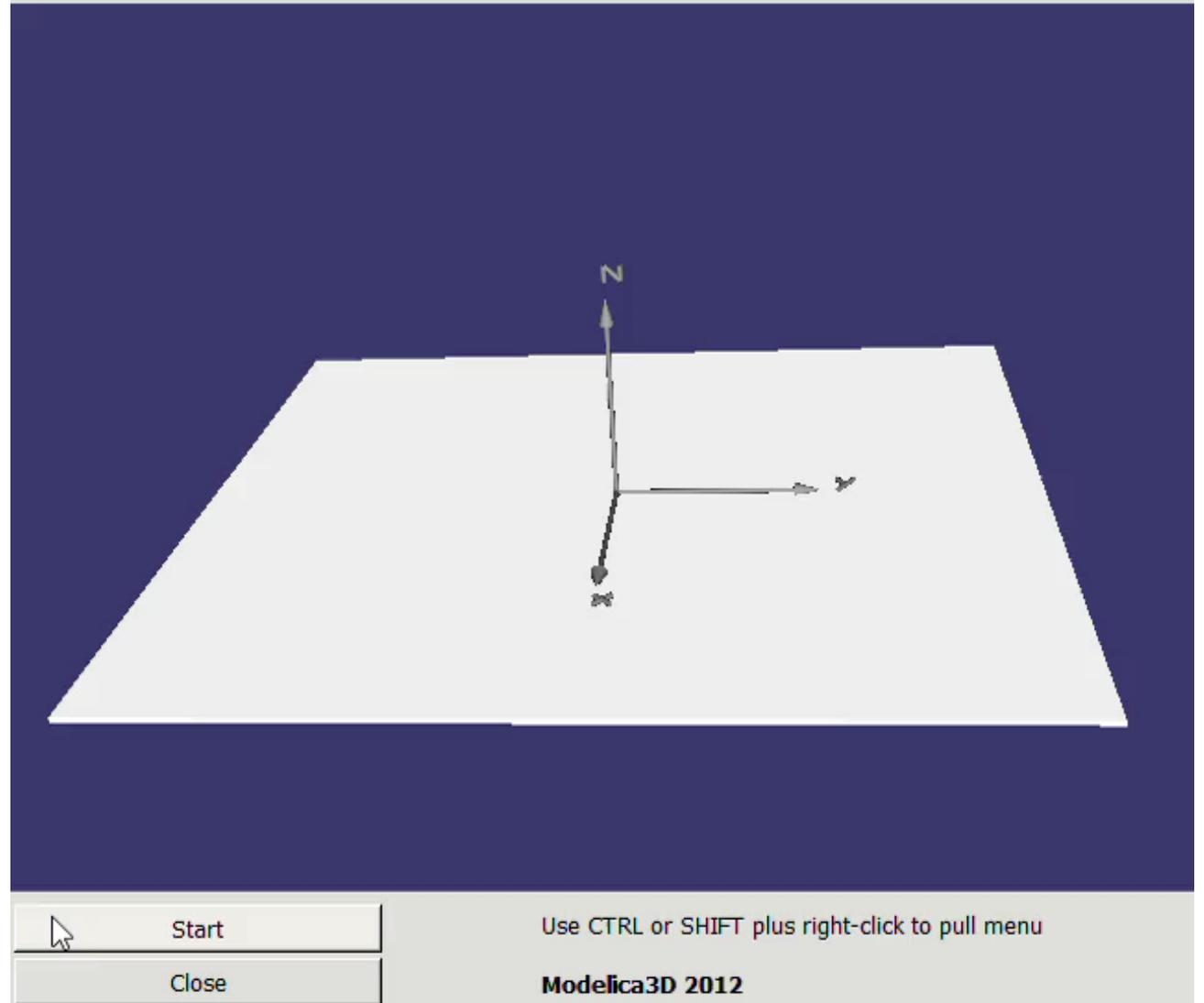
LineForceWithTwoMasses  
がうまく表示できない。



# Modelica.Mechanics.MultiBody.Examples.Elementary.Surfaces

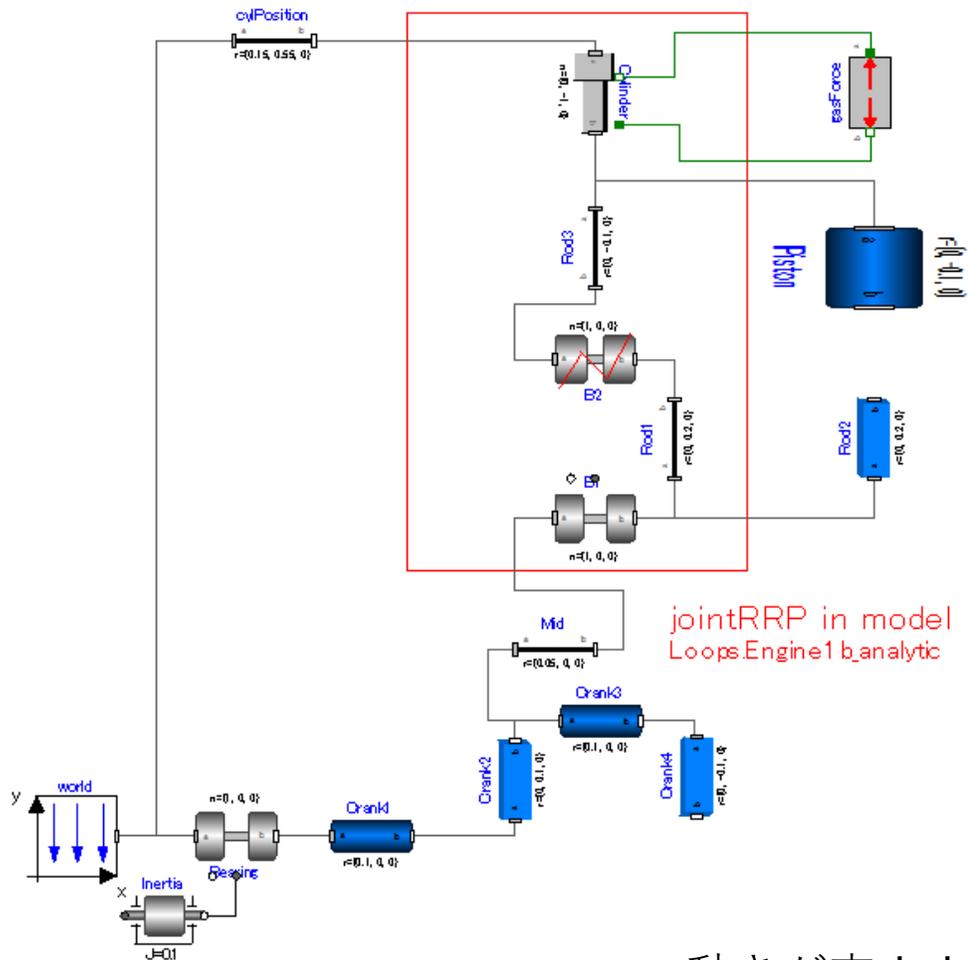


wheel, torus, pipeWithScalarField, Surface  
などが表示できず変化なし。



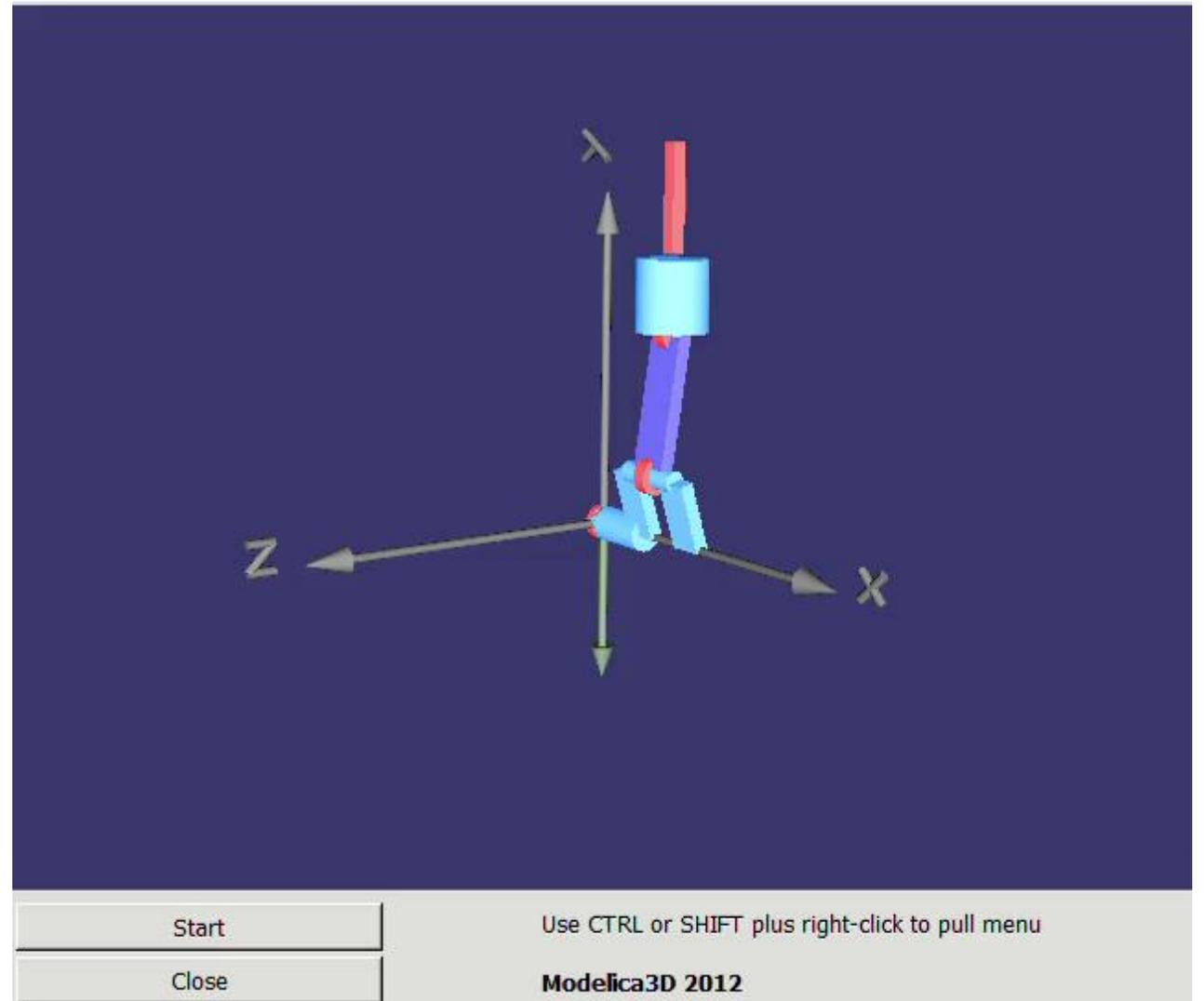


# Modelica.Mechanics.MultiBody.Examples.Loops.Engine1b

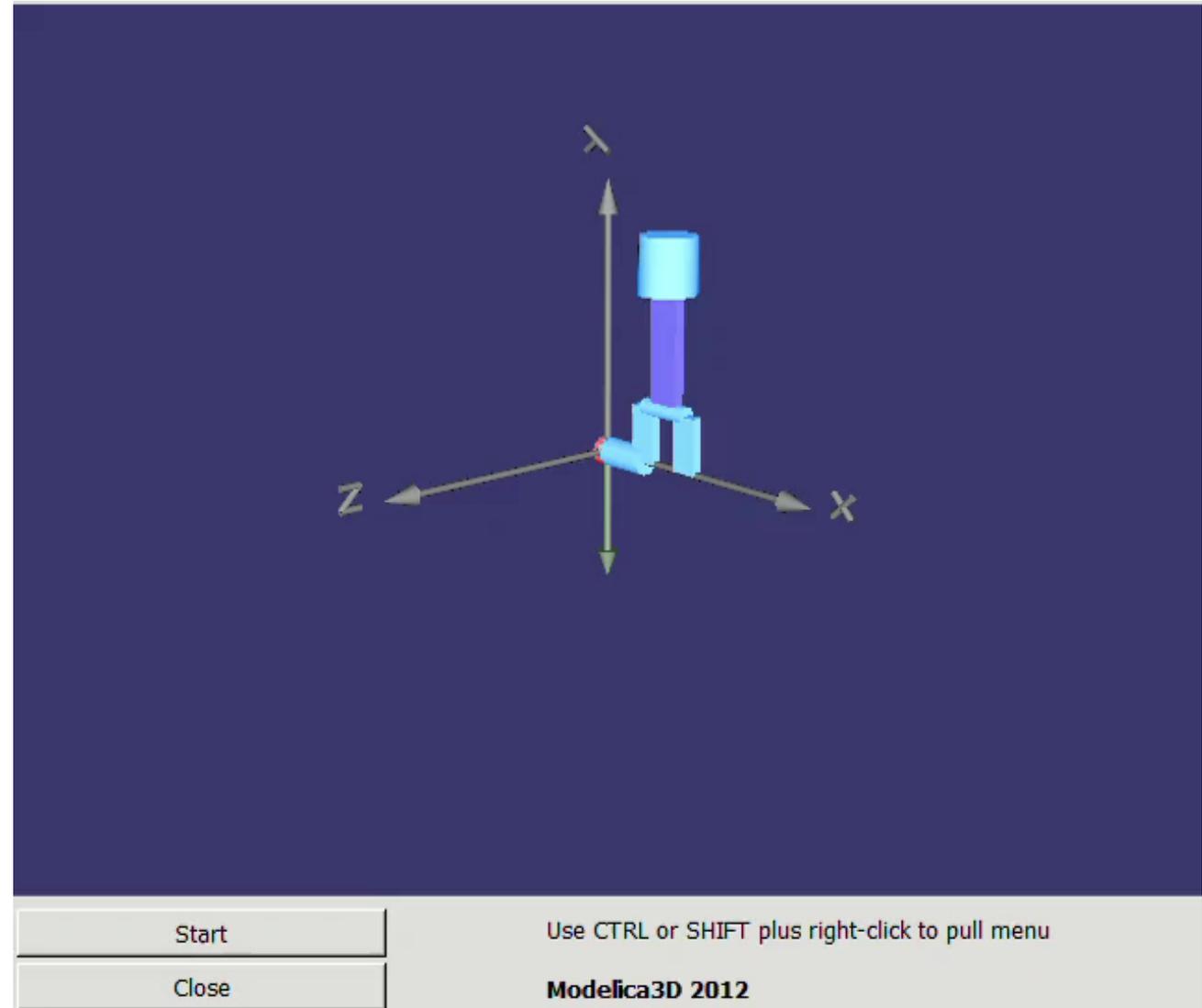
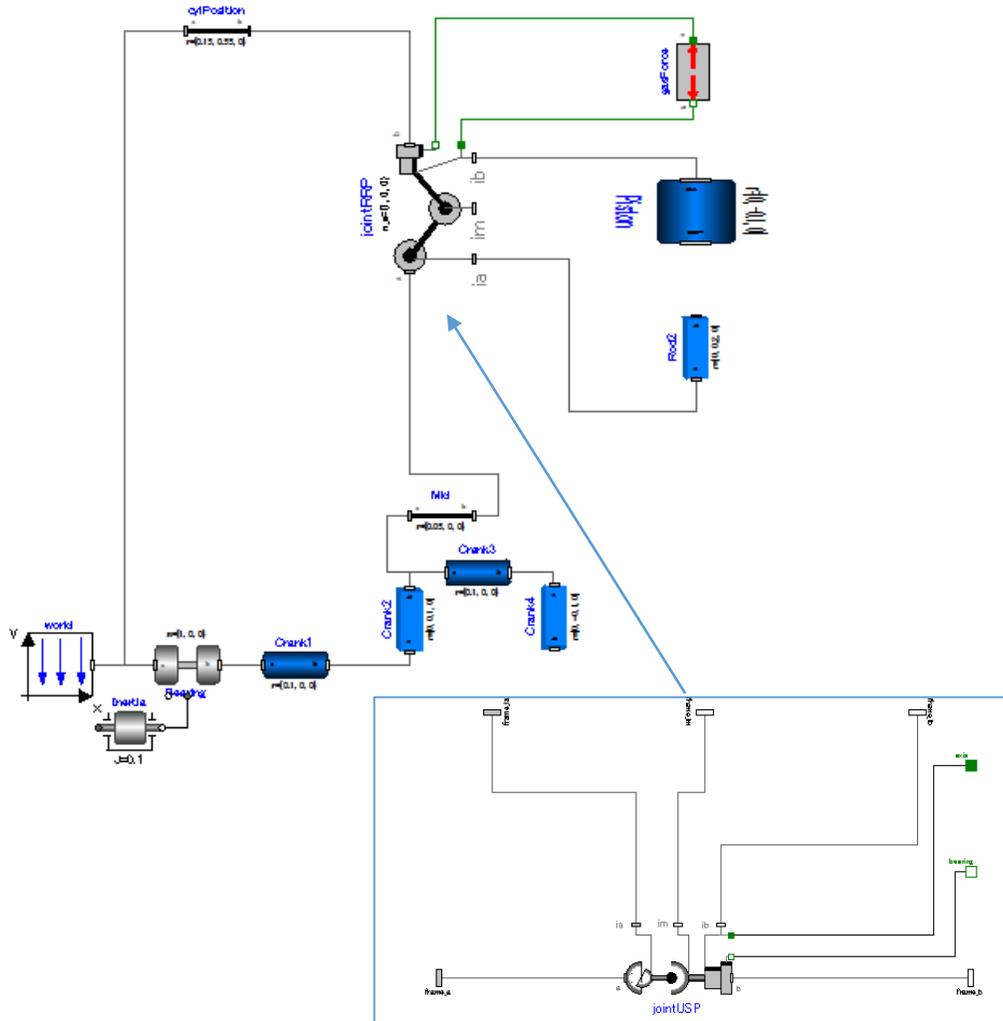


jointRRP in model  
Loops.Engine1\_b\_analytic

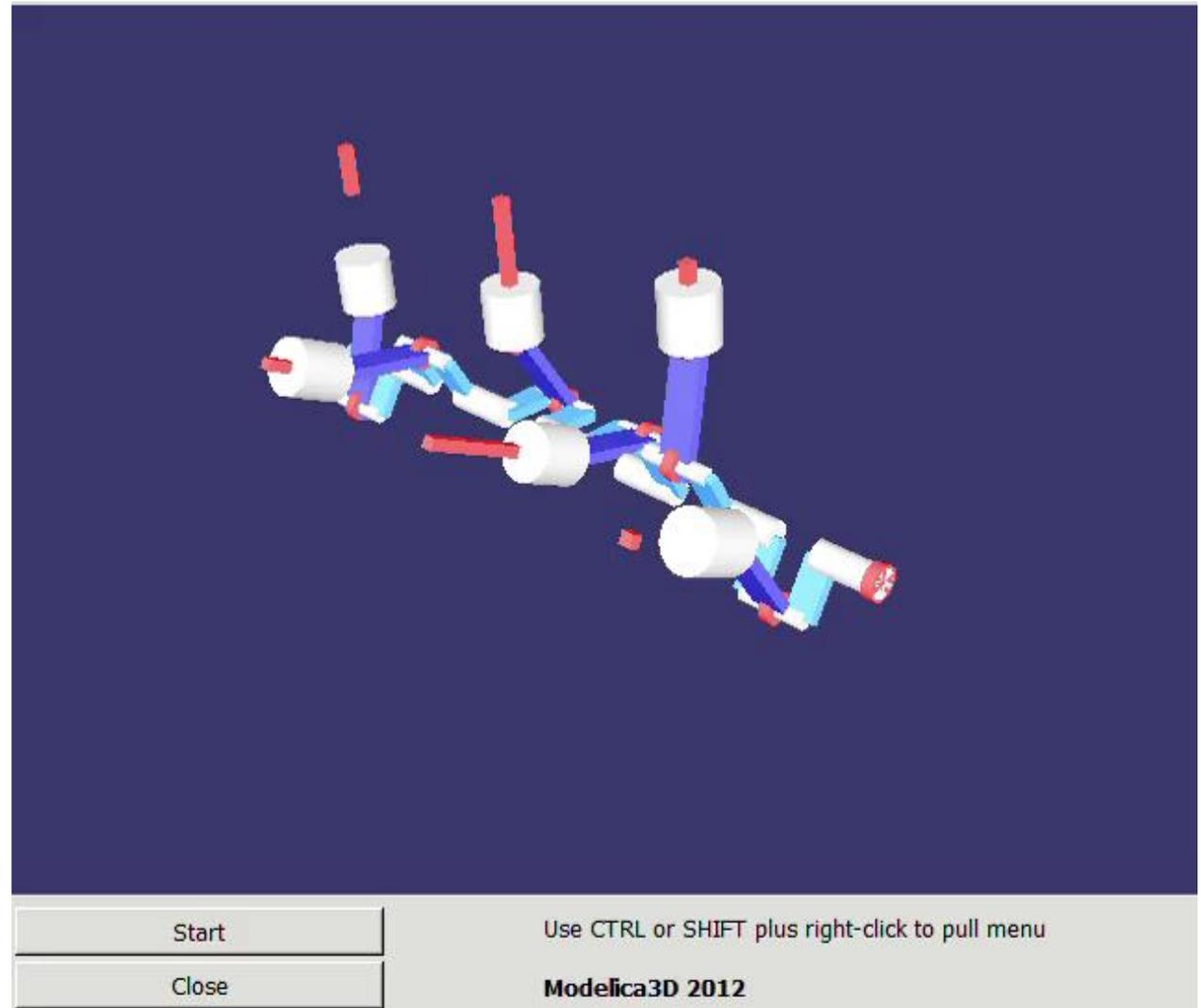
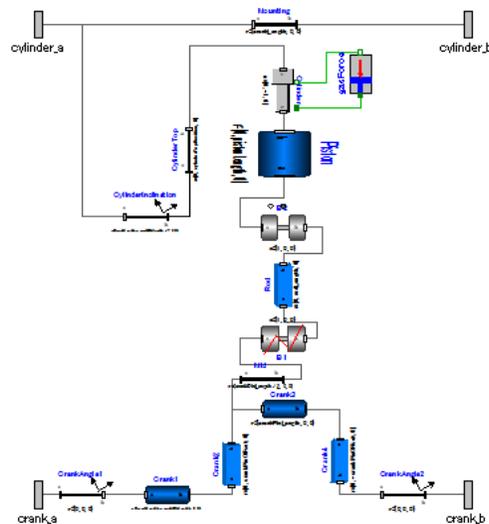
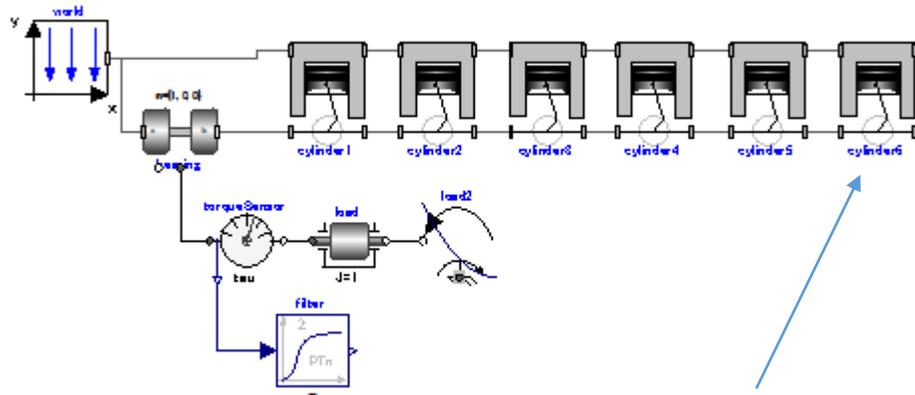
動きが変！！



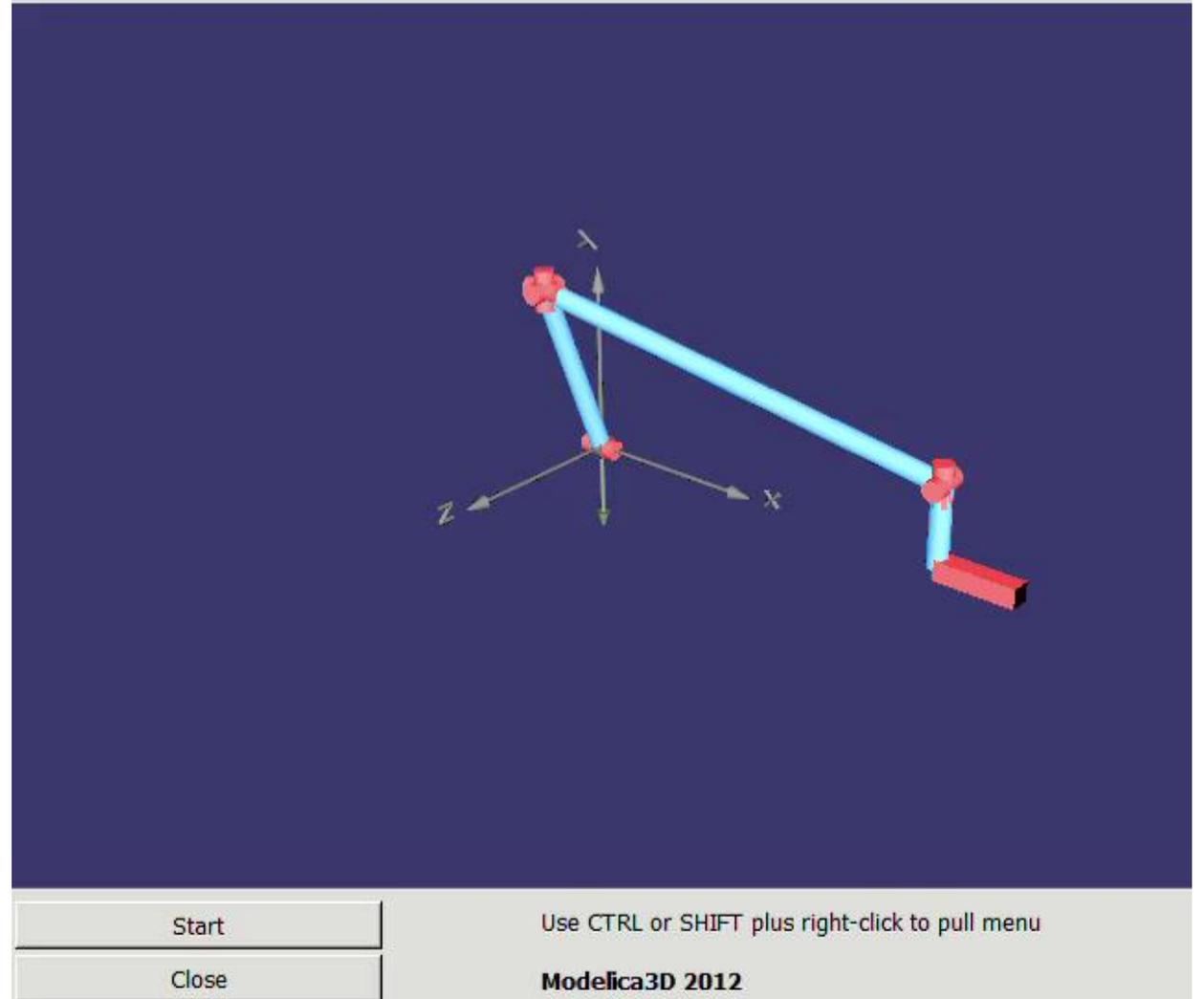
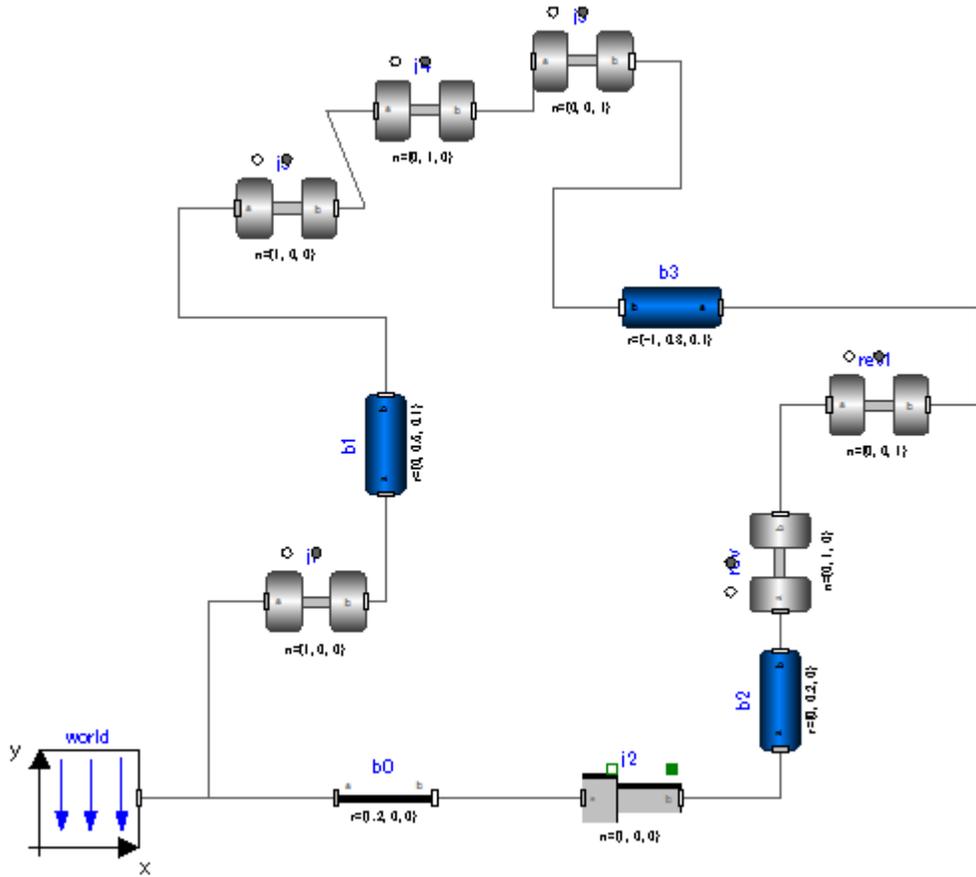
# Modelica.Mechanics.MultiBody.Examples.Loops.Engine1b\_analytic



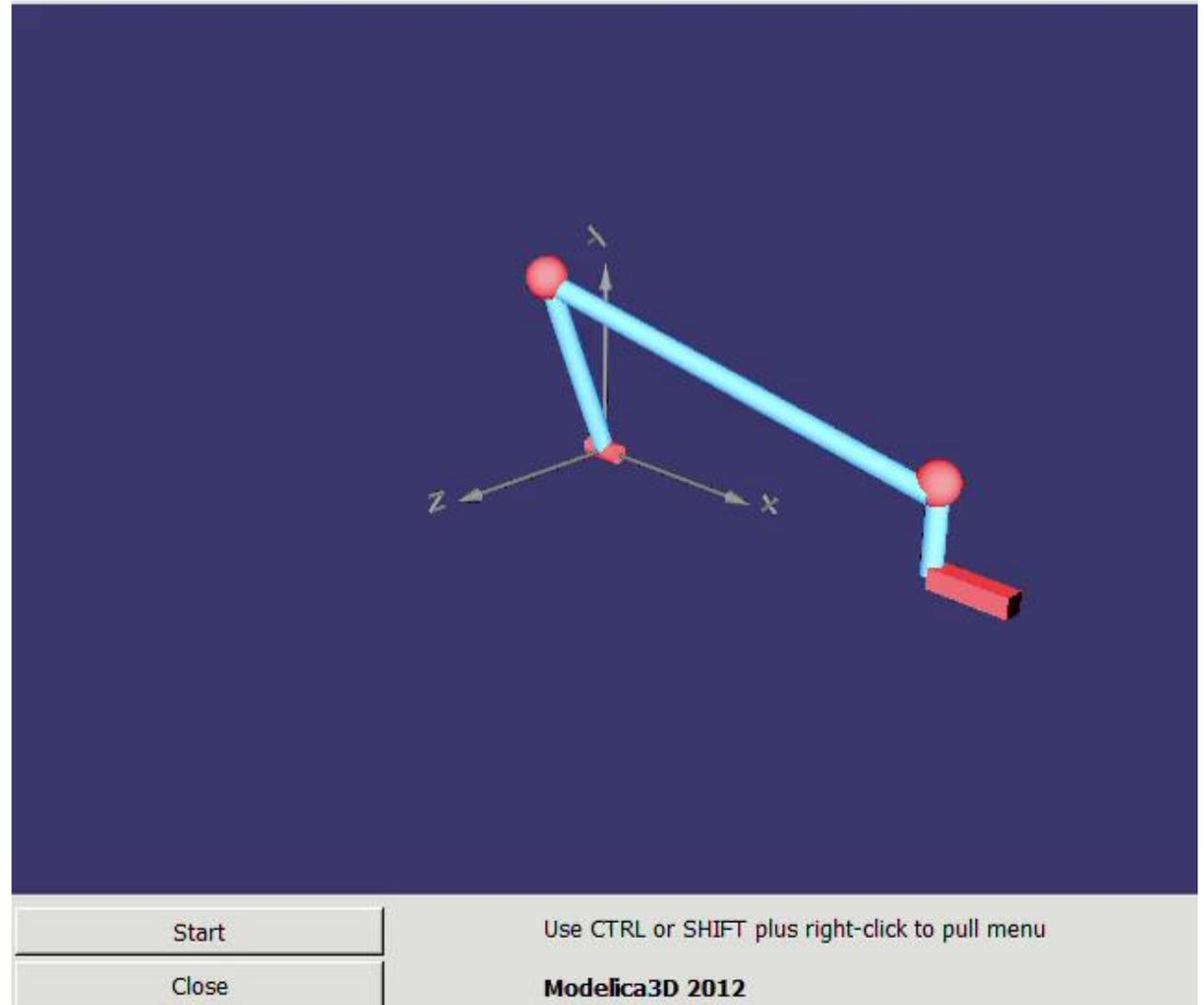
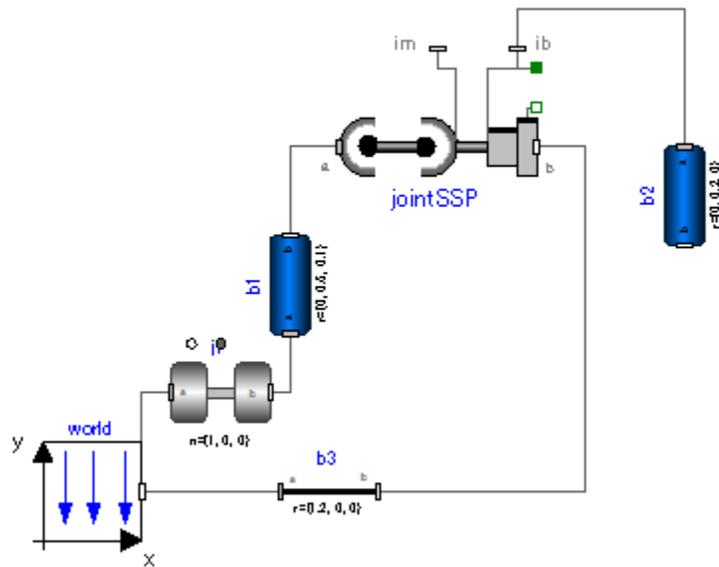
# Modelica.Mechanics.MultiBody.Examples.Loops.EngineV6



# Modelica.Mechanics.MultiBody.Examples.Loops.Fourbar1

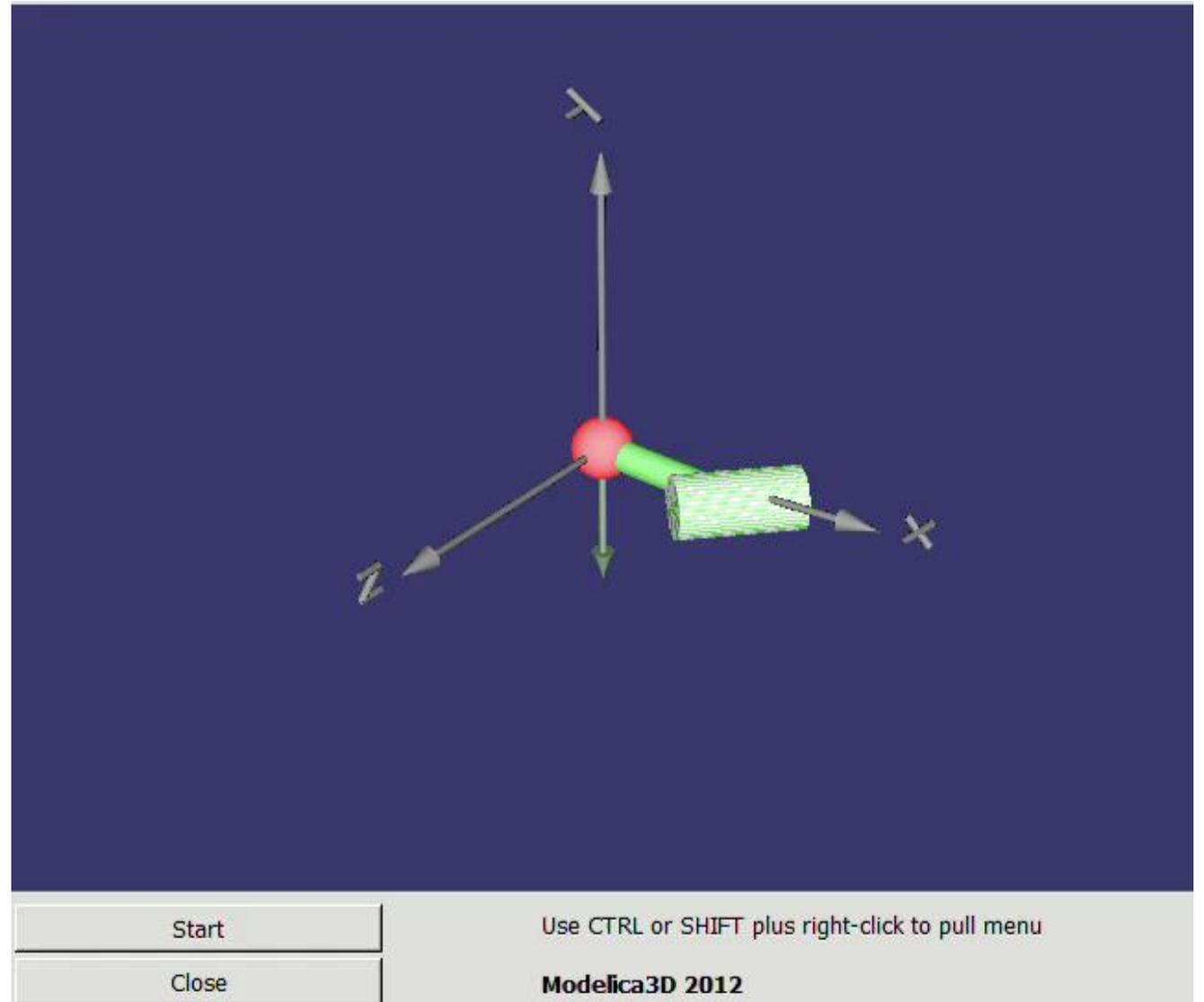
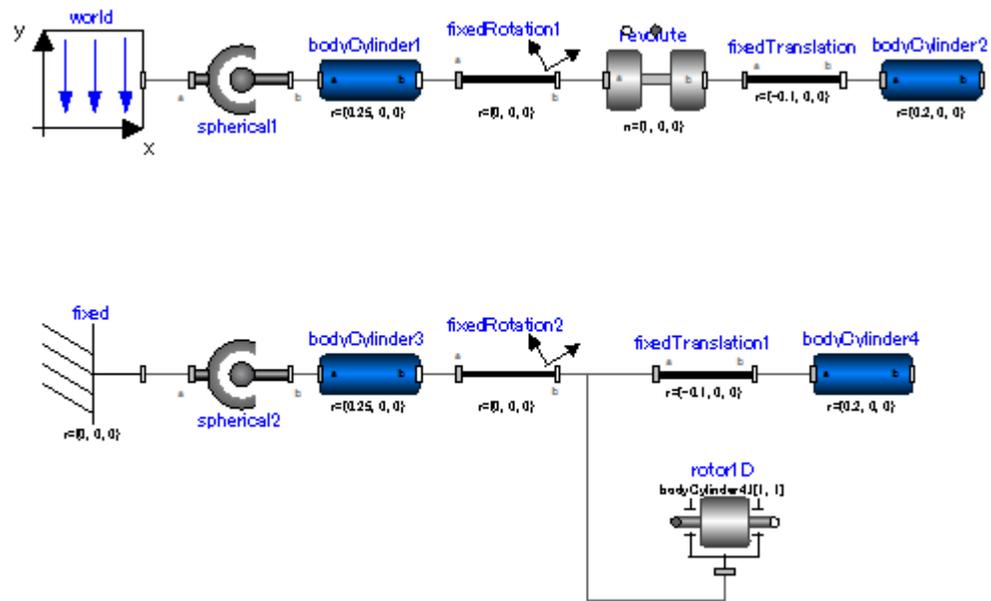


# Modelica.Mechanics.MultiBody.Examples.Loops.Fourbar\_analytic

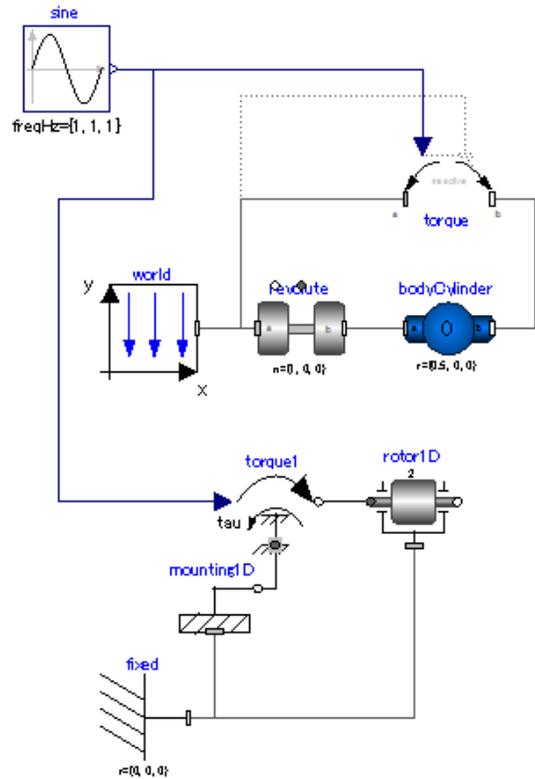




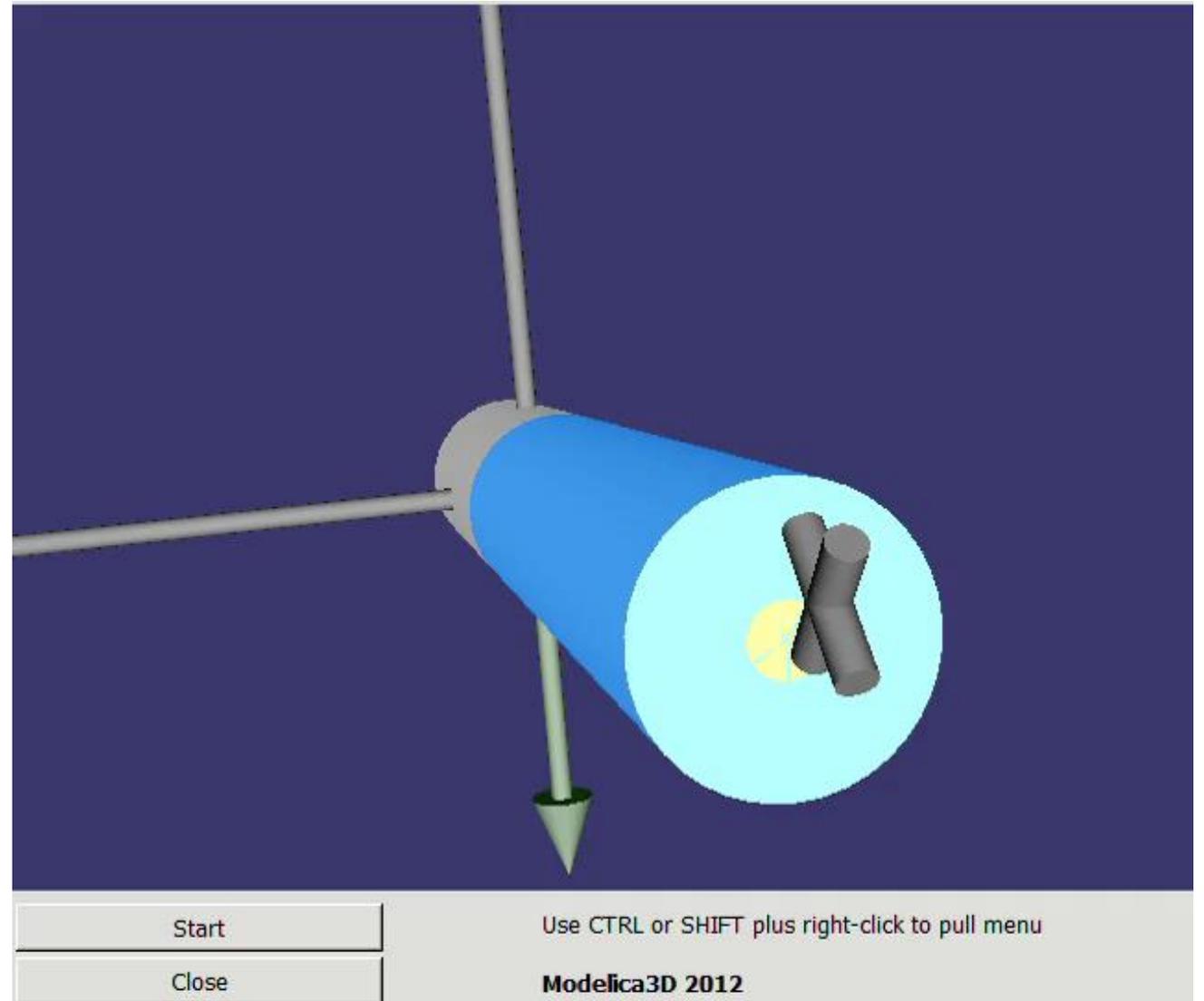
# Modelica.Mechanics.MultiBody.Examples.Rotational3DEffects. GyroscopicEffects



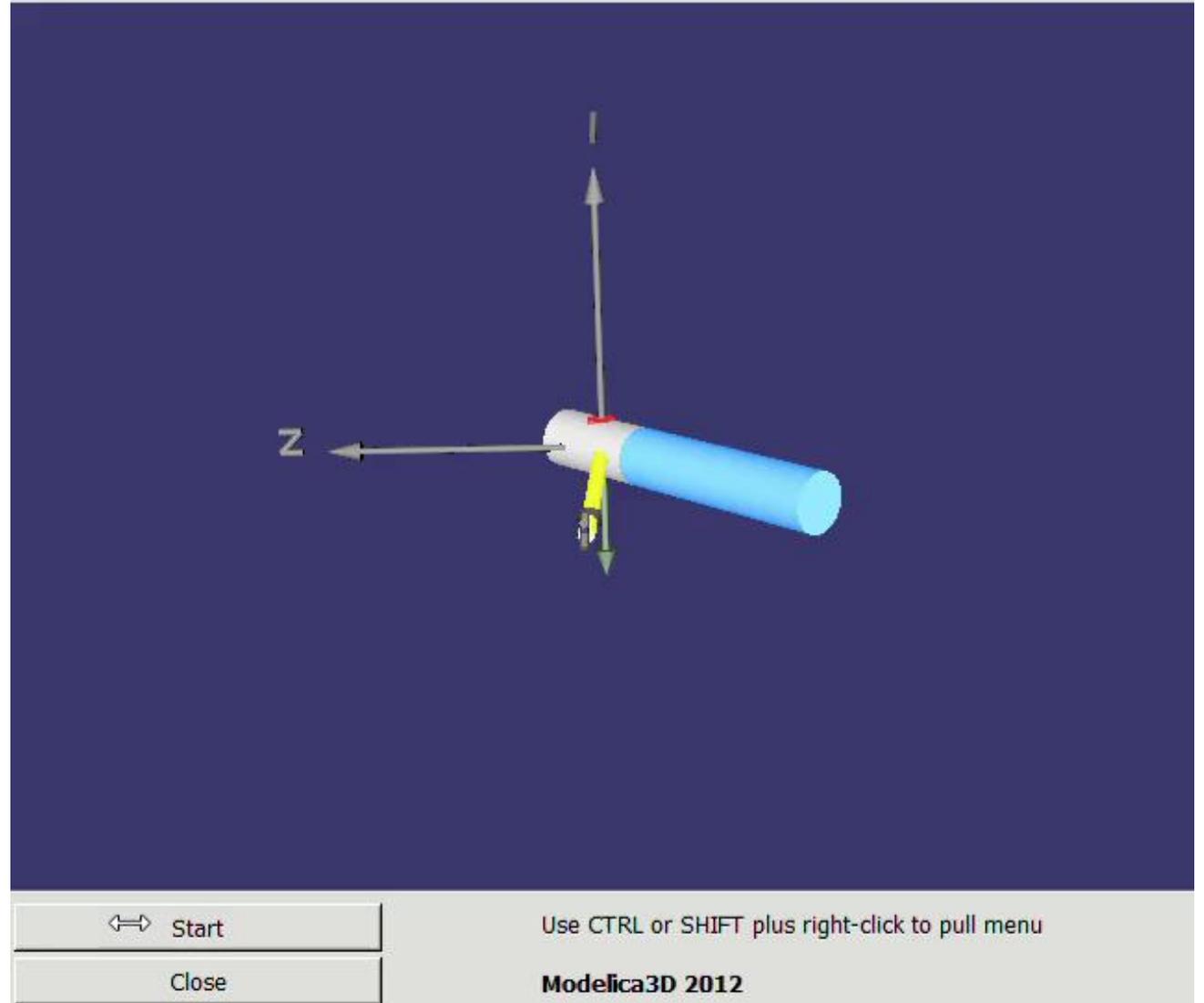
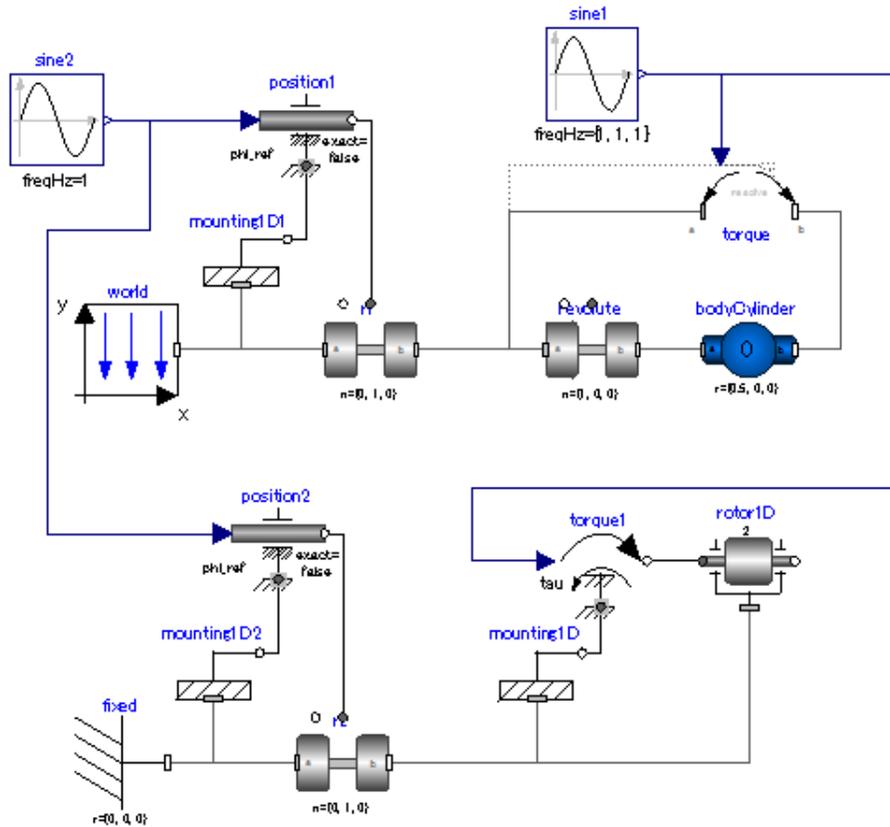
# Modelica.Mechanics.MultiBody.Examples.Rotational3DEffects. ActuatedDrive



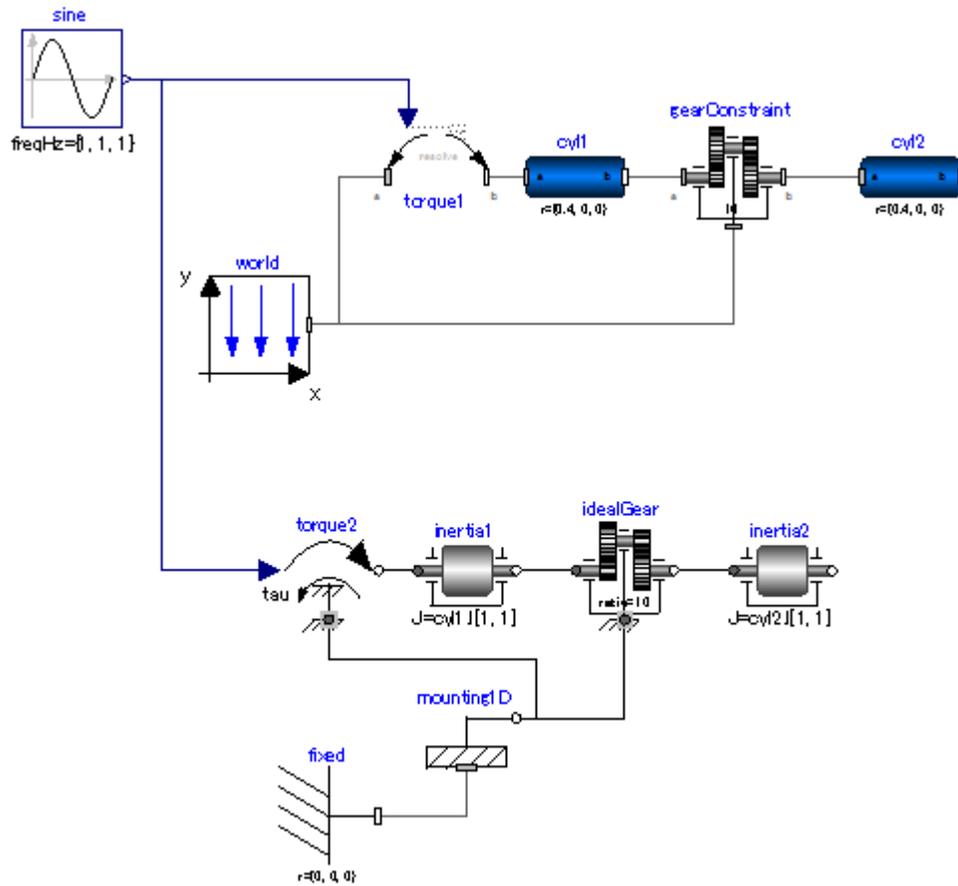
軸回転のみなのであまり変化が見られない。



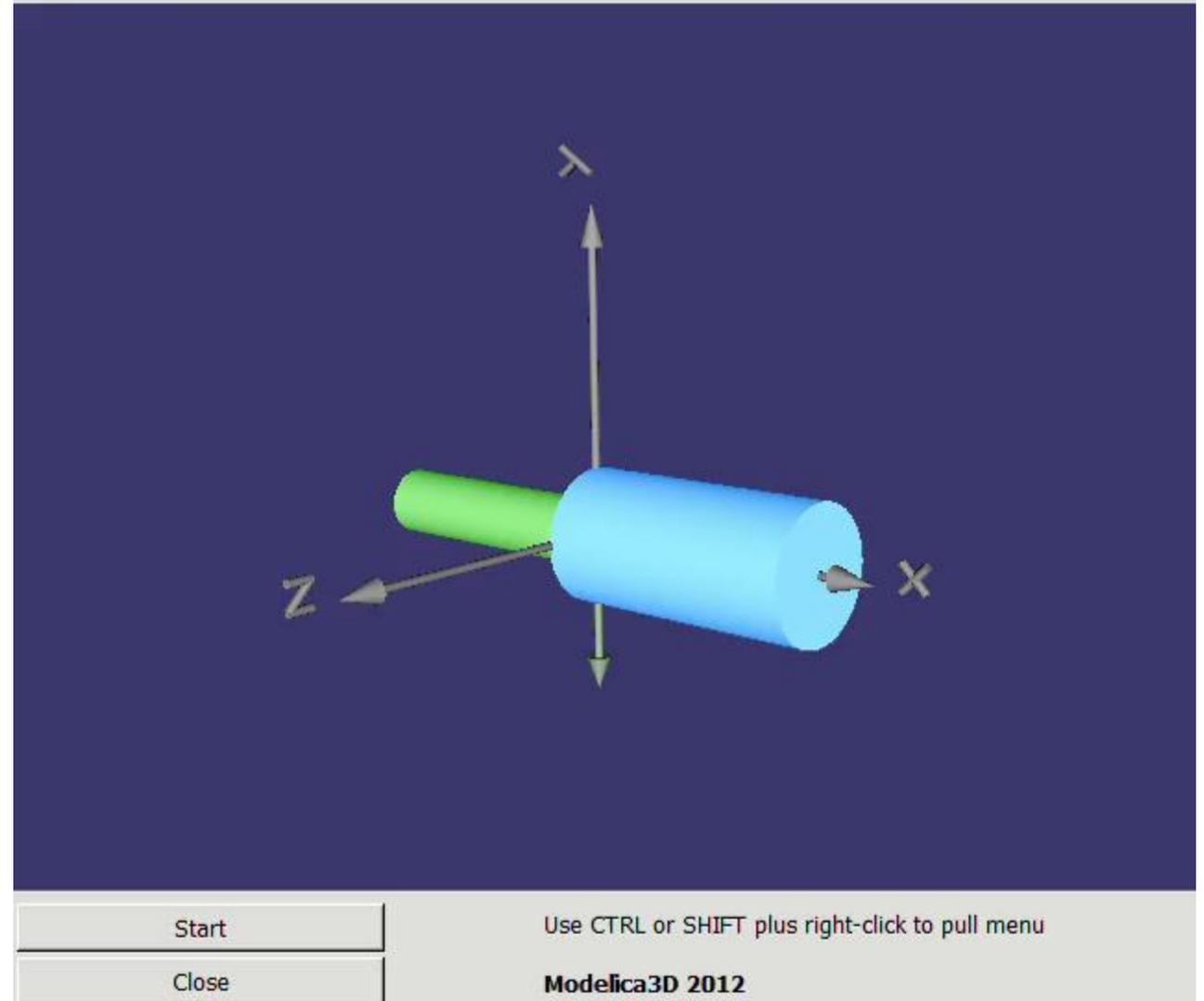
# Modelica.Mechanics.MultiBody.Examples.Rotational3DEffects. MovingActuatedDrive



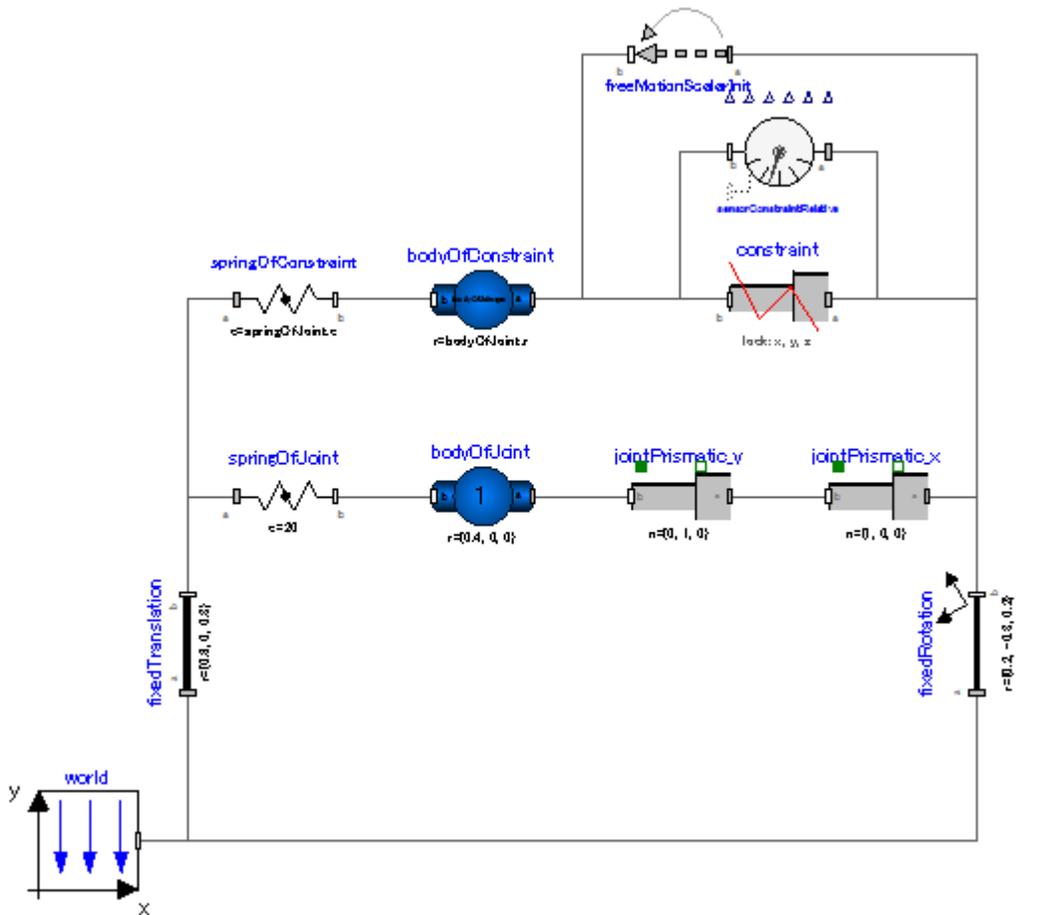
# Modelica.Mechanics.MultiBody.Examples.Rotational3DEffects. GearConstraint



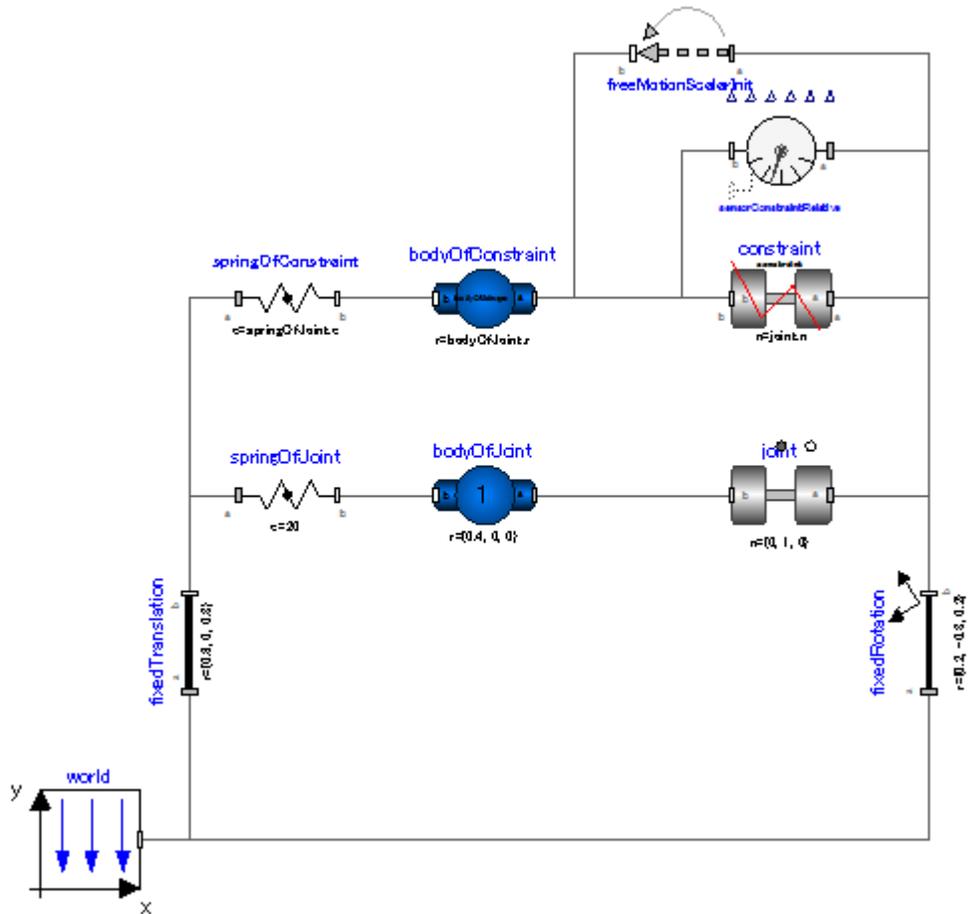
軸回転だけなので動きはみられない！！



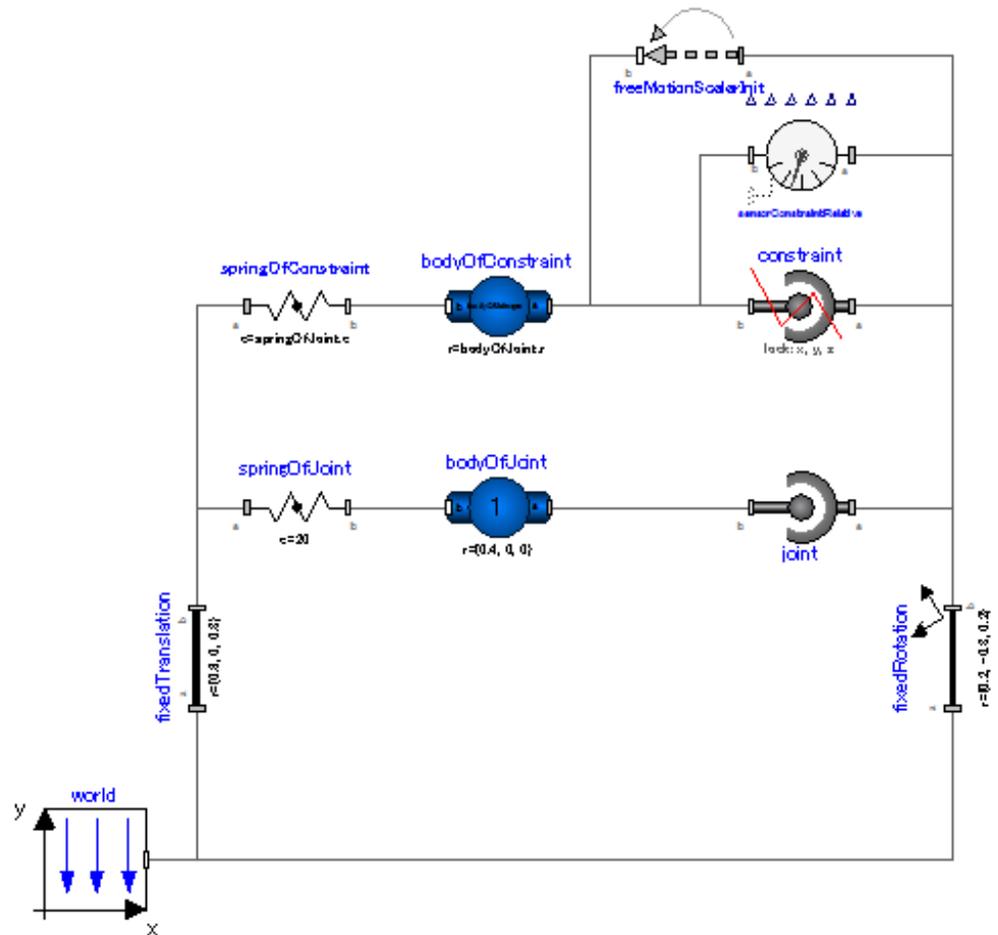
# Modelica.Mechanics.MultiBody.Examples.Constraints. PrismaticConstraint



# Modelica.Mechanical.MultiBody.Examples.Constraints. RevoluteConstraint



# Modelica.Mechanics.MultiBody.Examples.Constraints. SphericalConstraint





## 動かなかった例題モデル

- Modelica.Mechanics.MultiBody.Examples.Loops.EngineV6\_analytic
- Modelica.Mechanics.MultiBody.Examples.Loops.Fourbar2
- Modelica.Mechanics.MultiBody.Examples.System.RobotR3.oneAxis
- Modelica.Mechanics.MultiBody.Examples.System.RobotR3.fullRobot

## まとめ

現状では、表示が不完全なモデルや動作しないモデルがあるが、例題の 3 次元表示によって MultiBody ライブラリの機能が概観できた。

本ドキュメントは、OpenModelica, MultiBody ライブラリ, Modelica3D などを紹介するものであり、モデル図や文献の引用部分については、それぞれの著作者に著作権があります。

The purpose of this document is to give brief introductions of OpenModelica, MultiBody Library and Modelica3D Library. Copyright of each model image and each cited document belong to each owner. For the rest,

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