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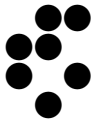

IJS Technical report xxxx

BodyModel 1.0
Quick User Manual

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Ljubljana, 2014

Contents

1 Introduction

For simulation of human body using standard simulation environments, the model a human body is prepared using standard descriptions used for robot systems. One of them is the Unified Robot Description Format (URDF) [1], which is an XML format for representing a robot model. Although the URDF specification is intended for serial link robot manipulators, it can be also used to describe a human body. Another XML based specification is the MuJoCo XML model format [3]. A model is built by different elements (links, joints, visual representation objects, ...), which have different attributes (position, orientation, child, ...). For details on model building check the specifications for each model type [1, 3].

The **BodyModel** is used to update values of some model parameters of a human body in these models. The parameters which can be updated are:

- joint position
- link length
- link mass and center of mass (COM)
- link inertia
- some additional dimensional parameters

The values of these parameters depend on two parameters:

- Body height
- Body weight

and are calculated according to the data published by Zatsiorsky [4] and Leva [2]. Note that all units are SI (m, kg), except the input of human body is for convenience in cm.

BodyModel allows to use for model attributes in the model description some predefined variables instead of constant values. These variables are then replaced by **BodyModel** with values according to the body height and weight. When preparing the model, there is no limitation in the structure of the model, i.e. links and joints of a human body (or part of a body) used in the model. The model structure is not changed by the **BodyModel**.

2 Human body parameters

To define the human body parameters, the body is divided into parts as shown in Fig. 1:

- Head
- Torso_U (upper part of the torso)
- Torso_M (middle part of the torso)
- Torso_L (lower part of the torso)
- UpperArm (left and right)
- LowerArm (left and right)
- Hand (left and right)
- Thigh (left and right)
- Shank (left and right)
- Foot (left and right)

and each of this parts has inertial parameters

- `Mass`
- `COM` (vertical distance of center of mass from parent joint)
- `Inertia.x`, `Inertia.y` and `Inertia.z` (moments around principal axes)

and geometric parameters

- Length
- Height
- Width

Note that only some geometric parameters are defined. These parameters are listed in Table 1, where their value is explained using distances between points (as shown in Fig. 1: the points $\mathbf{J}_i$ denote joint i position, C_i denote COM of corresponding body, and P_i are some auxiliary points). For more explanation see Fig. 2 and [2].

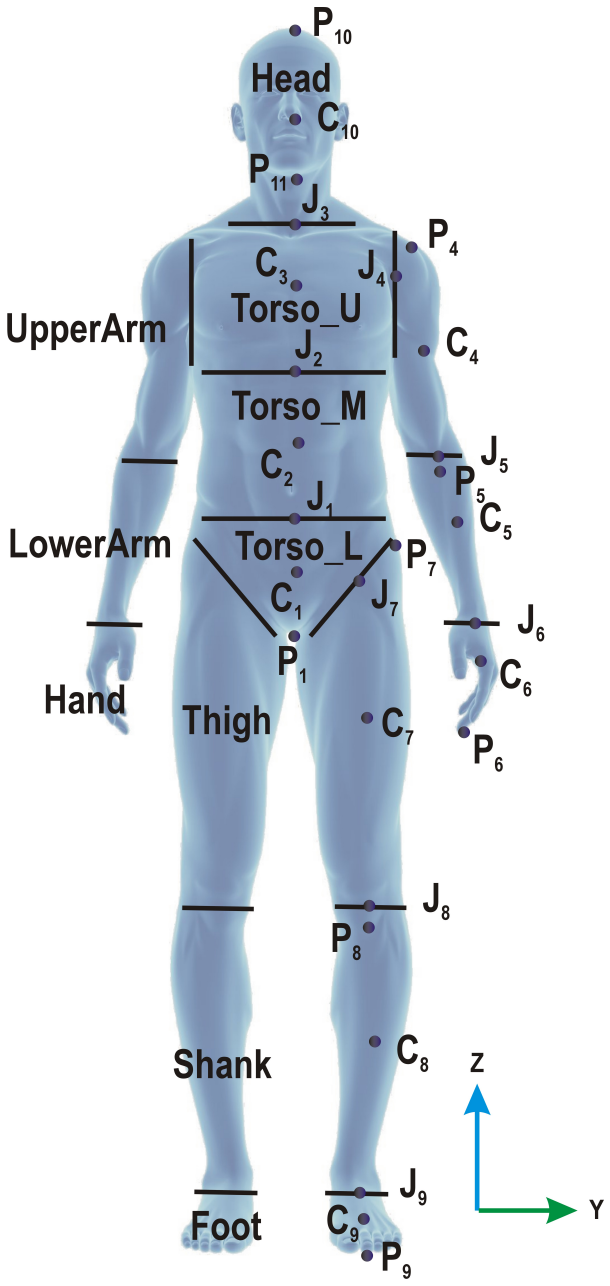

Figure 1: Body parts, joint locations (J), COM (C), aux. points (P)

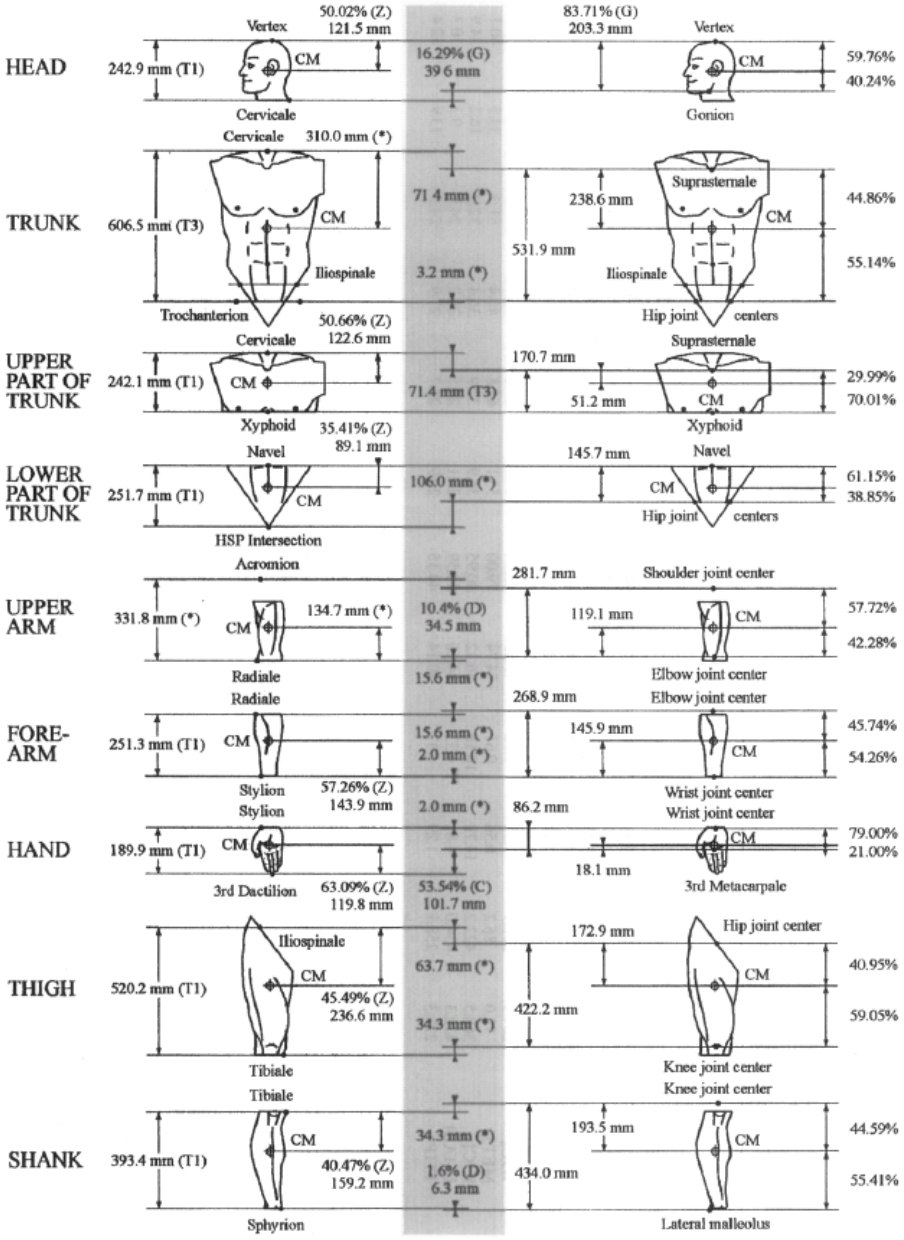

Fig. 1. A graphic description of the main adjustments to the relative CM positions for males. The adjusted distances are shown on the right of the shaded area. For all segments, except trunk and upper arm (see text), the shaded area indicates the longitudinal distances between original (on its left) and new (on its right) reference points. All percent values are relative to the segment lengths indicated on their left. (* = see text; C = Clauser *et al.*, 1969; D = de Leva, 1996; G = Gordon *et al.*, 1989; T1 = Table 1; T3 = Table 3; Z = Zatsiorsky *et al.*, 1990a).

Figure 2: Fig. 1 from [2]

Table 1: Dimensional model parameters: Height and Length are in vertical direction (z); Width is horizontal dimension (y); COM is in longitudinal direction (z, except foot in y)

Parameter	Value
`Head.Height`	$\mathbf{P}_{10} - \mathbf{J}_3$
`Torso_U.Height`	$\mathbf{P}_{11} - \mathbf{J}_2$
`Torso_M.Height`	$\mathbf{J}_2 - \mathbf{J}_1$
`Torso_L.Height`	$\mathbf{J}_1 - \mathbf{P}_1$
`Thigh.Height`	$\mathbf{P}_7 - \mathbf{P}_8$
`Shank.Height`	$\mathbf{P}_8 - \mathbf{J}_9$
`Foot.Height`	$\mathbf{J}_9 - \mathbf{P}_9$
`UpperArm.Height`	$\mathbf{P}_4 - \mathbf{P}_5$
`LowerArm.Height`	$\mathbf{P}_5 - \mathbf{J}_6$
`Hand.Height`	$\mathbf{J}_6 - \mathbf{P}_6$
`Head.Length`	$\mathbf{P}_{10} - \mathbf{P}_{11}$
`Torso_U.Length`	$\mathbf{J}_3 - \mathbf{J}_2$
`Torso_M.Length`	$\mathbf{J}_2 - \mathbf{J}_1$
`Torso_L.Length`	$\mathbf{J}_1 - \mathbf{J}_7$
`Thigh.Length`	$\mathbf{J}_7 - \mathbf{J}_8$
`Shank.Length`	$\mathbf{J}_8 - \mathbf{J}_9$
`Foot.Length`	$\mathbf{J}_9 - \mathbf{P}_9$
`UpperArm.Length`	$\mathbf{J}_4 - \mathbf{J}_5$
`LowerArm.Length`	$\mathbf{J}_5 - \mathbf{J}_6$
`Hand.Length`	$\mathbf{J}_6 - \mathbf{P}_6$
`Torso_U.Width`	distance between left and right $\mathbf{J}_4$
`Torso_L.Width`	distance between left and right $\mathbf{J}_7$
`Head.COM`	$\mathbf{C}_{10} - \mathbf{J}_3$
`Torso_U.COM`	$\mathbf{C}_3 - \mathbf{J}_2$
`Torso_M.COM`	$\mathbf{J}_2 - \mathbf{C}_2$
`Torso_L.COM`	$\mathbf{J}_1 - \mathbf{C}_1$
`Thigh.COM`	$\mathbf{J}_7 - \mathbf{C}_7$
`Shank.COM`	$\mathbf{J}_8 - \mathbf{C}_8$
`Foot.COM`	$\mathbf{J}_9 - \mathbf{C}_9$
`LowerArm.COM`	$\mathbf{J}_4 - \mathbf{C}_4$
`Upperarm.COM`	$\mathbf{J}_5 - \mathbf{C}_5$
`Hand.COM`	$\mathbf{J}_6 - \mathbf{C}_6$

2.1 Updating variables

In **BodyModel** a simple calculator is implemented, which allows to use some basic mathematical operations using the predefined variables. The predefined variables have the following form:

`<Body part>.<variable>` like, e.g. `Head.Height`

or

<Body part>.<variable>.<axis> like, e.g. Head.Inertia.x

The expression has to be enclosed in braces

{<expression>} like, e.g. {Head.Height/2+0.1}

and this expression is then replaced in the model file by the value of the expression.

For example, the URDF model of head can defined as

```
<link name="head">
  <inertial>
    <origin xyz="0 0 {Head.COM}" rpy="1.57079633 0 0"/>
    <mass value="{Head.Mass}"/>
    <inertia ixx="Head.Inertia.x"  ixy="0" ixz="0"
             iyy="Head.Inertia.y" iyz="0"
             izz="Head.Inertia.z" />
  </inertial>

  <visual>
    <origin xyz="0 0 {Head.Height-Head.Length/2}"
            rpy="1.57079633 0 0" />
    <geometry>
      <sphere radius="{Head.Length/2}" />
    </geometry>
  </visual>
</link>
```

and after **BodyModel** has updated the expression the result is

```
<link name="head">
  <inertial>
    <origin xyz="0 0 0.1185" rpy="1.57079633 0 0"/>
    <mass value="5.238"/>
    <inertia ixx="0.0289"  ixy="0" ixz="0"
             iyy="0.0314" iyz="0"
             izz="0.0214" />
  </inertial>

  <visual>
    <origin xyz="0 0 0.1378"
            rpy="1.57079633 0 0" />
    <geometry>
      <sphere radius="0.0992" />
    </geometry>
  </visual>
</link>
```

3 Installation

BodyModel is written in Pascal language using Lazarus IDE and can be compiled on Windows or Linux systems. The distribution contains the following files

`BodyModel_32.exe`	Windows executable (32 bit system)
`BodyModel_64.exe`	Windows executable (64 bit system)
`BodyModel_32`	Linux executable (64 bit system)
`BodyModel_64`	Linux executable (32 bit system)
`Body_MuJoCo.xml`	Sample MuJoCo model of a human body

No installation is needed to run the application. On Windows systems run

```
BodyModel.exe
```

and on Linux systems

```
BodyModel
```

(Make the file executable if necessary using `chmod +x BodyModel_32`)

4 Basic operation

Fig. 3 shows the main **BodyModel** window. The user can

- load the model file
- save the updated model file
- select the body height and weight
- prepare the body variables
- edit the model
- edit the attributes in the XML model file
- update the expressions in the model

4.1 Load model

In **BodyModel** any text file can be loaded. However, as most model descriptions files are using XML format, the **BodyModel** provides special Tree view for XML files.

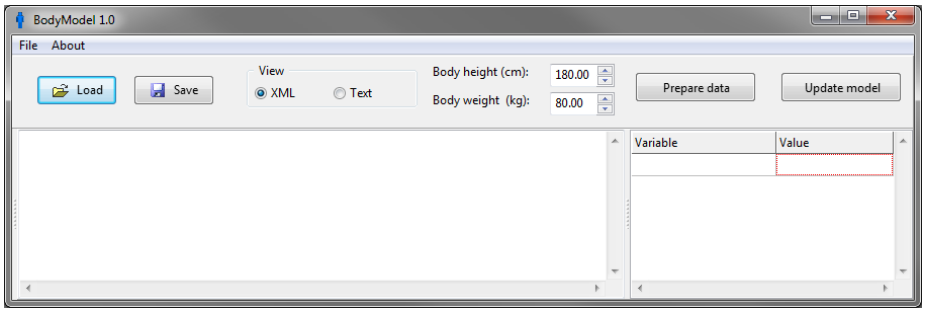

Figure 3: **BodyModel** - User interface

Figs. 4 and 5 show the standard Text view and XML tree view, respectively. The XML tree view is generated from XML file and is showing the overview of the model structure. The user can switch simply between them by selecting the corresponding radio button.

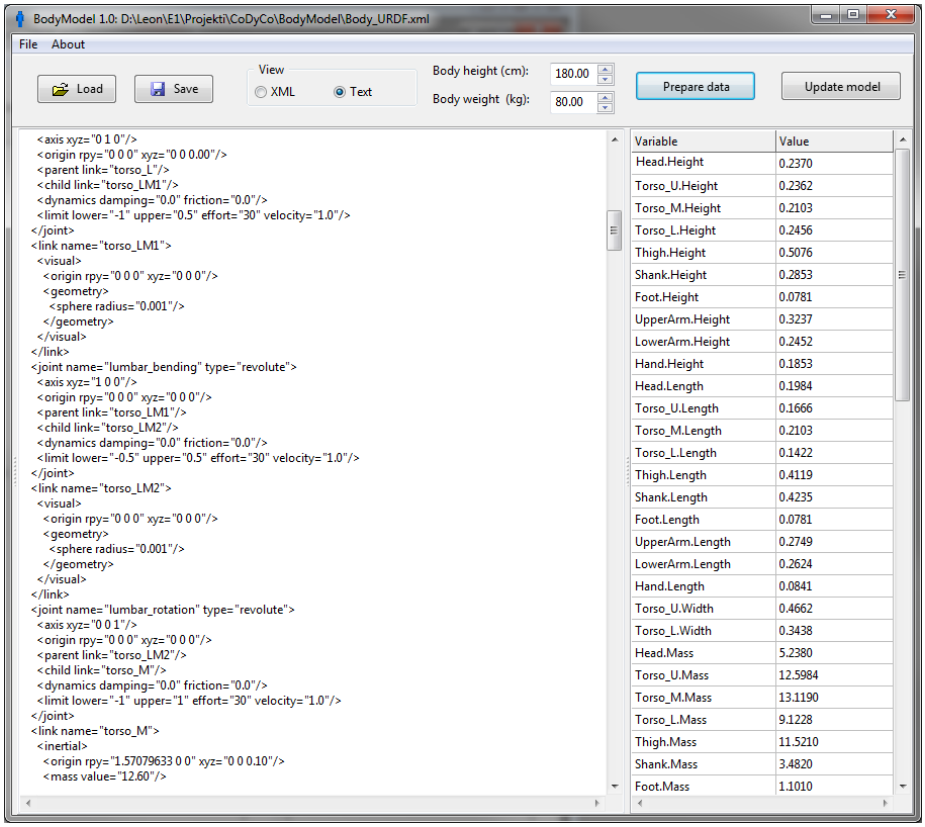

Figure 4: **BodyModel** - text view of the model

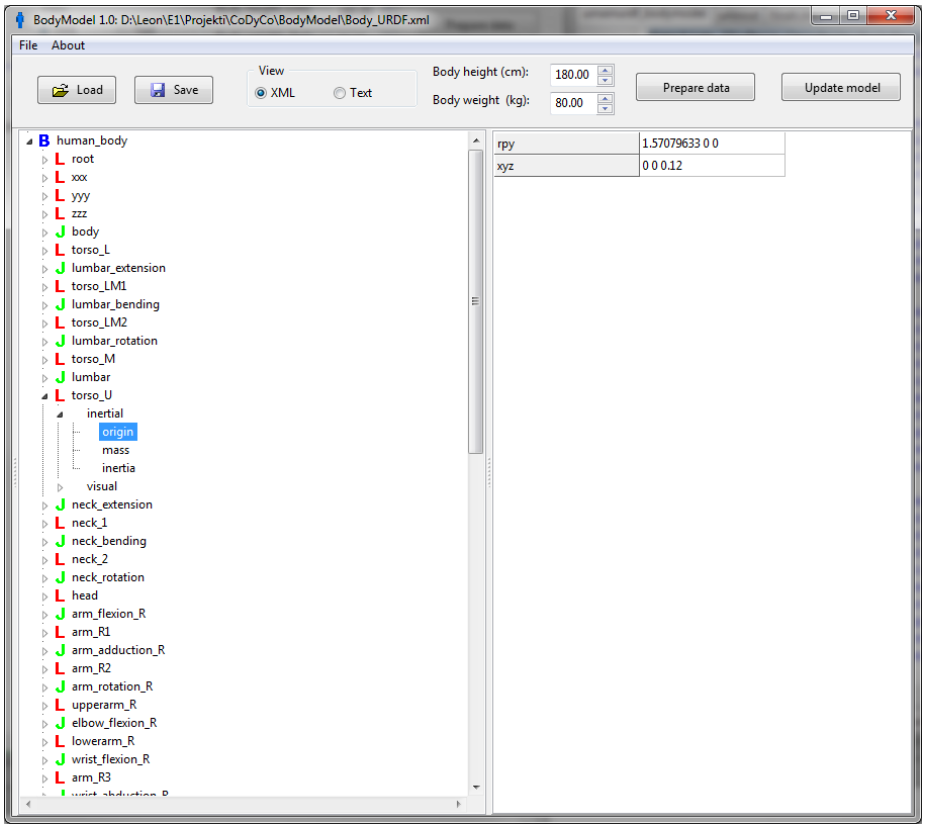

Figure 5: **BodyModel** - XML view of the model

4.2 Model editing

In normal Text view (see Fig. 4), a simple text editor enables manual changes of the model file.

In XML tree view the table on the right side shows the attributes of the selected XML element. The user can edit the attribute values.

4.3 Preparing variables

To prepare data for predefined variables, the user has to input desired body height and weight. Pressing the Update data button, the values of predefined variables are calculated and the list of all variables is shown on the right side of model file in Text view (see Figs. 4).

4.4 Model update

The model update depends on the selected view. In Text view, pressing the Update model button expressions in the model are replaced by the calculated values and if the load file is a valid XML model file, the Tree view is updated.

In XML tree view pressing the Update model button the model in the Text view is updated according to XML tree data.

4.5 Save model

After the model has been updated it can be saved bz pressing fboxSave button.

4.6 Model example

The model for the model file `Body_MuJoCo.xml`, which describes the human body for MuJoCo simulator [3], is shown in Fig. 6.

Acknowledgement

The work presented in this document was supported by the European Community Framework Programme 7 through the CoDyCo project, contract no. 600716.

References

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[2] Paolo de Leva. Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics*, 29(9):1223 – 1230, 10 1996.

[3] Emo Todorov, Yuval Tassa, and Tom Erez. *MuJoCo: Modeling and simulation of Multi-Joint dynamics with Contact*, 0.5.0 edition, June 2013.

[4] V. Zatsiorsky and V. Seluyanov. *Biomechanics VIII-B*, chapter The mass and inertia characteristics of the main segments of the human body, pages 1152–1159. Human Kinetics. 1983.

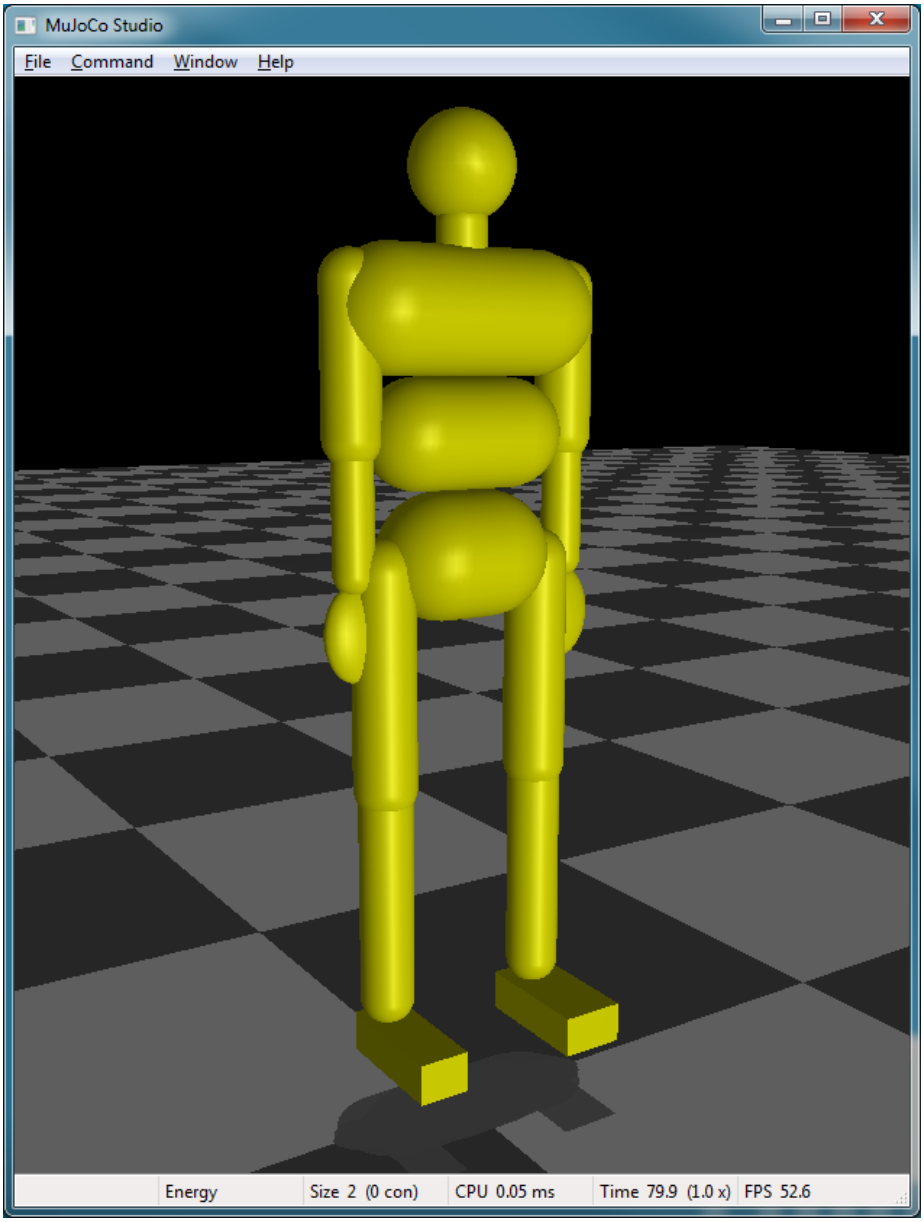

Figure 6: Model of a human body in MuJoCo simulator - model parameters are for body height 180cm and weight 80kg