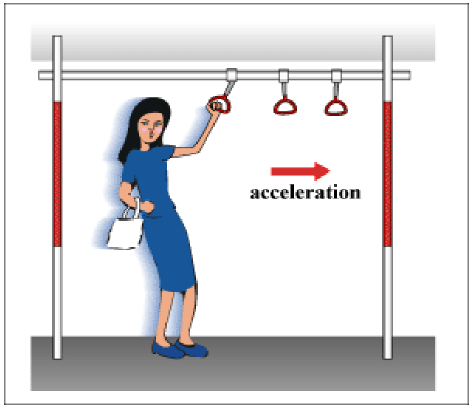
Musculoskeletal forces in the human body during Tokyo’s daily life of commuting



Julien Groud

Terrabyte

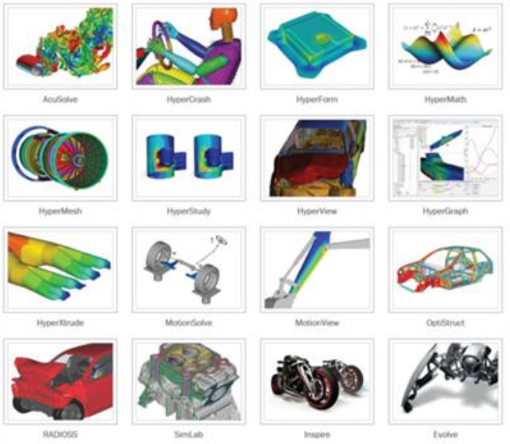
Presentation of Terrabyte Company

Software Engineering Company specializing in Computer Aided Engineering services.

Terrabyte Company provides multidiscipline support to Customers in various service menus.

CAE Software products

- ☐ Structure / Fluid dynamics / Electromagnetic analysis software
- ☐ High level technical support



CAE software products distributed by Terrabyte

Consulting Services

- ☐ Assistance in starting up analysis jobs
- ☐ Software introduction training
- ☐ Technical service
- ☐ Software development
- ☐ Analysis Engineer dispatch
- ☐ Material properties tests
- ☐ Basic technology seminars

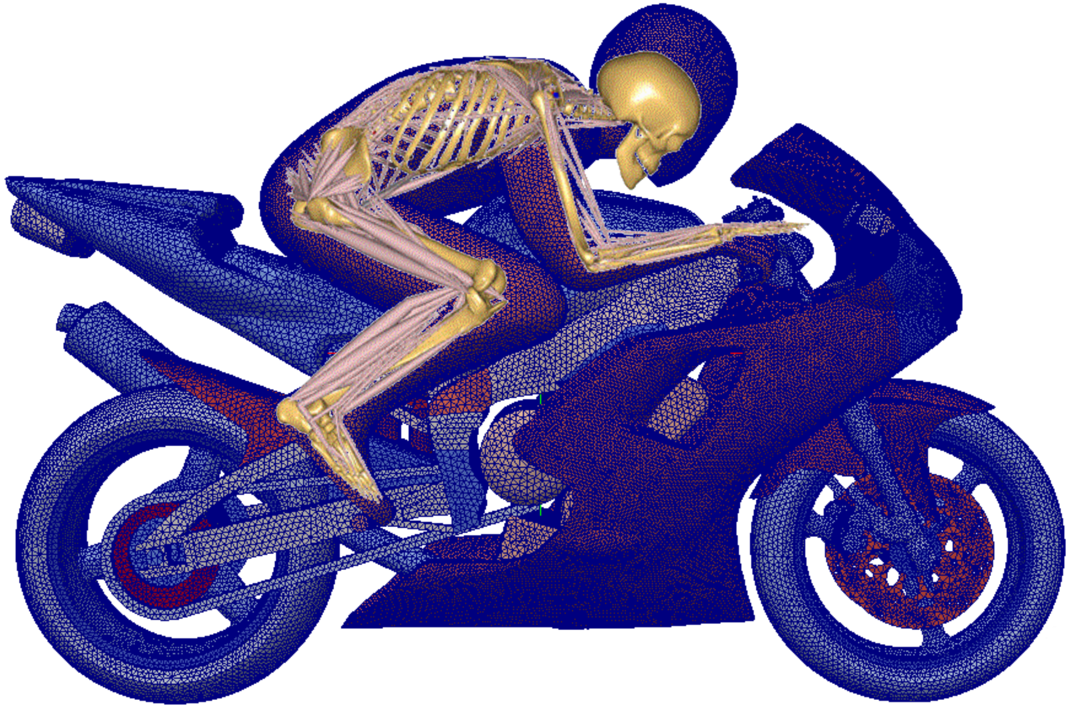
Outline

⇒ Effects of motorbike acceleration on human body

⇒ Ongoing study: different comfort aspects of bicycling in traffic

⇒ Comfort of passengers commuting in standing position

Effects of motorbike acceleration on the human body



Purpose and conditions

In this example, we will use AnyBody to study the muscle activity of someone accelerating in a sport motorbike.

Conditions

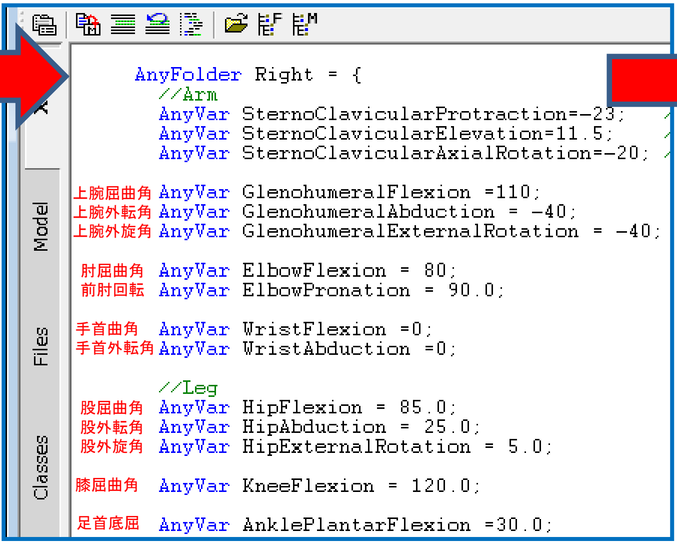
⇒ The motorbike accelerates from 0 to 100 km/h in 2.5 seconds.
⇒ The biker must hold the riding posture.

Settings of the model posture

Starting from the predefined “Human” model and setting up its anthropologic dimensions in “Mannequin.any”, we define a sport motorbike posture.

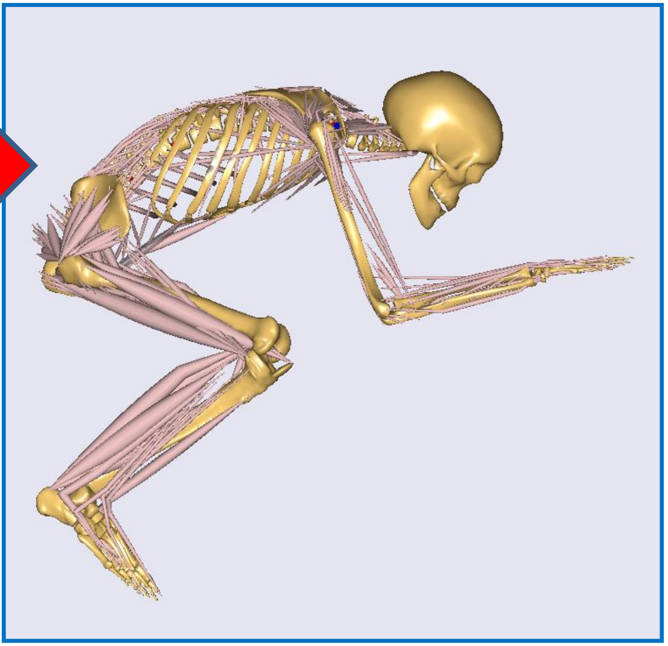
“Human” Initial posture settings

Mannequin.any



```
     AnyFolder Right = {
       //Arm
       AnyVar SternoClavicularProtraction=-23;
       AnyVar SternoClavicularElevation=11.5;
       AnyVar SternoClavicularAxialRotation=-20;

上腕屈曲角 AnyVar GlenohumeralFlexion =110;
上腕外転角 AnyVar GlenohumeralAbduction = -40;
上腕外旋角 AnyVar GlenohumeralExternalRotation = -40;

 肘屈曲角  AnyVar ElbowFlexion = 80;
 前肘回転  AnyVar ElbowPronation = 90.0;

手首曲角   AnyVar WristFlexion =0;
手首外転角 AnyVar WristAbduction =0;

       //Leg
 股屈曲角  AnyVar HipFlexion = 85.0;
 股外転角  AnyVar HipAbduction = 25.0;
 股外旋角  AnyVar HipExternalRotation = 5.0;

膝屈曲角   AnyVar KneeFlexion = 120.0;

足首底屈   AnyVar AnklePlantarFlexion =30.0;
```

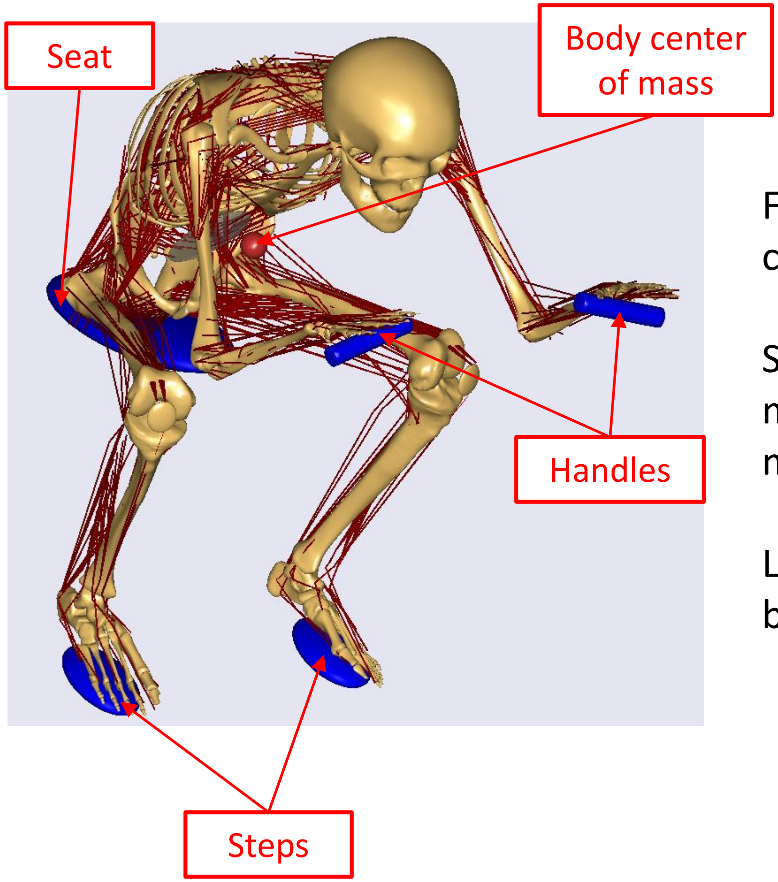
Sport motorbike posture



Contact areas and acceleration

If existing, the STL geometry of motorbike can be imported. Else, we just designed the contact areas between the biker and the motorbike.

In the “Environment.any” file, the seat, steps and handles were modeled.



First, after having built the contact areas, we set the contact conditions with the human model.

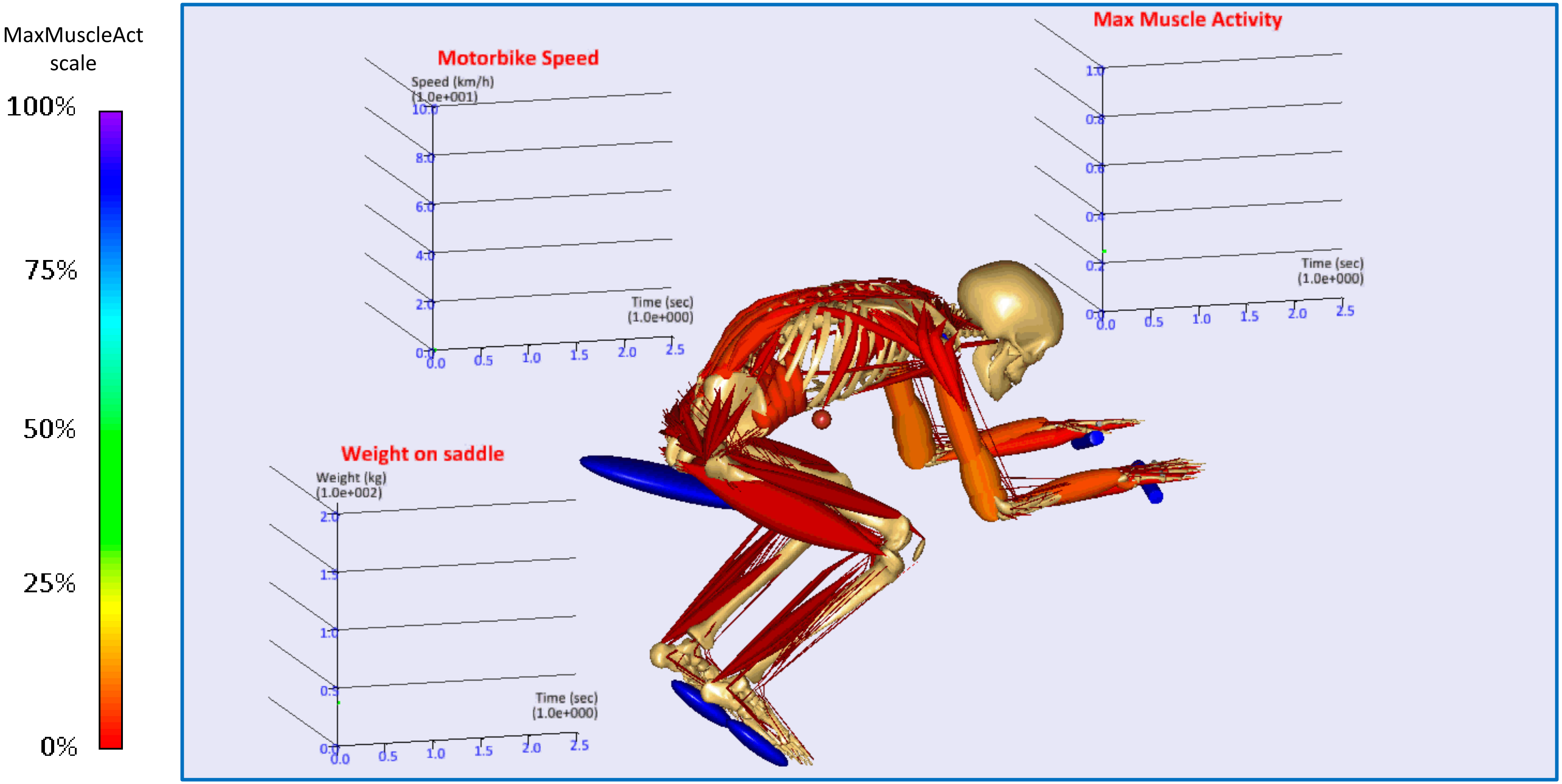
Spherical joint conditions were mostly used to connect the motorbike parts with the predefined nodes of the human model.

Lastly, the motorbike acceleration is defined as a force on the body center of mass.

Animation and results

By running an inverse dynamics analysis, we get the muscle activity of each muscle recruited to maintain the sport motorbike posture.

In those conditions, at the end of the acceleration, the maximum muscle activity reaches 40%.



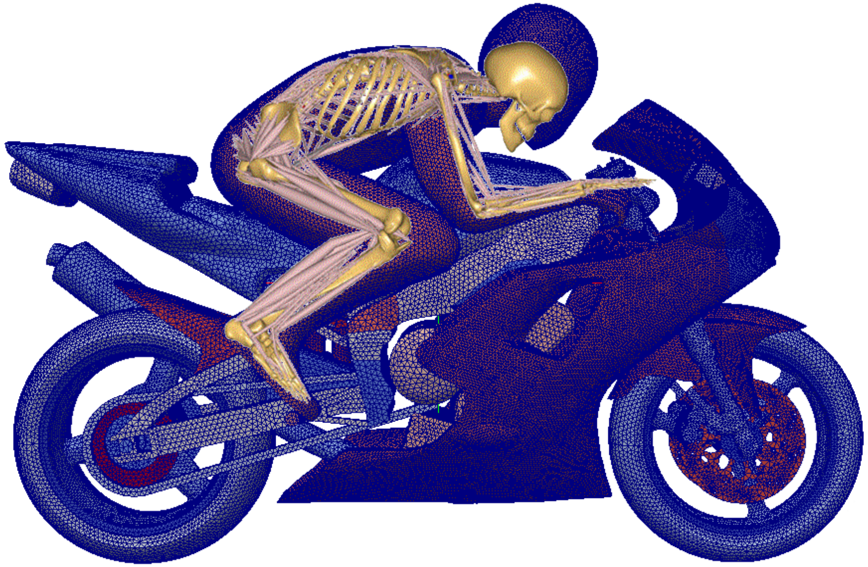
Further possibilities

⇒ Input the full acceleration/time profile

⇒ Change motorbike dimension/shape => human posture
(STL geometry files of the seats, handle and steps)

⇒ Scale the biker:
- Male/Female
- Height/Weight
- Body fat percentage

⇒ Consider other/more comfort criteria:
- Spine
- Shoulder



Different comfort aspects of bicycling in traffic

Purpose and conditions

In this case, we don’t want to simulate high performance cycling, but focus on comfort during commuting in traffic.

Conditions

⇒ Different cycling activities

⇒ Different cycling positions of rider

⇒ Different bicycle types.

Steps

⇒ Different cycling activities
  - Slow pedaling
  - Stop and Go
  - Getting on and off the bike

⇒ Scale the rider:
  - Male/Female
  - Height/Weight
  - Body fat percentage

⇒ Change bike dimension & rider posture
  - From upright to more sporty

⇒ Comfort criteria:
  - overall muscle activation
  - Spine loads
  - hip/knee

Presentation of Tokyo

⇒ 35.6 million people

⇒ 20 million of them commute everyday by train

⇒ World highest urban agglomeration GDP

Commuting in Tokyo

⇒ Standing posture is by far the most frequent

⇒ Depending on the posture you chose
(or the one the crowd has chosen for you), travelling may hurt!!

Purpose & Conditions

In this example, we will attempt to find the most comfortable position when standing up in an accelerating and decelerating train.

- The train
  - ⇒ For the sake of simplicity, we will take 4 km/h/s (≈ 2.5 mph/s) for the train acceleration and braking.
  - ⇒ Its cruise speed is 90 km/h (≈ 56 mph).
- The human model
  - ⇒ 170 cm tall and weighing 65 kg (≈ 5.6 ft., 143 lb.).
  - ⇒ The model must activate his muscles to hold the standing position.
  - ⇒ The passenger will not use the hand rests.

※ Unskilled passenger movements that may come from the train acceleration and deceleration will not be taken into account.

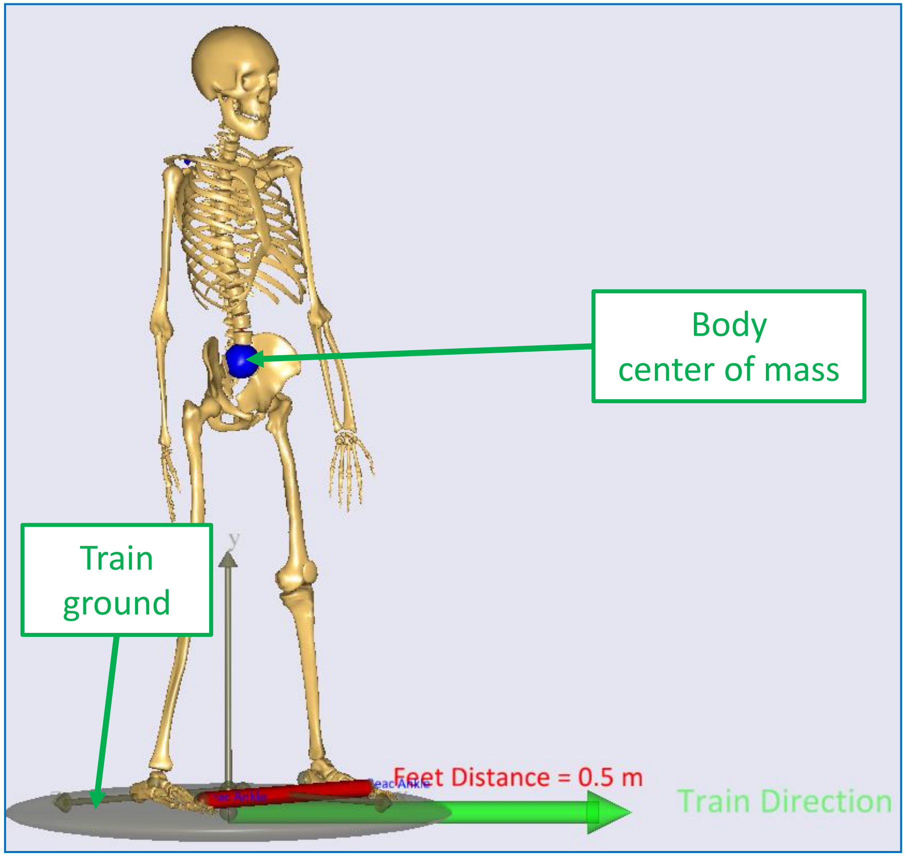
Modelization

Train acceleration and deceleration :

⇒ The body center of mass location is computed by AnyBody with the AnyKinCoM function.

We are then allowed to apply a force on it!

⇒ The acceleration force is obtained from the 2nd Law of motion $\vec{F} = m\vec{a}$.



Modelization

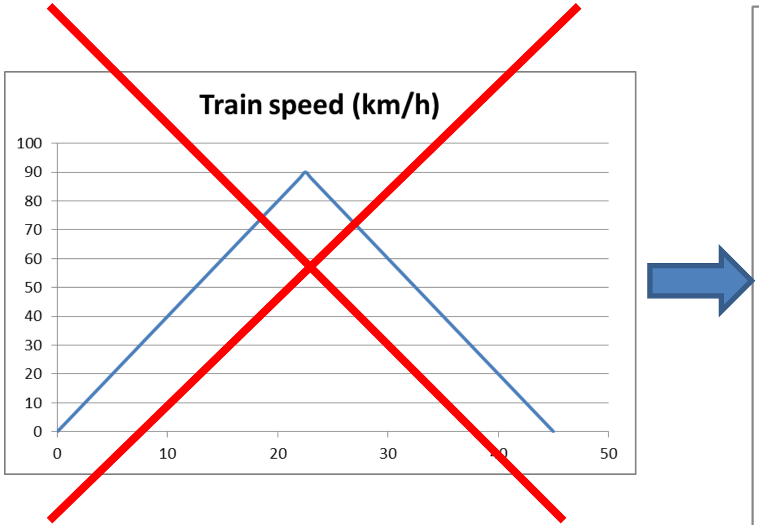
a = 4 km/h/s

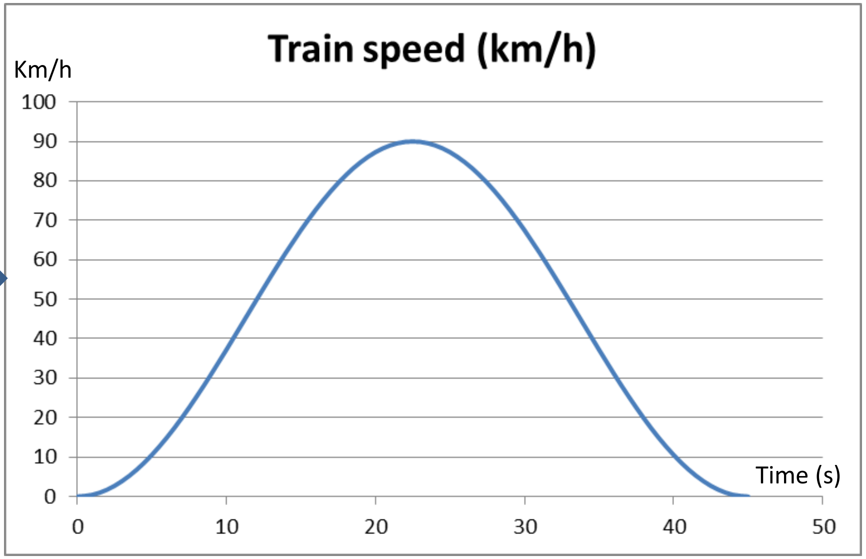
⇒ The train departs from the station, reaches its cruise speed (90 km/h) in 22.5 s, then fully brakes in 22.5 s and stops at the next station.

⇒ For comfort issues, we can assume that the variation of speed is not abrupt but smooth!

⇒ We will use a cosine function of time to express the speed. Then differentiating this function, we get the acceleration function.

$$\mathrm{V}(t) = \frac{V_{Cruise}}{2}\cos\left(\frac{2\pi}{T_{Total}}t + \pi\right) + \frac{V_{Cruise}}{2}$$





Settings of the parametric study

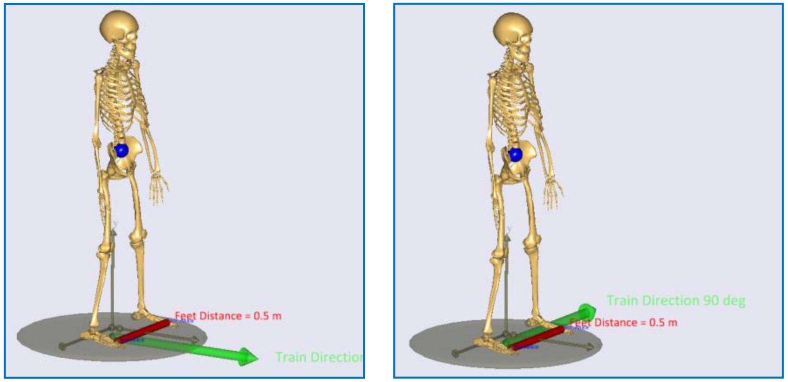
⇒ We will study the results from various postures:

- The angle made by the anteroposterior direction of the passenger and the train direction (from 0˚ to 90˚ , every 5˚)

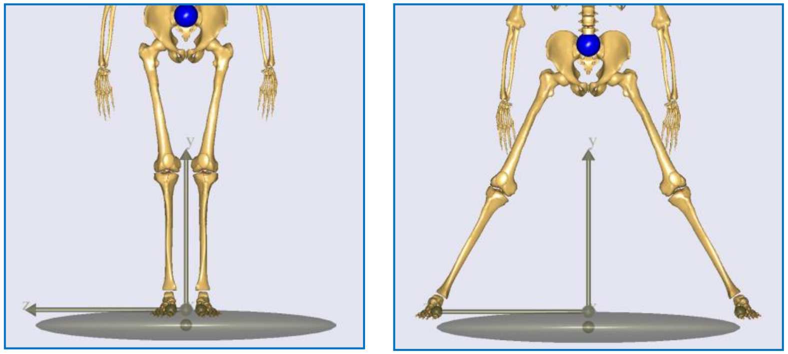
- The passenger feet distance (from 10cm to 1m, every 10cm)

⇒ TOTAL: 190 different postures!

Train direction
0˚ ⇒ 90˚



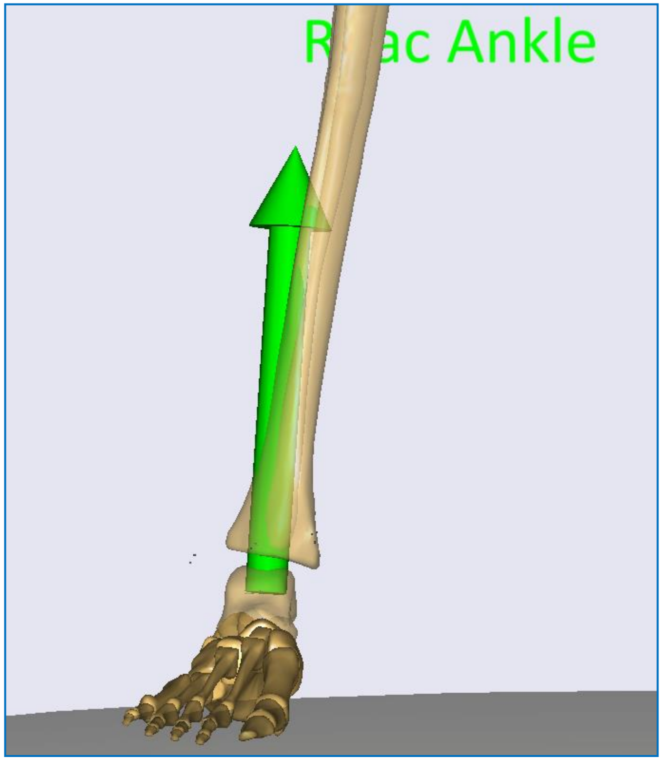
Feet distance
0.1 m ⇒ 1.0 m



Settings of the parametric study

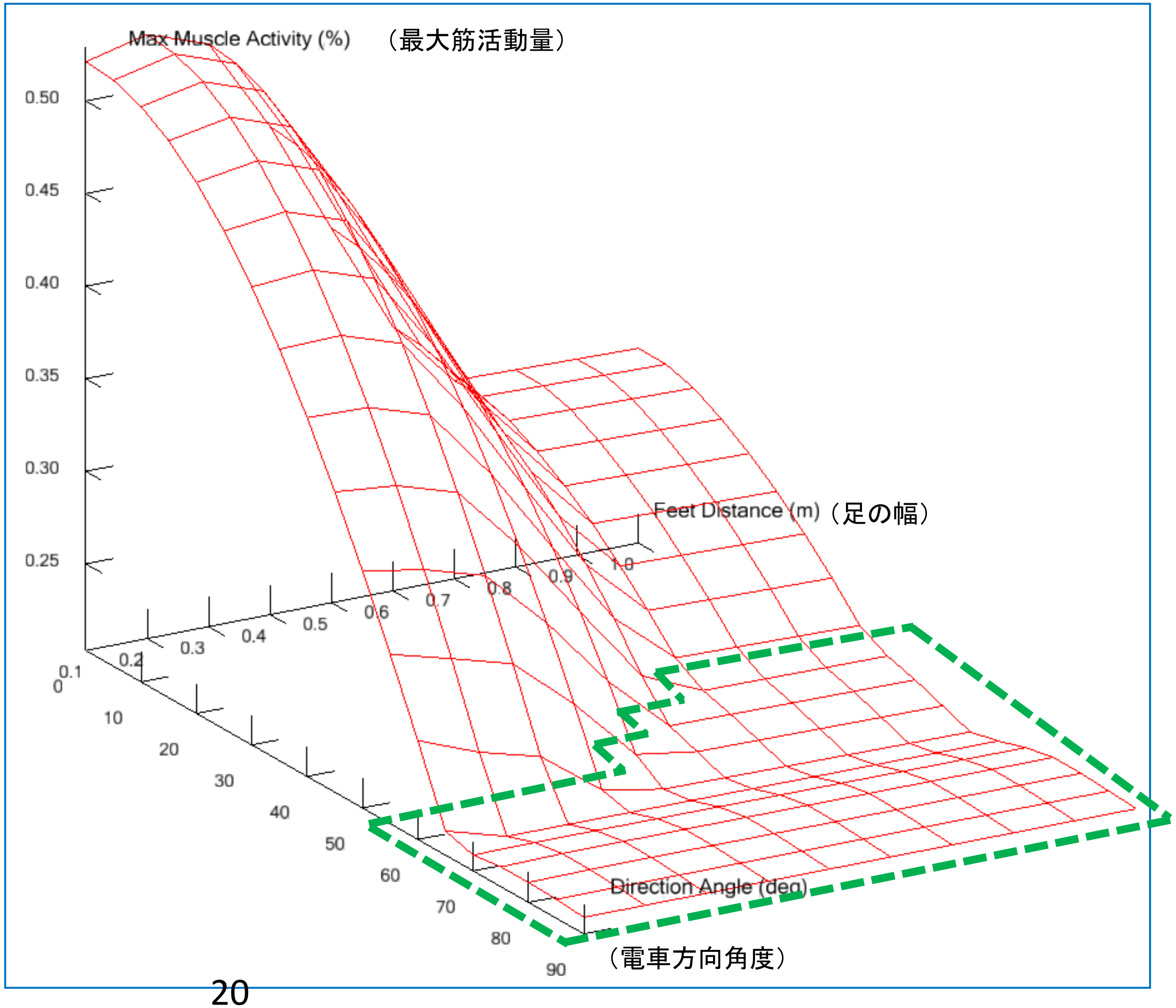
Comfort criteria :

⇒ In this analysis, the posture that minimizes the maximum muscle activity and the charge applied on the ankles will be considered as the most comfortable posture.



Results

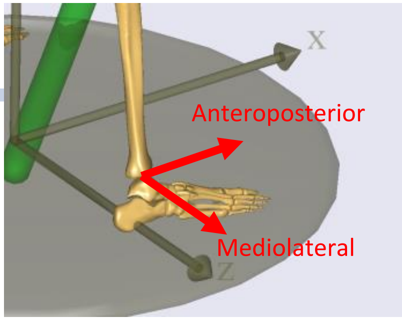
This is a 3D graph of the max muscle activity of each posture:
The posture with the lowest value is (60˚, 1.0m), with a max muscle activity that does not exceed 20.3 %.
The posture with the highest value is (0˚, 0.2m), with a max muscle activity reaching 52.9 %.



Now let’s have a look at reaction forces on ankles!

The green domain shows postures where the max muscle activity did not exceed 22%.

Postures outside this domain will be ignored in the next slide graph.

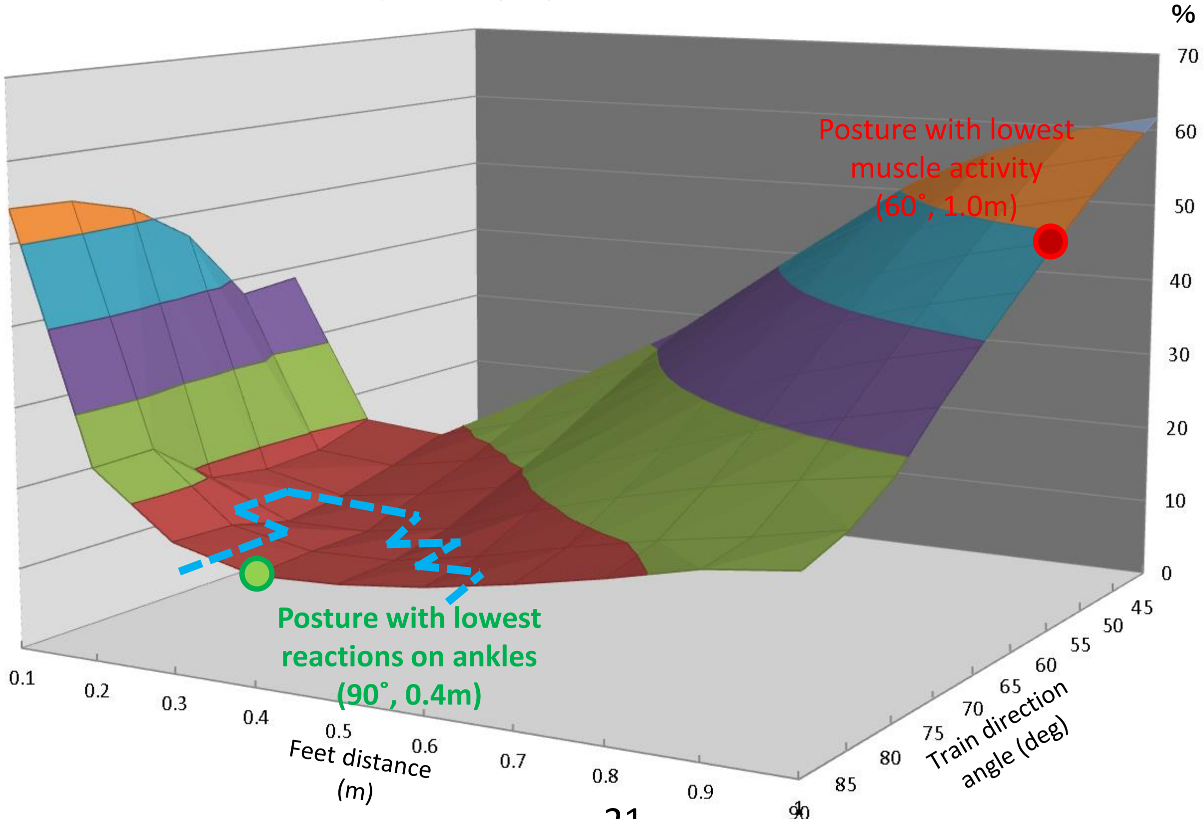


Results

This is a 3D graph of the anteroposterior and mediolateral reactions on ankles:

⇒ The posture with the minimum value of muscle activity (red point) is actually not the best ankle-wise!
⇒ In the blue domain of this graph, reactions on ankles do not exceed 15 % of their maximum value.
⇒ The posture (90˚, 0.4m) not exceeding 13.5 % of its maximum value, should be the most comfortable one.

Anteroposterior and mediolateral reaction forces on ankles
(percentage of their maximum value)



Posture with lowest muscle activity (60˚, 1.0m)

Posture with lowest reactions on ankles (90˚, 0.4m)

Observations

① The muscle activity from postures between (60˚, 0.4m) and (90˚, 1.0m) is low and does not significantly change.

② Lowest reaction forces on ankles occur when posturing between (80˚, 0.3m) and (90˚, 0.6m).

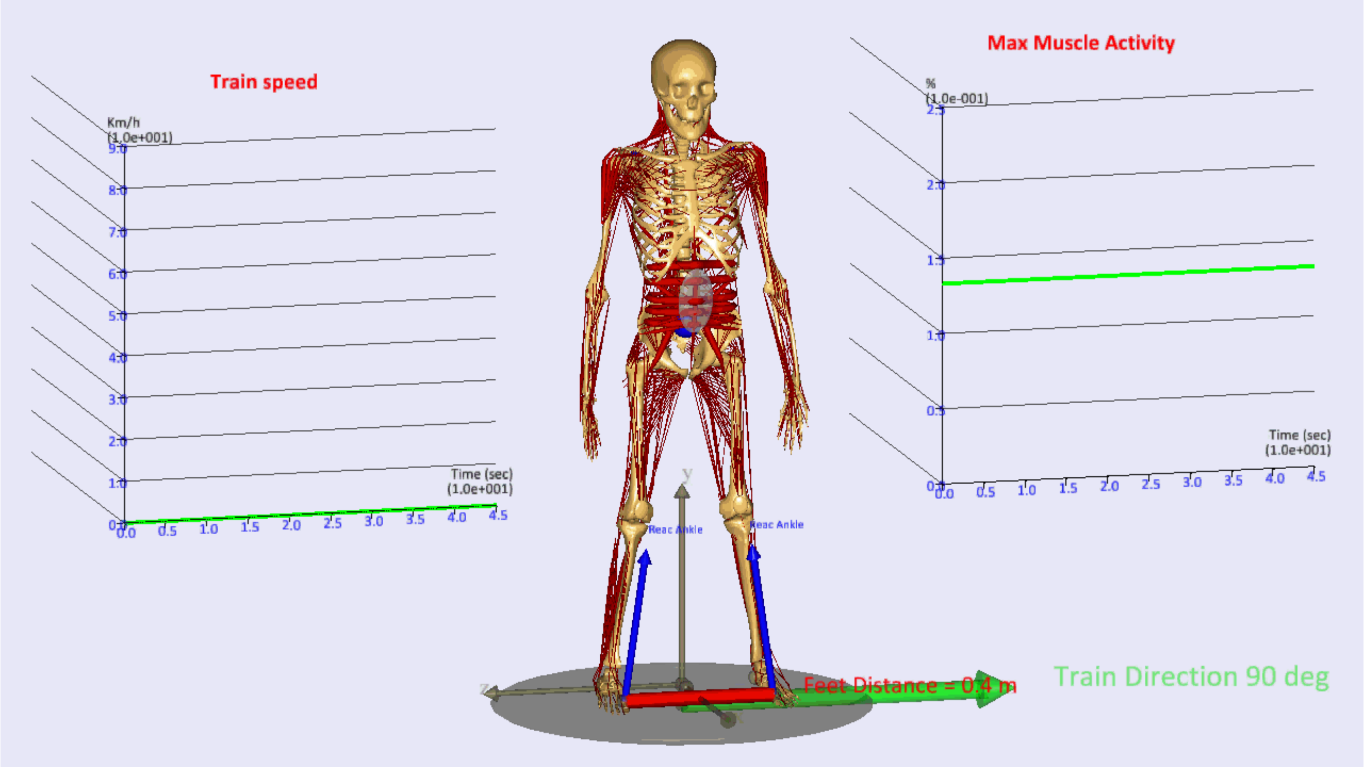
③ The result out from this parameter study is that the most comfortable posture is (90˚, 0.4m).

This result, standing transverse to the train direction, is actually close to the posture most people naturally take!

Animation of the (90 ˚, 0.4m) posture when accelerating and decelerating:

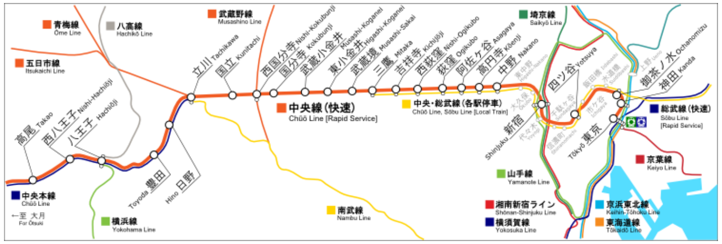
⇒ Train speed graph
⇒ Max muscle activity graph

⇒ Train speed vector (green)
⇒ Ankle reaction force vectors (blue)
⇒ Acceleration magnitude vector
⇒ Bulging of recruited muscles



Further possibilities

⇒ Input the full acceleration/time profile of a particular train line portion (Excel file)



⇒ Consider the inside train environment
(STL geometry files of the seats, holding bars and handle)

⇒ Scale the passenger:
  ○ Male/Female
  ○ Height/ Weight
  ○ Body fat percentage

⇒ Consider other/more comfort criteria:
  ○ Knee reaction forces
  ○ Specific muscle activity

⇒ Study other postures:
  ○ Subject holding a handle
  ○ Subject performing a move while accelerating