HuMoD Database
A versatile and open database for the investigation, modeling and simulation of human motion dynamics

Documentation
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## Contents

1 Introduction 2
2 Subjects 2
3 Motion Protocol 3
4 Measurement setup 3
5 Data Processing 4
6 Data Files 7
7 Computational Scripts 9

Appendix A  Treadmill Dimensions 12
Appendix B  Landmark Abbreviations 12
Appendix C  Muscle Abbreviations 14
Appendix D  Joint Abbreviations 14
Appendix E  Data Structure 15
Appendix F  References 24
1 Introduction

The HuMoD Database, derived from Human Motion Dynamics, is a versatile and open database for the investigation, modeling and simulation of human motion dynamics with a focus on lower limbs. The database contains raw and processed biomechanical measurement data from a three-dimensional motion capture system, an instrumented treadmill and an electromyographical measurement system for eight different motion tasks performed by a female and male subject as well as anthropometric parameters for both subjects. The quite unique combination of biomechanical measurement data with anthropometric parameters allows to create biomechanical models of the human locomotor system and to investigate and simulate human motion dynamics including muscle driven actuation. Besides investigations in biomechanics, the database can be of value especially for the design and development of musculoskeletal humanoid robots and for better understanding and benchmarking human-like robot locomotion. The biomechanical measurement data and the source code of the applied computational scripts is open and can be obtained free of charge from the HuMoD Database website:

http://www.sim.informatik.tu-darmstadt.de/humod/

The HuMoD Database is made available under the Open Database License v1.0. Any rights in individual contents of the database are licensed under the Database Contents License v1.0. The source code is licensed under the BSD 3-Clause License. Please cite the following publication, if you are using processed or raw data or computational scripts provided in the context of the HuMoD Database in your research:


Some texts, tables and figures in this documentation are taken from or are based on this publication.

2 Subjects

A healthy female and male subject performed eight different motion tasks without shoes dressed in underwear. The subjects were given time to become familiar with the measurement setup and equipment before the measurements and to rest between the trials. The measurement procedure was reviewed and approved by the ethical review committee of Friedrich-Schiller-Universität Jena, Germany. Both subjects provided informed consent in accordance with the policies of the ethical review committee. Table 1 lists some details of the subjects.

<table>
<thead>
<tr>
<th>Table 1: Details of the female and male subject.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject A</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Height</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Origin</td>
</tr>
<tr>
<td>Clothing</td>
</tr>
<tr>
<td>Date</td>
</tr>
</tbody>
</table>
3 Motion Protocol

The subjects performed eight motion tasks, partially at different speeds or under changed conditions resulting in thirteen trials. The motion tasks cover locomotion, interaction with an object and physical activity representing a sample of typical repetitive tasks and goal-oriented tasks useful for biomechanics and humanoid robotics research. These include walking, running, squatting and jumping as well as avoiding obstacles and kicking a ball. During the first and last 10 s of each trial the force plates of the instrumented treadmill remained unloaded. Before and after performing the particular motion task, the subject stood still on the treadmill for at least 10 s. This idle time was increased to 20 s after fast motion tasks. Details of the single trials are summarized in Table 2.

<table>
<thead>
<tr>
<th>#</th>
<th>Description</th>
<th>Initial idle time</th>
<th>Task duration</th>
<th>Final idle time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Straight walking at 1.0 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>1.2</td>
<td>Straight walking at 1.5 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>1.3</td>
<td>Straight walking at 2.0 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>2.1</td>
<td>Straight running at 2.0 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>20 s + 10 s</td>
</tr>
<tr>
<td>2.2</td>
<td>Straight running at 3.0 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>20 s + 10 s</td>
</tr>
<tr>
<td>2.3</td>
<td>Straight running at 4.0 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>20 s + 10 s</td>
</tr>
<tr>
<td>3</td>
<td>Sideways walking at 0.5 m/s</td>
<td>10 s + 10 s</td>
<td>60 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>4</td>
<td>Transition between standing and straight running at 4.0 m/s</td>
<td>10 s + 10 s</td>
<td>112 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>5.1</td>
<td>Avoiding a long box obstacle (41 × 20 × 15 cm) at 1.0 m/s</td>
<td>10 s + 10 s</td>
<td>120 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>5.2</td>
<td>Avoiding a wide box obstacle (20 × 41 × 15 cm) at 1.0 m/s</td>
<td>10 s + 10 s</td>
<td>120 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>6</td>
<td>Continuous squats with arms akimbo and stopped treadmill</td>
<td>10 s + 10 s</td>
<td>40 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>7</td>
<td>Kicking a soft football (20 cm, 160 g) with stopped treadmill</td>
<td>10 s + 10 s</td>
<td>100 s</td>
<td>10 s + 10 s</td>
</tr>
<tr>
<td>8</td>
<td>Continuous jumps with arms akimbo and stopped treadmill</td>
<td>10 s + 10 s</td>
<td>20 s</td>
<td>10 s + 10 s</td>
</tr>
</tbody>
</table>

* Transition between standing and straight running comprised accelerating from 0.0 m/s to 4.0 m/s at 0.1 m/s², holding 4.0 m/s for 20 s and decelerating from 4.0 m/s to 0.0 m/s at -0.1 m/s².

4 Measurement setup

The measurements were collected at the Locomotion Lab of André Seyfarth at Technische Universität Darmstadt, Germany. All trials were performed on the instrumented treadmill ADAL3D-WR (Tecmachine,
France). The belt of the treadmill runs over two force plates with four single-axis force sensors (Kistler, Switzerland) that were used to measure the vertical ground reaction forces $F_y$ of the left and right foot. The two force plates are mounted on top of four multi-axis force sensors (Kistler, Switzerland) that measured lateral forces $F_x$ and $F_z$. All forces were recorded at 1000 Hz. The software ADIMIX Walking 2.0 was used to control the treadmill and store the recorded force data. Figure 1 shows a schematic diagram of the instrumented treadmill and the single- and multi-axis force sensors. Detailed dimensions of the instrumented treadmill are provided in Appendix A.

The motion of upper and lower limbs was recorded at 500 Hz with a three-dimensional motion capture system consisting of four Oqus 310+ cameras and six Oqus 300+ cameras (Qualisys, Sweden). A set of thirty-five reflective markers with a diameter of 19 mm mounted on thin cardboard was placed on the skin at anatomical landmarks by an experienced examiner. One additional reflective marker was placed on top of the underpants above pubic symphysis [Reed1999]. Figure 2a illustrates the locations of the thirty-six reflective markers. A description of the associated landmarks and used abbreviations is given in Appendix B. For calibrating and controlling the motion capture system, storing the recorded motion data as well as assigning the recorded motion data to the individual markers, the software TrackManager 2.7 was applied.

The electrical activity of fourteen selected skeletal muscles in the legs was recorded at 2000 Hz with the electromyographical measurement system Bagnoli-16 Desktop (Delsys, USA). The measured signals were internally filtered to a bandwidth between 20 Hz and 450 Hz. The set of fourteen surface electrodes was placed according to SENIAM guidelines [Hermens2000] by an experienced examiner. Figure 2b shows the locations of the fourteen surface electrodes for electromyographical measurement. The associated muscles and used abbreviations are listed in Appendix C. The software EMGworks Acquisition 3.6 was used to control the electromyographical measurement system and store the recorded activity data.

5 Data Processing

The raw data measured with the motion capture system, instrumented treadmill and electromyographical measurement system was exported into the MAT file format and processed with the numerical computing software MATLAB (MathWorks, USA) in order to provide additional information for the investigation, modeling and simulation of human motion dynamics.
Raw motion and force data was synchronized by compensating temporal offset and drift as well as transforming the global reference frame of the motion capture system into the global reference frame of the instrumented treadmill considering the ISB recommendations for reference frame notation [Wu1995]. Figure 1 illustrates the applied global reference frame where the origin is located at the center of the rectangle spanned by the left and right force plates projected to the top of the belt surface.

Infrequent gaps in the raw kinematic motion data of up to 300 ms resulting from temporarily covered reflective markers were filled by applying polynomial approximations. The measured spatial positions of the reflective markers were then shifted to the approximated skin surface. This was achieved by approximating a normal vector perpendicular to the skin surface pointing towards the considered reflective marker from adjacent reflective markers and estimated joint centers. The normalized normal vector was multiplied with the reflective marker radius and additional support material thickness and subtracted from the measured spatial position.

**GLA**

The normal vector is parallel to the line connecting the midpoint between the TRA markers with the GLA marker.

**TRA**

The normal vector is parallel to the line connecting the TRA markers.

**SUP, C7**

The normal vector is parallel to the line connecting the C7 and SUP markers.

**T8**

The normal vector is parallel to vector sum of the normal vectors specified for the SUP, C7 and T12 markers.

**T12**

The normal vector is parallel to the line connecting the T8 and T12 markers rotated by $\frac{\pi}{2}$ rad about the line connecting the ACR markers.

**ACR**

The normal vector is perpendicular to the normal vector specified for the SUP and C7 markers and the line connecting the ACR markers.

**LHC**

The normal vector is perpendicular to the lines connecting the WRI and LHC markers as well as the estimated shoulder joint center and LHC marker.
The normal vector is parallel to the line connecting the midpoint between the ASIS markers with the midpoint between the PSIS markers.

PS
The normal vector is parallel to the line connecting the midpoint between the PSIS markers with the PS marker.

GTR
The normal vector is parallel to the line connecting the GTR markers.

LFC, MFC
The normal vector is parallel to the line connecting the LFC and MFC markers.

LM, MM
The normal vector is parallel to the line connecting the LM and MM markers.

CAL
The normal vector is parallel to the line connecting the CAL and MT2 markers.

MT2, MT5, HAL
The normal vector is perpendicular to the lines connecting the CAL and MT5 markers as well as the MT2 and MT5 markers.

The shifted spatial positions of the reflective markers were then used to estimate the joint centers of fifteen joints in arms, trunk, pelvis and legs by applying established regressing equations. A description of the used abbreviations is given in Appendix D.

LNJ
The lower neck joint center was estimated from the C7, SUP and ACR markers according to Reed et al. [Reed1999].

SJ_L, SJ_R
The shoulder joint centers were estimated from the C7, SUP and ACR markers according to Reed et al. [Reed1999].

EJ_L, EJ_R
The elbow joint centers were estimated from the WRI and LHC markers as well as the estimated shoulder joint centers according to Reed et al. [Reed1999].

ULJ
The upper lumbar joint center was estimated from the C7, T8, T12, SUP and ACR markers according to Reed et al. [Reed1999] and Dumas et al. [Dumas2015].

LLJ
The lower lumbar joint center was estimated from the ASIS, PSIS and PS markers according to Reed et al. [Reed1999].

HJ_L, HJ_R
The hip joint centers were estimated from the ASIS, PSIS and PS markers according to Harrington et al. [Harrington2007].

KJ_L, KJ_R
The knee joint centers were estimated from the LFC and MFC markers according to Dumas et al. [Dumas2007a].

AJ_L, AJ_R
The ankle joint centers were estimated from the LM and MM markers according to Dumas et al. [Dumas2007a].

TJ_L, TJ_R
The toe joint centers were estimated from the CAL, MT2 and MT5 markers based on definitions by Zatsiorsky [Zatsiorsky1998].

Additional regression equations from literature for hip, knee and ankle joints were implemented and can be used alternatively by applying the provided computational scripts [Reed1999; Leardini1999; Seidel1995; Davis1991; Bell1990; Dempster1955; Hicks1953].

For the estimation of the joint trajectories including joint positions, velocities and accelerations, a Kalman smoother in combination with a subject-specific forward kinematics model with thirty degrees of freedom and fourteen body segments was applied [DeGroote2008; Yu2004]. This approach allows to reduce the influences of instrumental errors and soft tissue artifacts. The forward kinematics model consists of a head, thorax and abdomen segment, two upper and lower arm segments, a pelvis segment and two thigh, shank and foot segments. The model structure is shown in Figure 3. The joint trajectories are given as Tait–Bryan angles in $x$-$y'$-$z''$ convention.
Figure 3: Forward kinematics model with thirty degrees of freedom.

The raw ground reaction force data was filtered using a sixth order zero-lag low-pass filter with a cut-off frequency of 50 Hz. In order to decompose the measured lateral ground reaction forces $F_x$ and $F_y$ and the measured vertical ground reaction force $F_z$ in the event of mixed force plate contact during double support phase for the locomotion trials, parametrized transition functions determined using a multiple regression analysis were applied [Villeger2014]. The transition functions approximate the ground reaction force decrease of the foot leaving the ground during double support phase. The ground reaction force data was then used to estimate the center of pressure and detect individual events like left and right steps, squats or kicks.

The raw muscle activity data was rectified and filtered using a root-mean square filter with a window size of 300 ms [Konrad2005]. In addition, the filtered muscle activity data was normalized to the maximum activity level over all trials of the subject. Each dataset provides filtered and non-normalized as well as filtered and normalized muscle activity data.

Subject-specific anthropometric parameters including body segment masses, centers of mass as well as moments and products of inertia were estimated with linear regression equations [Dumas2007a; Dumas2007b; Dumas2015]. Raphaël Dumas kindly provided an updated version of the applied regression tables with some corrections in the foot parameters. The required body segment lengths were obtained from averaged kinematic motion data taken at the beginning of the trials with stopped treadmill. The applied joint axes match the axes of the estimated body segment inertial parameters and comply with the ISB recommendations [Wu2002; Wu2005].

6 Data Files

The HuMoD Database website provides a number of data files that contain the raw and processed biomechanical measurement data for the different motion tasks, the anthropometric parameters for the subjects and supplemental data. Raw and processed biomechanical measurement data as well as anthropometric
parameters are stored in the MAT file format of the numerical computing software MATLAB (MathWorks, USA). Supplemental data is provided as PNG image files or WEBM video files. Links to the individual data files are organized in separate tables for each subject. The following graph gives a brief overview of the data file structure and content.

Data files
- **Subject parameters** (Parameters.mat)
  - The Parameters.mat data file provides anthropometric parameters and meta data for the subject.

Processed data
- **Dataset** (#.mat)
  - The#.mat data files, where # stands for the number of the motion task as given in Table 2, provide the processed biomechanical measurement data from the three-dimensional motion capture system, instrumented treadmill and electromyographical measurement system.

Raw data
- **Motion** (#-RawMotion.mat)
  - The #-RawMotion.mat data files, where # stands for the number of the motion task as given in Table 2, contain the raw marker coordinates measured with the three-dimensional motion capture system.
- **Muscle** (#-RawMuscle.mat)
  - The #-RawMuscle.mat data files, where # stands for the number of the motion task as given in Table 2, contain the raw muscle activity data measured with the electromyographical measurement system.
- **Force** (#-RawForce.mat)
  - The #-RawForce.mat data files, where # stands for the number of the motion task as given in Table 2, contain the raw ground reaction forces measured with the instrumented treadmill.

Ground reference (GroundReference.mat)
- The GroundReference.mat data file contains reference coordinates of the instrumented treadmill that are used to match the global reference frames of the motion capture system and the instrumented treadmill.

Diagrams
- **Muscle** (#.png)
  - The supplemental#.png image files, where # stands for the number of the motion task as given in Table 2, visualize the processed muscle activities.
- **Force** (#.png)
  - The supplemental#.png image files, where # stands for the number of the motion task as given in Table 2, visualize the processed ground reaction forces.

Videos
- **Motion** (#.webm)
  - The supplemental#.webm video files, where # stands for the number of the motion task as given in Table 2, play an animated visualization of the processed marker and joint center coordinates.

For most applications dealing with modeling and simulation of human motion dynamics, it is sufficient to employ the subject parameter file (Parameters.mat) and the processed data files (#.mat). The subject parameters can be used to create a subject-specific biomechanical kinematics and dynamics model, while the processed data files provide task-specific joint trajectories, ground reaction forces and muscle activities. For further investigations, the raw data files (#-RawMotion.mat, #-RawMuscle.mat, #-RawForce.mat) and the ground reference file (GroundReference.mat) allow to validate or modify the applied data processing and to derive additional information. A detailed description of the data
file structure and content is given in Appendix E. All abbreviations used in the data files are listed in Appendices B, C and D.

7 Computational Scripts

The source code of the applied computational scripts is available in an online repository with distributed revision control. Additional helper scripts are located in the Scripts subdirectory. When starting with the raw biomechanical measurement data, some of the scripts require data extracted or generated by a different script. The following graph gives a brief overview of the computational scripts and provides a suggested execution sequence.

Computational scripts

- **Directory structure generation** (DirectoryStructureGeneration.m)
  This script generates a directory structure that is used by the computational scripts. Please modify the global path in Scripts/getPath.m and the local paths in Scripts/getFile.m if required.

- **Ground reference estimation** (GroundReferenceEstimation.m)
  This script estimates the rotation and translation parameters to transform points from the reference frame of the motion capture system into the the reference frame of the instrumented treadmill. The reference frame of the instrumented treadmill is the global reference frame for all datasets. This script creates the ground structure in the processed data files #.mat.

- **Motion gap filling** (MotionGapFilling.m)
  This tool processes the raw marker trajectories of the motion capture system and can be used to fill small gaps. It has a graphical user interface and provides different methods for gap filling. It transforms the reference frame according to ISB recommendations [Wu1995] and creates the initial motion structure in the processed data files #.mat. Figure 4 shows the graphical user interface and exemplary settings for filling a gap with the constrained fit method.

- **Motion transformation** (MotionTransformation.m)
  This script transforms the marker coordinates in the motion variable in the processed data files #.mat into the the reference frame of the instrumented treadmill. The reference frame of the instrumented treadmill is the global reference frame for all datasets.

- **Joint center estimation** (JointCenterEstimation.m)
  This script estimates the marker coordinates shifted to skin surface and the joint center positions from measured and estimated marker coordinates according to predictive methods given in different references.

- **Motion visualization** (MotionVisualization.m)
  This script creates an animated visualization of the processed marker and estimated joint center positions.

- **Subject parameter estimation** (SubjectParameterEstimation.m)
  This script estimates subject parameters based on segment lengths and on regression equations [Dumas2007a; Dumas2007b; Dumas2015] and with local reference frames according to ISB recommendations [Wu2002; Wu2005].

- **Joint trajectory estimation** (JointTrajectoryEstimation.m)
  This script estimates the joint trajectories including joint positions, velocities and accelerations and smoothes the estimated joint center positions by applying a Kalman smoother [DeGroote2008; Yu2004] and a subject-specific forward kinematics model.

- **Trajectory visualization** (TrajectoryVisualization.m)
  This script creates an animated visualization of the processed joint trajectories and smoothed joint center positions.
Force filtering (ForceFilter.m)
This script processes the raw ground reaction forces of the instrumented treadmill and transforms the reference frame according to ISB recommendations [Wu1995]. It synchronizes motion and force data by compensating the time delay between the motion capture system and the instrumented treadmill. This script creates the initial force structure in the processed data files *.mat.

Force separation (ForceSeparation.m)
This script smooths the measured ground reaction forces and separates the forces for left and right side by applying parametrized transition functions [Villeger2014]

Force matching (ForceMatching.m)
This script matches the ground reaction forces for left and right side by shifting residual ground reaction forces during single support.

Force visualization (ForceVisualization.m)
This script creates a visualization of the total and separate processed ground reaction forces.

Event detection (EventDetection.m)
This tool applies an event detection algorithm to find the start and end of events like steps or jumps. A graphical user interface allows to check and correct the automatically detected events. For some motion tasks, the events have to be defined manually within the graphical user interface. The tool creates the initial events structure in the processed data files *.mat. Figure 5 shows the graphical user interface with a detected event for slow straight walking.

Event visualization (EventVisualization.m)
This script creates a visualization of the processed ground reaction forces with an overlay of the detected events.

Center of pressure estimation (CenterOfPressureEstimation.m)
This script estimates the center of pressure positions from the processed ground reaction forces, measured force sensor data and given force sensor positions. The estimated center of pressure positions are limited to the foot dimensions in order to compensate high error amplification at low force sensor values.

Muscle filtering (MuscleFilter.m)
This script processes the raw muscle activities of the electromyographical measurement system. It rectifies the signals and applies a zero-phase low-pass, moving-average or root-mean-squares filter with adjustable parameters [Konrad2005]. The script creates the initial muscle structure in the processed data files *.mat.

Muscle normalization (MuscleNormalization.m)
This script normalizes the filtered muscle activities by finding the global maximum values in all datasets and correcting scattered outliers.

Muscle visualization (MuscleVisualization.m)
This script creates a visualization of the filtered or normalized muscle activities.

Meta data generation (MetaDataGeneration.m)
This script adds some meta data to the datasets. It creates the meta structure in the processed data files *.mat.
Figure 4: Graphical user interface of MotionGapFilling.m.

Figure 5: Graphical user interface of EventDetection.m.
A Treadmill Dimensions

The eight single-axis force sensors L1 to L4 and R1 to R4 were used to measure the vertical ground reaction forces $F_y$ of the left and right foot. The four multi-axis force sensors S1 to S4 measured the lateral forces $F_x$ and $F_z$.

B Landmark Abbreviations

GLA  Glabella: Undepressed skin surface point obtained by palpating the most forward projection of the forehead in the midline at the level of the brow ridges [Reed1999].

TRA_L, TRA_R  Left and right tragion: Undepressed skin surface point obtained by palpating the most anterior margin of the cartilaginous notch just superior to the tragus of the ear located at the upper edge of the external auditory meatus [Reed1999].

SUP  Suprasternale: Undepressed skin surface point at the superior margin of the jugular notch of the manubrium on the midline of the sternum [Reed1999].

C7  7th cervical vertebra: Depressed skin surface point at the most posterior aspect of the spinous process of the 7th cervical vertebra [Reed1999].

T8  8th thoracic vertebra: Depressed skin surface point at the most posterior aspect of the spinous process of the 8th thoracic vertebra [Reed1999].
T12  

12th thoracic vertebra: Depressed skin surface point at the most posterior aspect of the spinous process of the 12th thoracic vertebra [Reed1999].

ACR<sub>L</sub>, ACR<sub>R</sub>  

Left and right acromion: Undepressed skin surface point obtained by palpating the most anterior portion of the lateral margin of the acromial process of the scapula [Reed1999].

LHC<sub>L</sub>, LHC<sub>R</sub>  

Left and right lateral humeral epicondyle: Undepressed skin surface point at the most lateral aspect of the humeral epicondyle [Reed1999].

WRI<sub>L</sub>, WRI<sub>R</sub>  

Left and right wrist: Undepressed skin surface point on the dorsal surface of the wrist midway between the radial and ulnar styloid processes [Reed1999].

ASIS<sub>L</sub>, ASIS<sub>R</sub>  

Left and right anterior-superior iliac spine: Depressed skin surface point at the anterior-superior iliac spine. Located by palpating proximally on the midline of the anterior thigh surface until the anterior prominence of the iliac spine is reached [Reed1999].

PSIS<sub>L</sub>, PSIS<sub>R</sub>  

Left and right posterior-superior iliac spine: Depressed skin surface point at the posterior-superior iliac spine. This landmark is located by palpating posteriorly along the margin of the iliac spine until the most posterior prominence is located, adjacent to the sacrum [Reed1999].

PS  

Pubic symphysis: Depressed skin surface point at the anterior margin of pubic symphysis, located by the subject by palpating inferiorly on the midline of the abdomen until reaching the pubis. The subject is instructed to rock his or her fingers around the lower margin of the symphysis to locate the most anterior point [Reed1999].

GTR<sub>L</sub>, GTR<sub>R</sub>  

Left and right greater trochanter: Undepressed skin surface point at the most lateral prominent of the upper femur.

LFC<sub>L</sub>, LFC<sub>R</sub>  

Left and right lateral femoral epicondyle: Undepressed skin surface point at the most lateral aspect of the lateral femoral epicondyle [Reed1999].

MFC<sub>L</sub>, MFC<sub>R</sub>  

Left and right medial femoral epicondyle: Undepressed skin surface point at the most medial aspect of the medial femoral epicondyle.

LM<sub>L</sub>, LM<sub>R</sub>  

Left and right lateral malleolus: Undepressed skin surface point at the most lateral aspect of the malleolus of the fibula [Reed1999].

MM<sub>L</sub>, MM<sub>R</sub>  

Left and right medial malleolus: Undepressed skin surface point at the most medial aspect of the malleolus of the tibia.

CAL<sub>L</sub>, CAL<sub>R</sub>  

Left and right calcaneus: Undepressed skin surface point at the most posterior prominent of the calcaneus.

MT2<sub>L</sub>, MT2<sub>R</sub>  

Left and right 2nd metatarsal head: Undepressed skin surface point above the distal head of the 2nd metatarsal.

MT5<sub>L</sub>, MT5<sub>R</sub>  

Left and right 5th metatarsal head: Undepressed skin surface point above the distal head of the 5th metatarsal.

HAL<sub>L</sub>, HAL<sub>R</sub>  

Left and right hallux: The anterior point of the 1st digit of each foot.

In the provided data files, all landmarks are identified by labels of the form [xxx] [/_L/_R]. The first part xxx is the two-, three- or four-letter landmark abbreviation as listed above. The last part _L or _R indicates the left or right body side if applicable.
**C Muscle Abbreviations**

<table>
<thead>
<tr>
<th>Muscle Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOL&lt;sub&gt;L&lt;/sub&gt;, SOL&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right soleus muscle:</strong> Plantar flexion of the ankle joint [Hermens2000].</td>
</tr>
<tr>
<td>TIA&lt;sub&gt;L&lt;/sub&gt;, TIA&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right tibialis anterior muscle:</strong> Dorsiflexion of the ankle joint and assistance in inversion of the foot [Hermens2000].</td>
</tr>
<tr>
<td>GLS&lt;sub&gt;L&lt;/sub&gt;, GLS&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right gastrocnemius lateralis muscle:</strong> Flexion of the ankle joint and assist in flexion of the knee joint [Hermens2000].</td>
</tr>
<tr>
<td>VSL&lt;sub&gt;L&lt;/sub&gt;, VSL&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right vastus lateralis muscle:</strong> Extension of the knee joint [Hermens2000].</td>
</tr>
<tr>
<td>RCF&lt;sub&gt;L&lt;/sub&gt;, RCF&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right rectus femoris muscle:</strong> Extension of the knee joint and flexion of the hip joint [Hermens2000].</td>
</tr>
<tr>
<td>BCF&lt;sub&gt;L&lt;/sub&gt;, BCF&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right biceps femoris muscle:</strong> Flexion and lateral rotation of the knee joint. The long head also extends and assists in lateral rotation of the hip joint [Hermens2000].</td>
</tr>
<tr>
<td>GLX&lt;sub&gt;L&lt;/sub&gt;, GLX&lt;sub&gt;R&lt;/sub&gt;</td>
<td><strong>Left and right gluteus maximus muscle:</strong> Extends, laterally rotates and lower fibres assist in adduction of the hip joint. The upper fibres assist in adduction. Through its insertion into the iliotibial tract, helps to stabilise the knee in extension [Hermens2000].</td>
</tr>
</tbody>
</table>

In the provided data files, all muscles are identified by labels of the form [xxx]_[_R/_L]. The first part xxx is the three-letter muscle abbreviation as listed above. The last part _L or _R indicates the left or right body side if applicable.

**D Joint Abbreviations**

<table>
<thead>
<tr>
<th>Joint Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJ</td>
<td>Base joint that connects the human model at the lower lumbar joint with the environment and provides three prismatic and three revolute degrees of freedom.</td>
</tr>
<tr>
<td>LNJ</td>
<td>Lower neck joint (C7/T1) [Reed1999].</td>
</tr>
<tr>
<td>SJ&lt;sub&gt;L&lt;/sub&gt;, SJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right shoulder joint.</td>
</tr>
<tr>
<td>EJ&lt;sub&gt;L&lt;/sub&gt;, EJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right elbow joint.</td>
</tr>
<tr>
<td>ULJ</td>
<td>Upper lumbar joint (T12/L1) [Reed1999; Dumas2015].</td>
</tr>
<tr>
<td>LLJ</td>
<td>Lower lumbar joint (L5/S1) [Reed1999].</td>
</tr>
<tr>
<td>HJ&lt;sub&gt;L&lt;/sub&gt;, HJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right hip joint.</td>
</tr>
<tr>
<td>KJ&lt;sub&gt;L&lt;/sub&gt;, KJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right knee joint.</td>
</tr>
<tr>
<td>AJ&lt;sub&gt;L&lt;/sub&gt;, AJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right ankle joint.</td>
</tr>
<tr>
<td>TJ&lt;sub&gt;L&lt;/sub&gt;, TJ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Left and right toe joint.</td>
</tr>
</tbody>
</table>

In the provided data files, all joints are identified by labels of the form [p/r][xxx][y]_[_R/_L]. The small letters p or r in the first part indicate, if the joint is a prismatic joint given in millimeters or a revolute joint given in radians. The second part xxx is the two- or three-letter joint abbreviation as listed above. The single letter y in the third part gives the joint axis X, Y or Z in the local reference frame. The last part _L or _R indicates the left or right body side if applicable.
E Data Structure

**Subject parameters** (Parameters.mat)

- **subject** [string] ........................................... Subject identifier string
- **age** [double scalar] ........................................... Age in years
- **gender** [string] ............................................. Gender string
- **bodyHeight** [double scalar] .................................. Body height in mm
- **bodyMass** [double scalar] ..................................... Body mass in kg
- **equipmentMass** [double scalar] ................................ Measurement equipment mass in kg
- **origin** [string] .................................................. Origin string

**head** [struct]

- **segmentLengthY** [double scalar] .................................. Head length along local y axis in mm
- **mass** [double scalar] .............................................. Head mass in kg
- **comX** [double scalar] .......................................... Head center of mass position in local x direction in mm
- **comY** [double scalar] .......................................... Head center of mass position in local y direction in mm
- **comZ** [double scalar] .......................................... Head center of mass position in local z direction in mm
- **moiXX** [double scalar] ........................................... Head moment of inertia about local x axis in kg m^2
- **moiYY** [double scalar] ........................................... Head moment of inertia about local y axis in kg m^2
- **moiZZ** [double scalar] ........................................... Head moment of inertia about local z axis in kg m^2
- **poiXY** [double scalar] ........................................... Head product of inertia about local x and y axes in kg m^2
- **poiXZ** [double scalar] ........................................... Head product of inertia about local x and z axes in kg m^2
- **poiYZ** [double scalar] ........................................... Head product of inertia about local y and z axes in kg m^2
- **origin** [struct]
  - **point** [string] ................................................ Local origin identifier string
  - **type** [string] ................................................ Local origin type string

**relativePosition** [struct]

- **xxx_x** [double vector] ..................................... xxx_x marker or joint positions in local coordinates in mm

**thorax** [struct]

- **segmentLengthY** [double scalar] ................................. Thorax length along local y axis in mm
- **mass** [double scalar] .......................................... Thorax mass in kg
- **comX** [double scalar] ......................................... Thorax center of mass position in local x direction in mm
- **comY** [double scalar] ......................................... Thorax center of mass position in local y direction in mm
- **comZ** [double scalar] ......................................... Thorax center of mass position in local z direction in mm
- **moiXX** [double scalar] ......................................... Thorax moment of inertia about local x axis in kg m^2
- **moiYY** [double scalar] ......................................... Thorax moment of inertia about local y axis in kg m^2
- **moiZZ** [double scalar] ......................................... Thorax moment of inertia about local z axis in kg m^2
***Thorax***

- **poiXY** [**double scalar**] .................. Thorax product of inertia about local x and y axes in kg m²
- **poiXZ** [**double scalar**] .................. Thorax product of inertia about local x and z axes in kg m²
- **poiYZ** [**double scalar**] .................. Thorax product of inertia about local y and z axes in kg m²

- **origin** [**struct**]
  - **point** [**string**] ............................... Local origin identifier string
  - **type** [**string**] ................................. Local origin type string

- **relativePosition** [**struct**]
  - **xxx_x** [**double vector**] .............. xxx, marker or joint positions in local coordinates in mm

***Abdomen***

- **segmentLengthY** [**double scalar**] .................... Abdomen length along local y axis in mm
- **mass** [**double scalar**] .......................... Abdomen mass in kg
- **comX** [**double scalar**] ....................... Abdomen center of mass position in local x direction in mm
- **comY** [**double scalar**] ....................... Abdomen center of mass position in local y direction in mm
- **comZ** [**double scalar**] ....................... Abdomen center of mass position in local z direction in mm
- **moiXX** [**double scalar**] ..................... Abdomen moment of inertia about local x axis in kg m²
- **moiYY** [**double scalar**] ..................... Abdomen moment of inertia about local y axis in kg m²
- **moiZZ** [**double scalar**] ..................... Abdomen moment of inertia about local z axis in kg m²
- **poiXY** [**double scalar**] ..................... Abdomen product of inertia about local x and y axes in kg m²
- **poiXZ** [**double scalar**] ..................... Abdomen product of inertia about local x and z axes in kg m²
- **poiYZ** [**double scalar**] ..................... Abdomen product of inertia about local y and z axes in kg m²

- **origin** [**struct**]
  - **point** [**string**] ............................... Local origin identifier string
  - **type** [**string**] ................................. Local origin type string

- **relativePosition** [**struct**]
  - **xxx_x** [**double vector**] .............. xxx, marker or joint positions in local coordinates in mm

***Upper Arm***

- **segmentLengthY** [**double scalar**] .................... Torso length along local y axis in mm
- **mass** [**double scalar**] .......................... Upper arm mass in kg
- **comX** [**double scalar**] ....................... Upper arm center of mass position in local x direction in mm
- **comY** [**double scalar**] ....................... Upper arm center of mass position in local y direction in mm
- **comZ** [**double scalar**] ....................... Upper arm center of mass position in local z direction in mm
- **moiXX** [**double scalar**] ..................... Upper arm moment of inertia about local x axis in kg m²
- **moiYY** [**double scalar**] ..................... Upper arm moment of inertia about local y axis in kg m²
- **moiZZ** [**double scalar**] ..................... Upper arm moment of inertia about local z axis in kg m²
- **poiXY** [**double scalar**] ..................... Upper arm product of inertia about local x and y axes in kg m²
- **poiXZ** [**double scalar**] ..................... Upper arm product of inertia about local x and z axes in kg m²

---

16
_poiYZ [double scalar] ................. Upper arm product of inertia about local y and z axes in kg m$^2$

_origin [struct]
  _point [string] .................................. Local origin identifier string
  _type [string] .................................. Local origin type string

_relativePosition [struct]
  _xxx_x [double vector] ............... xxx$_x$ marker or joint positions in local coordinates in mm

_lowerArm_x [struct]
  _segmentLengthY [double scalar] .......... Lower arm length along local y axis in mm
  _mass [double scalar] .......................... Lower arm mass in kg
  _comX [double scalar] ...................... Lower arm center of mass position in local x direction in mm
  _comY [double scalar] ...................... Lower arm center of mass position in local y direction in mm
  _comZ [double scalar] ...................... Lower arm center of mass position in local z direction in mm
  _moiXX [double scalar] .................... Lower arm moment of inertia about local x axis in kg m$^2$
  _moiYY [double scalar] .................... Lower arm moment of inertia about local y axis in kg m$^2$
  _moiZZ [double scalar] .................... Lower arm moment of inertia about local z axis in kg m$^2$
  _poiXY [double scalar] .................... Lower arm product of inertia about local x and y axes in kg m$^2$
  _poiXZ [double scalar] .................... Lower arm product of inertia about local x and z axes in kg m$^2$
  _poiYZ [double scalar] .................... Lower arm product of inertia about local y and z axes in kg m$^2$

_origin [struct]
  _point [string] .................................. Local origin identifier string
  _type [string] .................................. Local origin type string

_relativePosition [struct]
  _xxx_x [double vector] ............... xxx$_x$ marker or joint positions in local coordinates in mm

_pelvis [struct]
  _segmentLengthY [double scalar] .......... Pelvis length along local y axis in mm
  _segmentLengthZ [double scalar] .......... Pelvis length along local z axis in mm
  _mass [double scalar] .......................... Pelvis mass in kg
  _comX [double scalar] ...................... Pelvis center of mass position in local x direction in mm
  _comY [double scalar] ...................... Pelvis center of mass position in local y direction in mm
  _comZ [double scalar] ...................... Pelvis center of mass position in local z direction in mm
  _moiXX [double scalar] .................... Pelvis moment of inertia about local x axis in kg m$^2$
  _moiYY [double scalar] .................... Pelvis moment of inertia about local y axis in kg m$^2$
  _moiZZ [double scalar] .................... Pelvis moment of inertia about local z axis in kg m$^2$
  _poiXY [double scalar] .................... Pelvis product of inertia about local x and y axes in kg m$^2$
  _poiXZ [double scalar] .................... Pelvis product of inertia about local x and z axes in kg m$^2$
  _poiYZ [double scalar] .................... Pelvis product of inertia about local y and z axes in kg m$^2$
<table>
<thead>
<tr>
<th><strong>origin [struct]</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>_point [string]</td>
</tr>
<tr>
<td>_type [string]</td>
</tr>
<tr>
<td><strong>relativePosition [struct]</strong></td>
</tr>
<tr>
<td>_xxx_x [double vector]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>thigh_x [struct]</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>_segmentLengthY [double scalar]</td>
</tr>
<tr>
<td>_mass [double scalar]</td>
</tr>
<tr>
<td>_comX [double scalar]</td>
</tr>
<tr>
<td>_comY [double scalar]</td>
</tr>
<tr>
<td>_comZ [double scalar]</td>
</tr>
<tr>
<td>_moiXX [double scalar]</td>
</tr>
<tr>
<td>_moiYY [double scalar]</td>
</tr>
<tr>
<td>_moiZZ [double scalar]</td>
</tr>
<tr>
<td>_poiXY [double scalar]</td>
</tr>
<tr>
<td>_poiXZ [double scalar]</td>
</tr>
<tr>
<td>_poiYZ [double scalar]</td>
</tr>
<tr>
<td><strong>origin [struct]</strong></td>
</tr>
<tr>
<td>_point [string]</td>
</tr>
<tr>
<td>_type [string]</td>
</tr>
<tr>
<td><strong>relativePosition [struct]</strong></td>
</tr>
<tr>
<td>_xxx_x [double vector]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>shank_x [struct]</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>_segmentLengthY [double scalar]</td>
</tr>
<tr>
<td>_mass [double scalar]</td>
</tr>
<tr>
<td>_comX [double scalar]</td>
</tr>
<tr>
<td>_comY [double scalar]</td>
</tr>
<tr>
<td>_comZ [double scalar]</td>
</tr>
<tr>
<td>_moiXX [double scalar]</td>
</tr>
<tr>
<td>_moiYY [double scalar]</td>
</tr>
<tr>
<td>_moiZZ [double scalar]</td>
</tr>
<tr>
<td>_poiXY [double scalar]</td>
</tr>
<tr>
<td>_poiXZ [double scalar]</td>
</tr>
<tr>
<td>_poiYZ [double scalar]</td>
</tr>
<tr>
<td><strong>origin [struct]</strong></td>
</tr>
<tr>
<td>_point [string]</td>
</tr>
</tbody>
</table>
The measurement equipment consisted of reflective markers of the motion capture system and electrodes, wires and two switching boxes of the electromyographical measurement system. The mass of the reflective markers is neglectable small in relation to the components of the electromyographical measurement system. The switching boxes and wire connectors were placed about 50 mm inferior and 50 mm lateral of the respective PSIS<sub>x</sub> markers.

Processed data (#.mat)

```matlab
meta (struct)
  subject (string) .................................................. Subject identifier string
  experiment (string) ............................................. Measurement identifier string
```
date [string] .......................................................... Measurement date string
duration [double scalar] ........................................... Total duration in s
startTime [double scalar] ....................................... Motion task start time in s
endTime [double scalar] ........................................... Motion task end time in Hz
author [string] ....................................................... Author string
license [string] ...................................................... License string
version [string] ...................................................... Version number string

motion [struct]
  frameRate [integer scalar] ...................................... Frame rate in Hz
  frames [integer scalar] ......................................... Total frame number \( f_{mo} \)
  markerSize [double scalar] ..................................... Marker diameter in mm
  markerX [double matrix] \( r \times f_{mo} \) matrix of reflective marker positions in global x coordinates in mm
  markerY [double matrix] \( r \times f_{mo} \) matrix of reflective marker positions in global y coordinates in mm
  markerZ [double matrix] \( r \times f_{mo} \) matrix of reflective marker positions in global z coordinates in mm
  markerE [double matrix] \( r \times f_{mo} \) matrix of reflective marker residuals in mm
  markerLabels [cell array] ....................................... \( 1 \times r \) array of reflective marker labels

jointX [struct]
  estimated [double matrix] \( j_e \times f_{mo} \) matrix of estimated joint positions in global x coordinates in mm
  smoothed [double matrix] \( j_s \times f_{mo} \) matrix of smoothed joint positions in global x coordinates in mm

jointY [struct]
  estimated [double matrix] \( j_e \times f_{mo} \) matrix of estimated joint positions in global y coordinates in mm
  smoothed [double matrix] \( j_s \times f_{mo} \) matrix of smoothed joint positions in global y coordinates in mm

jointZ [struct]
  estimated [double matrix] \( j_e \times f_{mo} \) matrix of estimated joint positions in global z coordinates in mm
  smoothed [double matrix] \( j_s \times f_{mo} \) matrix of smoothed joint positions in global z coordinates in mm

jointLabels [struct]
  estimated [cell array] ........................................... \( 1 \times j_e \) array of joint labels for estimated joint positions
  smoothed [cell array] .......................................... \( 1 \times j_s \) array of joint labels for smoothed joint positions

surfaceX [double matrix] \( s \times f_{mo} \) matrix of surface marker positions in global x coordinates in mm
surfaceY [double matrix] \( s \times f_{mo} \) matrix of surface marker positions in global y coordinates in mm
surfaceZ [double matrix] \( s \times f_{mo} \) matrix of surface marker positions in global z coordinates in mm
surfaceLabels [double matrix] .................................. \( 1 \times s \) array of surface marker labels

trajectory [struct]
  q [double matrix] ............................................. \( j_e \times f_{mo} \) matrix of smoothed joint positions in mm and rad
  dqdt [double matrix] ......................................... \( j_s \times f_{mo} \) matrix of smoothed joint velocities in mm s\(^{-1}\) and rad s\(^{-2}\)
  ddqddt [double matrix] ..................................... \( j_s \times f_{mo} \) matrix of smoothed joint accelerations in mm s\(^{-2}\) and rad s\(^{-2}\)
_trajectoryLabels [cell array] ........................................... 1×j, array of joint labels
_subjectVelocity [double vector] .......... Subject velocity at the midpoint of the ASIS markers in m/s
_clothThickness [double scalar] ........................................... Cloth thickness in mm
_supportThickness [double scalar] ...................................... Cardboard thickness in mm

_force [struct]
  _frameRate [integer scalar] ................................. Frame rate in Hz
  _frames [integer scalar] ............................................ Total frame number f_fo
  _grfX [double vector] ............ 1×f_fo vector of total ground reaction forces in global x direction in N
  _grfX_x [double vector] ........ 1×f_fo vector of separated ground reaction forces in global x direction in N
  _grfY [double vector] ............ 1×f_fo vector of total ground reaction forces in global y direction in N
  _grfY_x [double vector] ........ 1×f_fo vector of separated ground reaction forces in global y direction in N
  _grfZ [double vector] ............. 1×f_fo vector of total ground reaction forces in global z direction in N
  _grfZ_x [double vector] ........ 1×f_fo vector of separated ground reaction forces in global z direction in N
  _copX_x [double vector] .......... 1×f_fo vector of center of pressure positions in global x coordinates in mm
  _copY_x [double vector] .......... 1×f_fo vector of center of pressure positions in global y coordinates in mm
  _copZ_x [double vector] .......... 1×f_fo vector of center of pressure positions in global z coordinates in mm
  _forceSensorX [double vector] .......... 1×f_fo vector of force sensor data in global x direction in N
  _forceSensorY_xx [double vector] .......... 1×f_fo vector of force sensor data in global y direction in N
  _forceSensorZx [double vector] .......... 1×f_fo vector of force sensor data in global z direction in N
  _treadmillVelocity [double vector] .......... f_fo×1 vector of treadmill velocities in m/s

_muscle [struct]
  _activities [struct]
    _filteredActivities [double matrix] .......... m×f_mu matrix of filtered muscle activities in V
    _normalizedActivities [double matrix] .... m×f_mu matrix of normalized muscle activities in V
    _filterAlgorithm [string] ................................. Filter algorithm string
    _filterWindowSize [integer scalar] ................. Filter window size
  _frameRate [integer scalar] ................................. Frame rate in Hz
  _frames [integer scalar] ............................................ Total frame number f_fo
  _maximumValues [double vector] ........ 1×m vector of maximum activities used in normalization in V
  _minimumValues [double vector] ........ 1×m vector of minimum activities used in normalization in V
  _muscleLabels [cell array] ..................................... 1×m array of muscle labels

_events [struct]
  _eventStart_x [double vector] ......................... 1×e vector of event start times in s
  _eventEnd_x [double vector] ................................. 1×e vector of event end times in s
  _contactPhase_x [boolean vector] ........ 1×f_fo vector of booleans indicating ground contact
grfCorrection_x [boolean vector] 1x1 vector of booleans indicating ground reaction force correction
copCorrection_x [boolean vector] 1x1 vector of booleans indicating center of pressure correction

ground [struct]
  groundPosition [double vector] Global origin in global coordinates in mm
  groundNormal [double vector] Ground normal in global coordinates in mm
  translationMotion2Force [double vector] 1x3 translation vector in mm
  rotationMotion2Force [double matrix] 3x3 rotation matrix
  sensorLabels [cell array] 1xN array of force sensor labels
  sensorX [double vector] N×1 vector of force sensor positions in global x coordinates in mm
  sensorY [double vector] N×1 vector of force sensor positions in global y coordinates in mm
  sensorZ [double vector] N×1 vector of force sensor positions in global z coordinates in mm

Raw motion data (#-RawMotion.mat)

meta [struct]
  subject [string] Subject identifier string
  experiment [string] Measurement identifier string
  date [string] Measurement date string
  duration [double scalar] Total duration in s
  startTime [double scalar] Motion task start time in s
  endTime [double scalar] Motion task end time in Hz
  author [string] Author string
  license [string] License string
  version [string] Version number string

Motion_x [struct]
  File [string] Filename string
  Timestamp [string] Timestamp string
  FrameRate [integer scalar] Frame rate in Hz
  Frames [integer scalar] Total frame number f_{rmo}
  StartFrame [integer scalar] Start frame number
  Trajectories [struct]
    Labeled [struct]
      Count [integer scalar] Number of labeled markers l
      Labels [cell array] 1x1 array of labeled markers
      Data [double matrix] l×4×f_{rmo} matrix of labeled marker positions’ and residuals in mm
    Unidentified [struct]
      Count [integer scalar] Number of unidentified trajectories u

Data [double matrix] \( u \times 4 \times f_{rmo} \) matrix of unidentified trajectories and residuals in mm

Discarded [struct]

Count [integer scalar] Number of discarded trajectories \( d \)

Data [double matrix] \( d \times 4 \times f_{rmo} \) matrix of discarded trajectories and residuals in mm

* The local reference frame of the raw marker and trajectory coordinates differs from the global reference frame applied in the HuMoD Database.

Raw muscle data (#-RawMotion.mat)

meta [struct]

subject [string] Subject identifier string

experiment [string] Measurement identifier string

date [string] Measurement date string

duration [double scalar] Total duration in s

startTime [double scalar] Motion task start time in s

endTime [double scalar] Motion task end time in Hz

author [string] Author string

license [string] License string

version [string] Version number string

fs [integer scalar] Frame rate in Hz

cnt [integer scalar] Number of used channels \( c \)

lbl [cell array] 1x\( c \) array of channel labels

xxx_x [double vector] \( x \)-muscle activities in V

header [struct] Supplemental information

Raw force data (#-RawMotion.mat)

meta [struct]

subject [string] Subject identifier string

experiment [string] Measurement identifier string

date [string] Measurement date string

duration [double scalar] Total duration in s

startTime [double scalar] Motion task start time in s

endTime [double scalar] Motion task end time in Hz

author [string] Author string

license [string] License string

version [string] Version number string

fs [integer scalar] Frame rate in Hz
<table>
<thead>
<tr>
<th>cnt [integer scalar]</th>
<th>Number of measured values ( v )</th>
</tr>
</thead>
<tbody>
<tr>
<td>t [double scalar]</td>
<td>Measurement end time in s</td>
</tr>
<tr>
<td>lbl [cell array]</td>
<td>( 1 \times v ) array of value labels</td>
</tr>
<tr>
<td>Sgnl [cell array]</td>
<td>( 1 \times v ) array of value labels</td>
</tr>
<tr>
<td>vB [double vector]</td>
<td>( w \times 1 ) vector of unfiltered treadmill velocities in ( \frac{m}{s} )</td>
</tr>
<tr>
<td>vBden [double vector]</td>
<td>( w \times 1 ) vector of filtered treadmill velocities in ( \frac{m}{s} )</td>
</tr>
<tr>
<td>Fx [double vector]</td>
<td>( w \times 1 ) vector of total ground reaction forces in local x direction* in N</td>
</tr>
<tr>
<td>Fxx [double vector]</td>
<td>( w \times 1 ) vector of separate ground reaction forces in local x direction* in N</td>
</tr>
<tr>
<td>Fy [double vector]</td>
<td>( w \times 1 ) vector of total ground reaction forces in local y direction* in N</td>
</tr>
<tr>
<td>Fyx [double vector]</td>
<td>( w \times 1 ) vector of separate ground reaction forces in local y direction* in N</td>
</tr>
<tr>
<td>Fz [double vector]</td>
<td>( w \times 1 ) vector of total ground reaction forces in local z direction* in N</td>
</tr>
<tr>
<td>Fzz [double vector]</td>
<td>( w \times 1 ) vector of separate ground reaction forces in local z direction* in N</td>
</tr>
</tbody>
</table>

* The local reference frame of the raw ground reaction forces is the original reference frame used by the manufacturer (Tecmachine, France) and differs from the global reference frame applied in the HuMoD Database.

**Ground reference** *(GroundReference.mat)*

<table>
<thead>
<tr>
<th>meta [struct]</th>
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<tbody>
<tr>
<td>subject [string]</td>
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<td>experiment [string]</td>
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<td>duration [double scalar]</td>
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<table>
<thead>
<tr>
<th>motion [struct]</th>
</tr>
</thead>
<tbody>
<tr>
<td>frameRate [integer scalar]</td>
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<tr>
<td>frames [integer scalar]</td>
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<tr>
<td>markerLabels [cell array]</td>
</tr>
<tr>
<td>markerX [double matrix]</td>
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<td>markerY [double matrix]</td>
</tr>
<tr>
<td>markerZ [double matrix]</td>
</tr>
<tr>
<td>markerE [double matrix]</td>
</tr>
</tbody>
</table>

**F References**


