CusToM Workshop

XSENS Force prediction

Charles Pontonnier, Pierre Puchaud
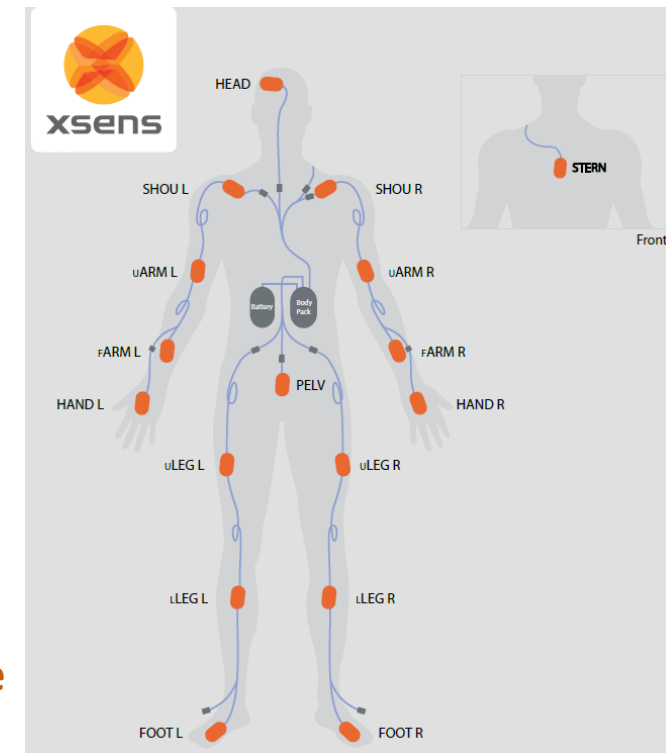
Pre-work

1. Go in `Examples`/`2_Tennis_Force_Prediction`

What is XSENS ?

IMU SENSORS

Full body motion capture

Motions to analyse – Tennis Service

XSENS provide the motion
What if we want to predict external forces ?

https://content.xsens.com/motion-data

Force prediction: what does this mean ?

Sometimes, you want to do dynamics without force platforms

It is therefore necessary to generate - predict the external forces on the whole motion capture to make consistent inverse dynamics

Measuring

Motion-based external forces prediction [Muller2019a, Muller 2019b]

Motivation : are we able to compute relevant dynamical information without any force measure ?
  on-site ergonomics evaluation

A few methods exist
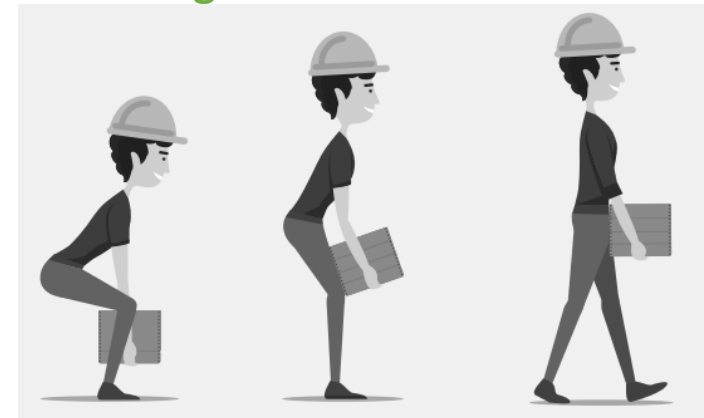 Machine learning **[Oh2013]**
  Analytical **[Koopman1995,Dijkstra2015]**
  Optimisation based **[Fluit2014,Skals2017]**

Handling tasks

Only for Ground Reaction Forces

What about hand contact forces ?

employsure.co.nz

GenerateParameters
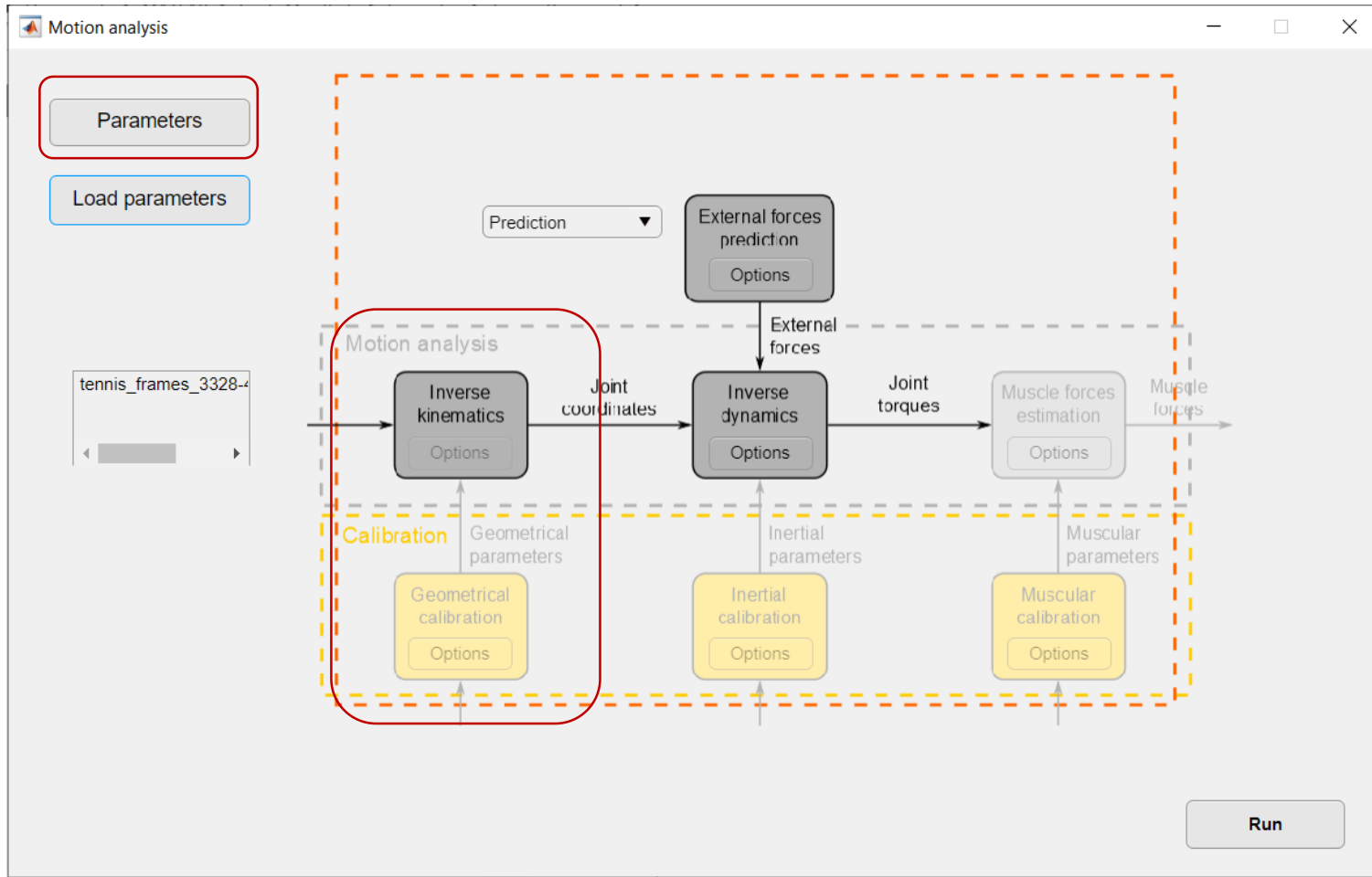
```
>> GenerateParameters
```

Subject's height: 1.80m
Subject's weight: 70 kg

Model: Full Body

Markerset : not important

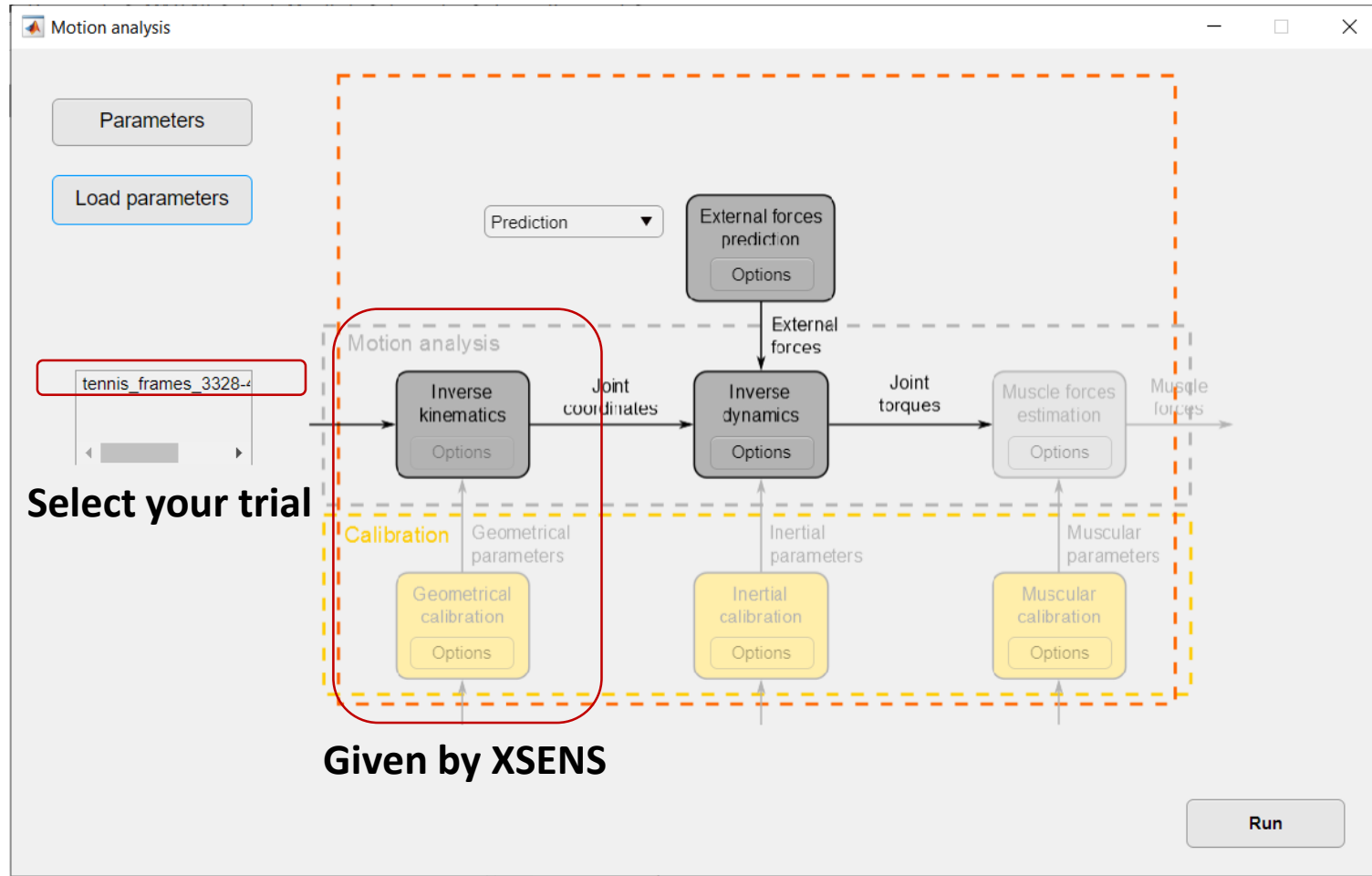**Muscle set: no muscles**

# AnalysisParameters

AnalysisParameters

AnalysisParameters
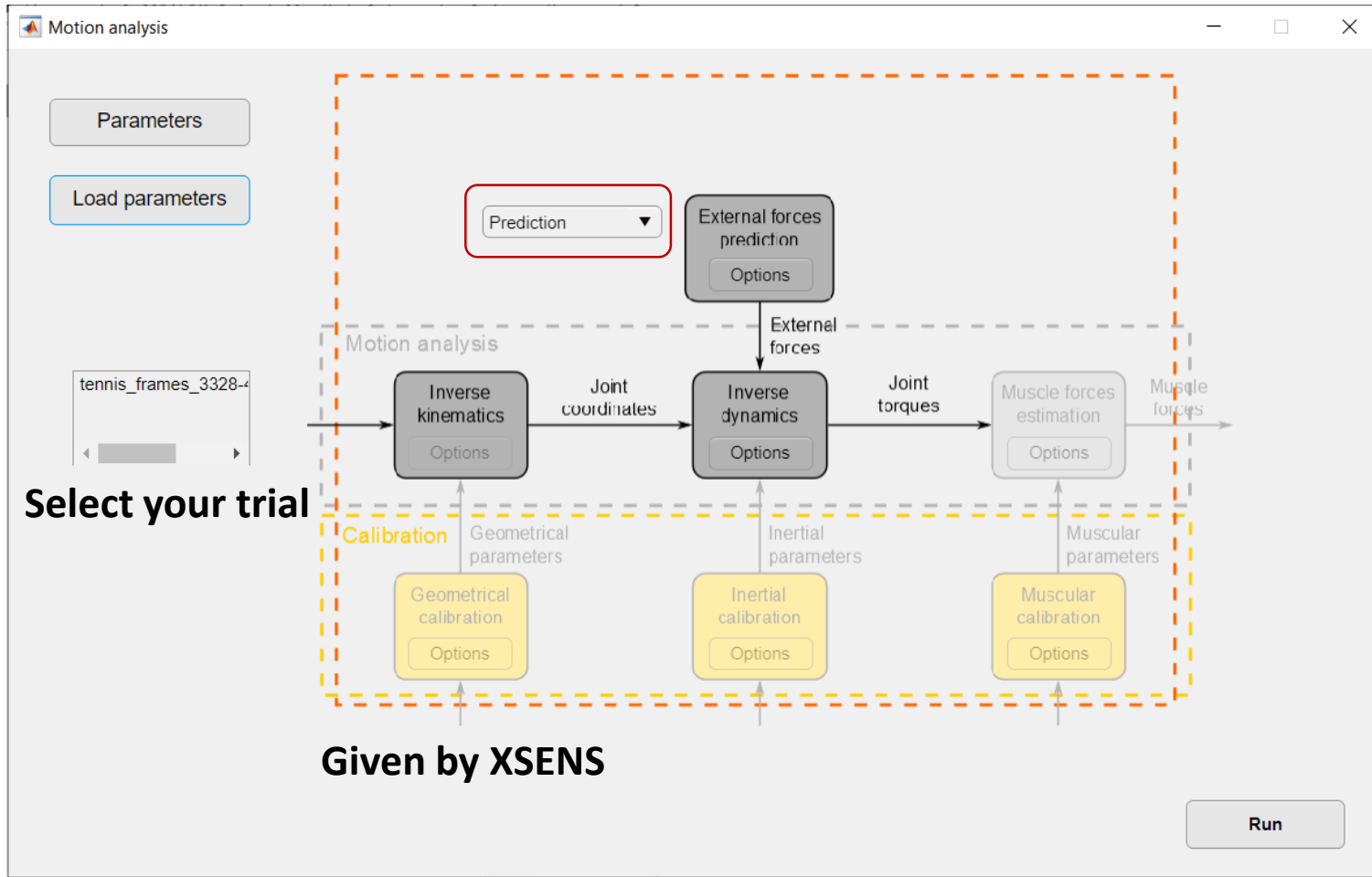
Generate AnalysisParameters

- Open Options

- Add contact points: « Rfoot » and select all the « RfootPrediction » points

- Add contact points: « RightToe » and select all the « RightToe Prediction » points

- Add contact points: « Lfoot » and select all the « LfootPrediction » points

- Add contact points: « LeftToe » and select all the « RfootPrediction » points

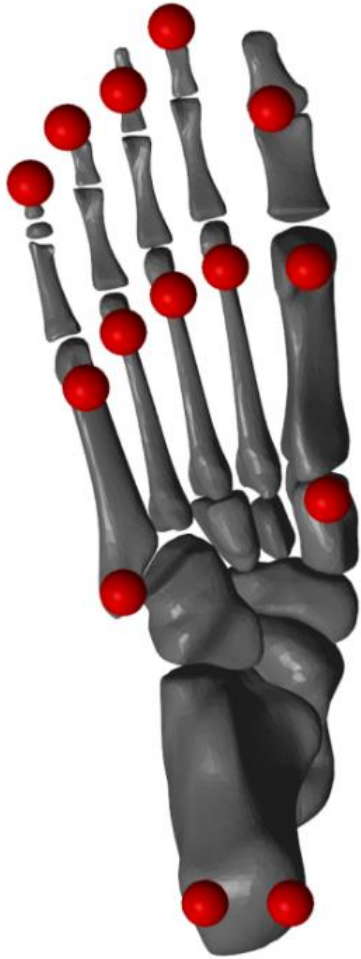**Use Crtl+Click or Shift+Click to select multiple points**
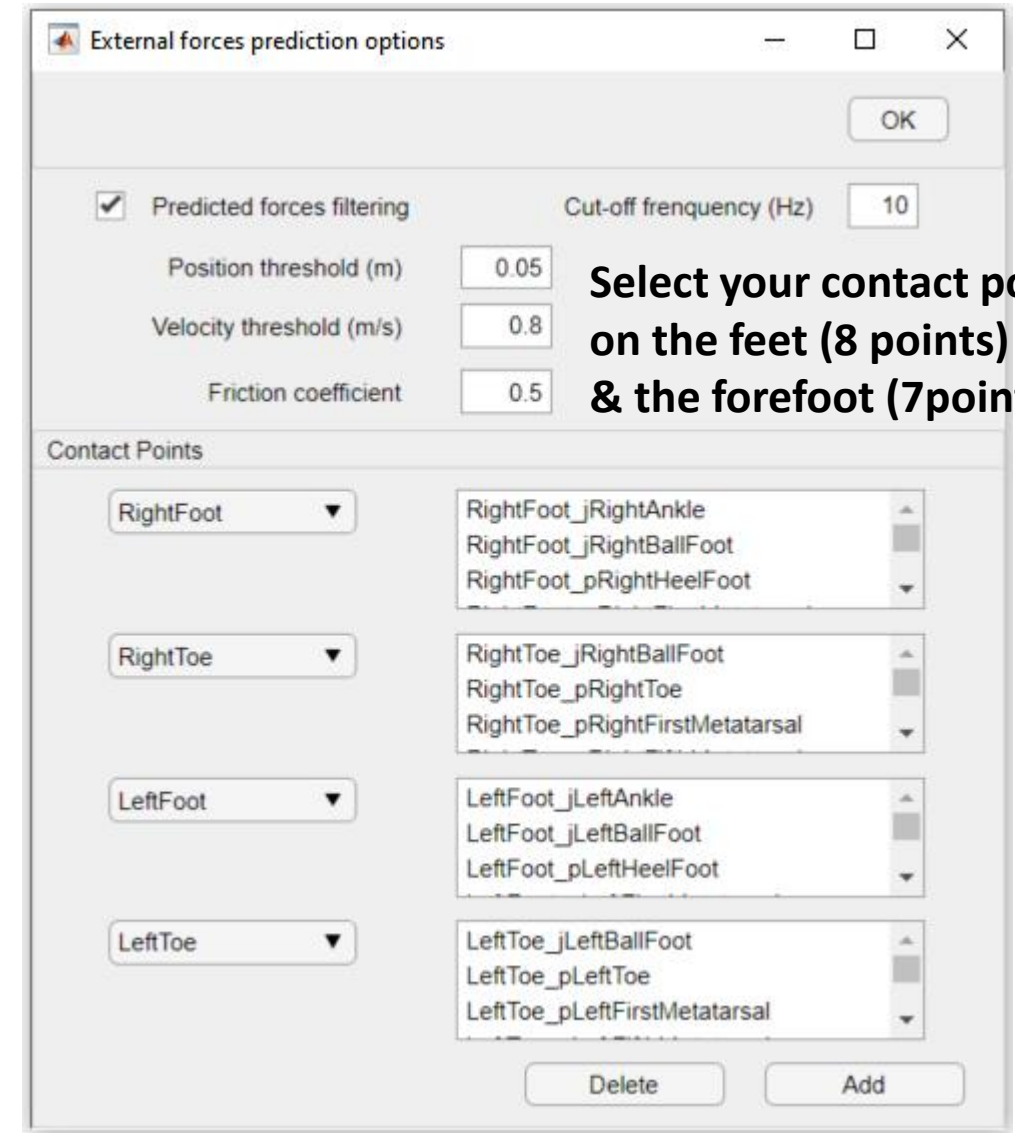
RUN

External Forces Prediction (ChgtDirection04) ...
... External Forces Prediction (ChgtDirection04) done
Inverse dynamics (ChgtDirection04) ...
... Inverse dynamics (ChgtDirection04) done
Forces Computation (ChgtDirection04) ...
... Forces Computation (ChgtDirection04) done

new

What are the points ?

Anatomical points defined on the feet as contact points

See **...\Functions\Models\Osteoarticular\Leg\ModelParts\foot.m**

R. Fluit, M. S. Andersen, S. Kolk, N. Verdonschot, and H. F. Koopman, "Prediction of ground reaction forces and moments during various activities of daily living," Journal of biomechanics vol. 47, no. 10, pp. 2321–2329, 2014

S. Skals, M. K. Jung, M. Damsgaard, and M. S. Andersen,
"Prediction of ground reaction forces and moments during sports-related movements," Multibody system dynamics, vol. 39, no. 3,pp. 175–195, 2017

Muller A., Pontonnier C., Dumont G. Motion-based prediction of hands and feet contact efforts during asymmetric handling tasks, in review

You can add contact points on any segment of the model !
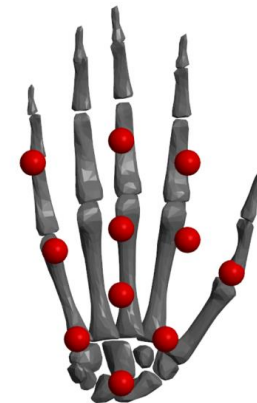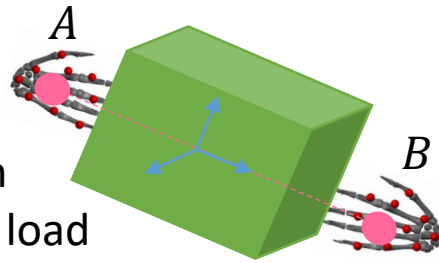
What are the tresholds ?
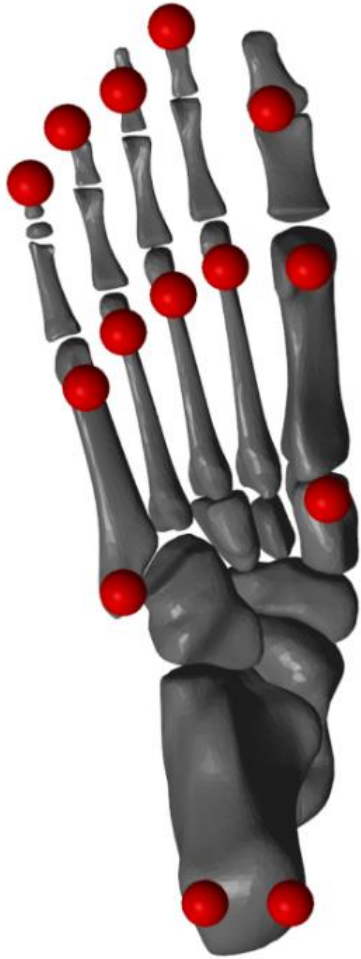
Contact is allowed (force is allowed to be generated on the considered point) if thresholds are reached and maximal force per point is constrained to 0.4 BW. Coulombs law links normal and tangential components of the force

✔ Predicted forces filtering	Cut-off frenquency (Hz)	5
Position threshold (m)	0.05	
Velocity threshold (m/s)	0.8	
Friction coefficient	0.5	

Measuring

Handling tasks

Motion-based external forces prediction

Marker-based motion reconstruction of the load

v_A, γ_A

l

v_B, γ_B

Grip/deposit event detection (NN)

Probability of a grip or deposit moment

Time

GE_{ref} DE_{ref}
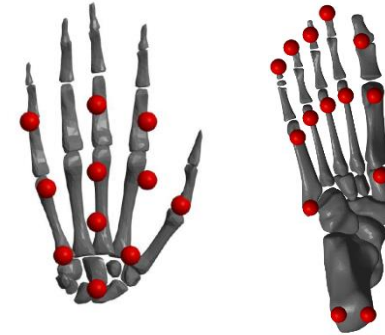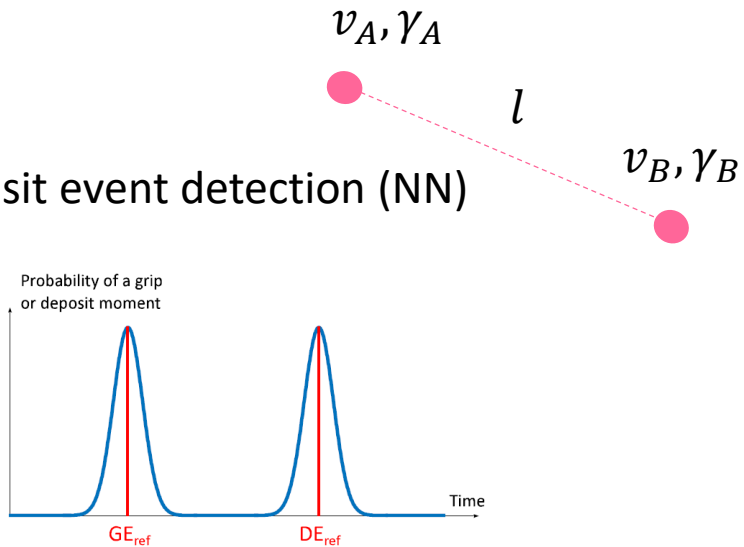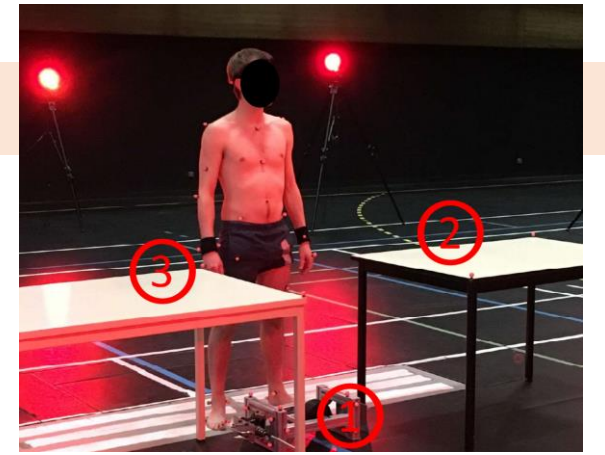
Contact zones mapping

$$\min_F \sum_{i=1}^{2N_f} \|\boldsymbol{F_i}\|^2$$

$$s.t. \begin{cases} M_s(\boldsymbol{q})\ddot{\boldsymbol{q}} + C_s(\boldsymbol{q}, \dot{\boldsymbol{q}}) + G_s(\boldsymbol{q}) + \boldsymbol{E_s} = \boldsymbol{0} \\ M_l(\boldsymbol{q})\ddot{\boldsymbol{q}} + C_l(\boldsymbol{q}, \dot{\boldsymbol{q}}) + G_l(\boldsymbol{q}) + \boldsymbol{E_l} = \boldsymbol{0} \\ \forall i \in [1, 2(N_f + N_h)], \boldsymbol{F_i} < \boldsymbol{F_{i_{max}}} \end{cases}$$

Measuring
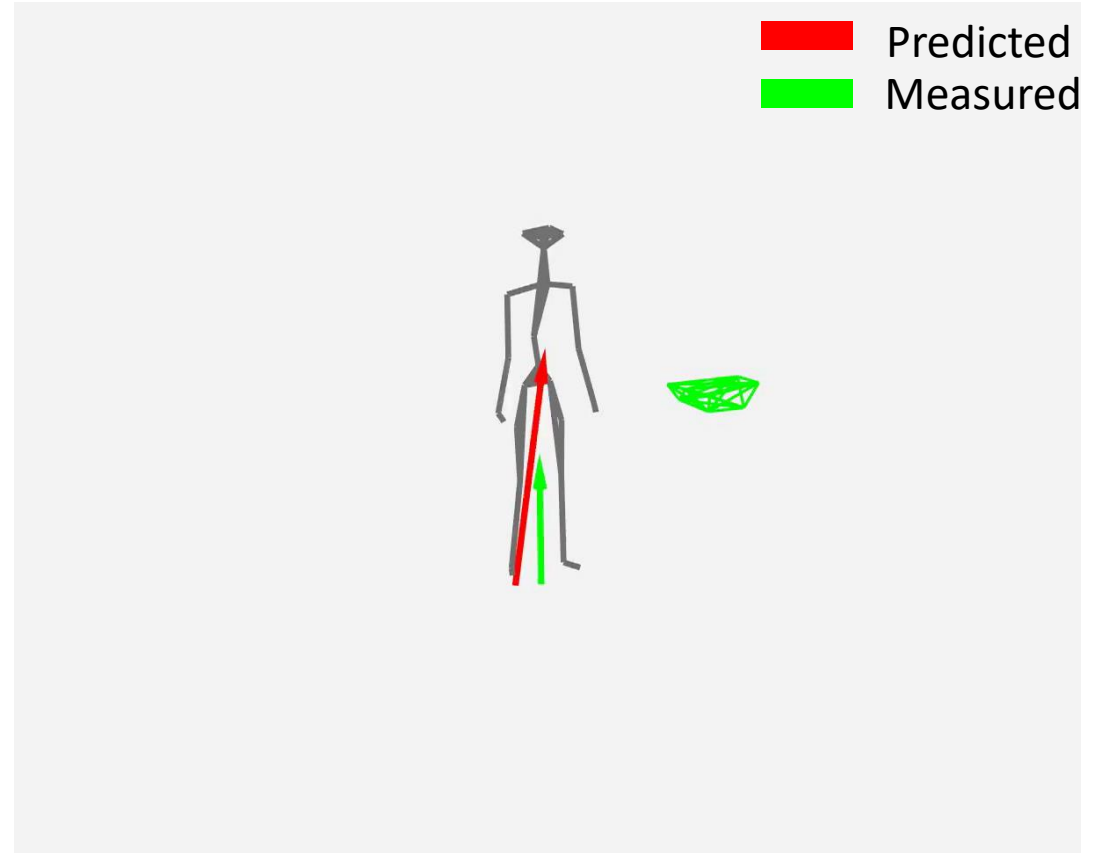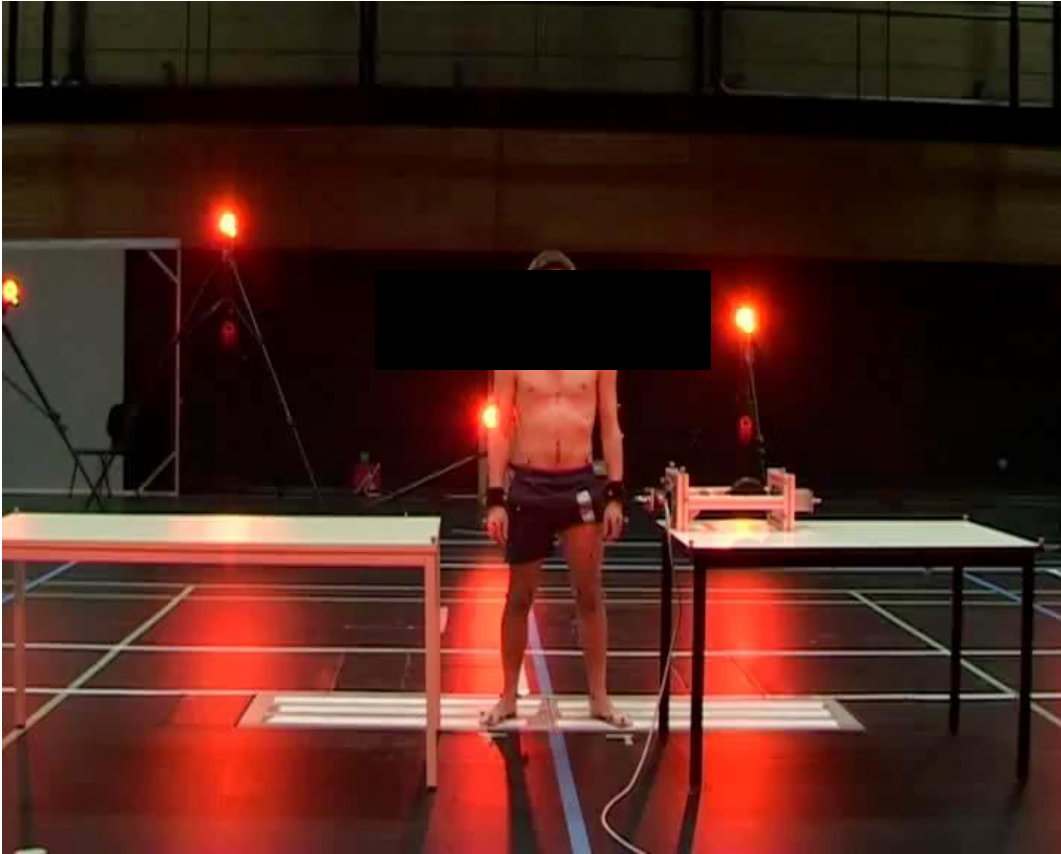
Measuring

Motion-based external forces prediction
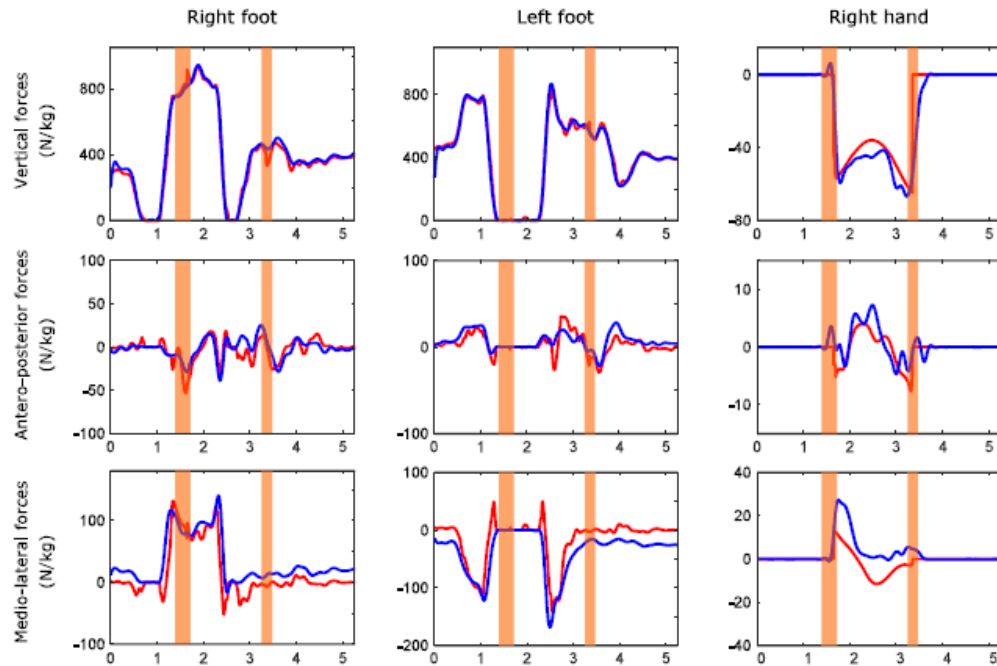
Fine for vertical forces ~2.5% RMSE

Ok for antero-posterior forces ~15% RMSE

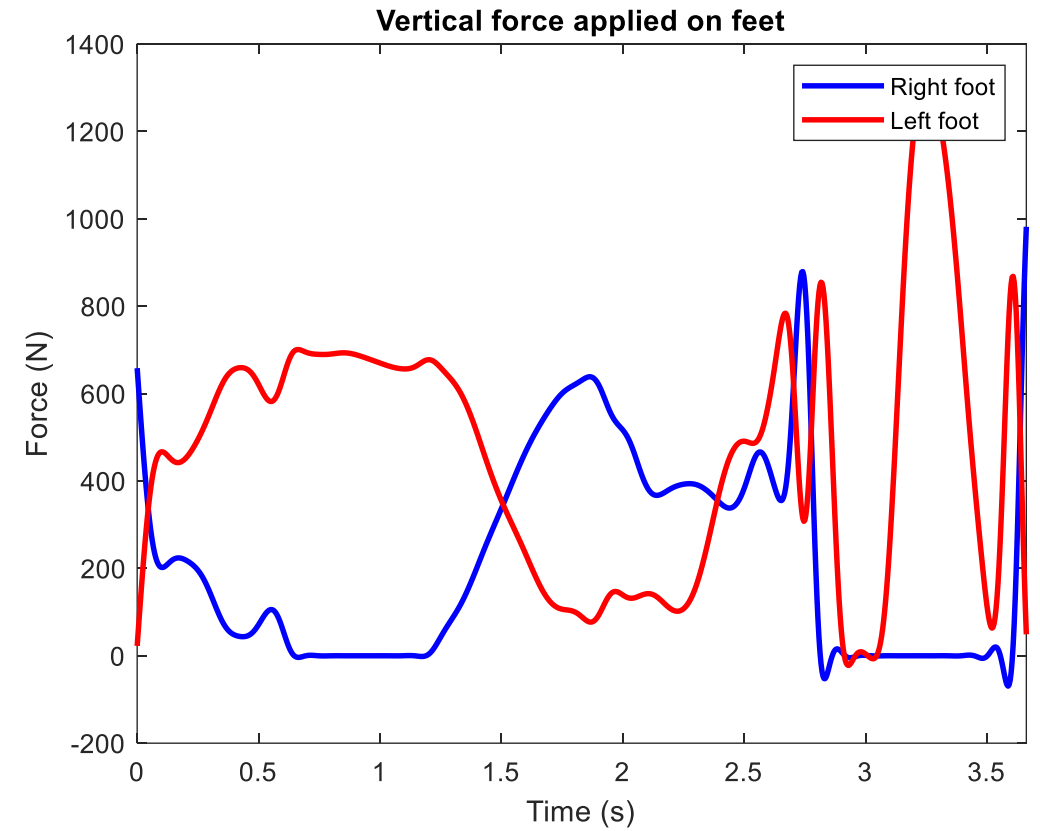Bad for medio-lateral forces ~40% RMSE

Contact parameters ?

Internal torques ?

Contact points ?

Good enough to predict forces for standardized tasks (not much variability in the handling)

Postprocessing

Run the postProcessing to visualize the predicted ground reaction forces

Animation

Video