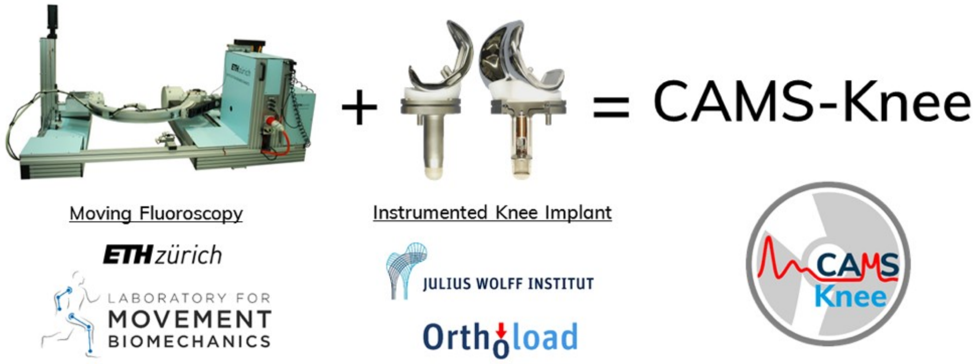
Description of the CAMS-Knee 'Stan' dataset

Version 1.0



General notes

This document supplements the CAMS-Knee database description document and the publication

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The purpose of this document is solely to describe the format 'Stan's' data is delivered in.

For a description of 'Stan', the underlying rationale, and methods, please refer to the publication referenced above (hereafter named 'Stan paper'). Also note the supplementary material associated with the Stan paper, which contains the CAMS-EXTREME100 loads and kinematics.

For a description of the CAMS-Knee dataset, the associated measurements, coordinate systems, files, etc., please refer to the document 'Description of the complete CAMS-Knee datasets' (hereafter named 'CAMS documentation').

Coordinate systems

In the CAMS documentation, two different coordinate systems have been used for the tibial and femoral implants: CS_{JWI} and CS_{LMB}. For Stan, only the CS_{JWI} coordinate systems are used.

To this end, all kinematic and kinetic data were converted into the same CS_{JWI} coordinate systems for a right-sided knee, a size M10 inlay and a size M+ femoral component. Loads are expressed in the tibial CS_{JWI} inlay coordinate system, which is consistent with the original CAMS-Knee dataset.

Structure of the Database

The Stan data fits into the database structure described in the CAMS documentation, but contains only a subset of the folders:

1. Processed data

All the processed kinematic and kinetic are presented according to activity (**task**). For example, 'CamsKneeData\Stan_aver\level_walking\' contains all the data related to level walking for Stan, while 'CamsKneeData\Stan_aver\squat\' comprises all the data for squat trials. The directory for processed data for Stan includes only the 'export_proc' folder:

1.1. export_proc

All the processed data are reported in 'CamsKneeData\Stan_aver**task**\export_proc\', in .csv format. Note that the content of this file slightly differs from the original CAMS-Knee datasets. It includes the following data:

- ***Load factors***
  - High- and peak-load-factors F_H and F_P as described in the Stan paper.

- ***Gait events***
  - Heel-strike and toe-off events during the motion cycle, where time is normalized to the motion cycle duration.

- ***Normalized time***
  - starting from 0 and ending at 1.

- ***In-vivo joint loads***
  - This is the loads data reported in the plots of the Stan paper
  - All force data was synchronised with the motion data
  - **F_x, F_y, F_z, and F_{res}**; three components and the resultant contact force (normalized to bodyweight) measured by the instrumented implant and reported in CS_{JWI_TIB} as described by Kutzner et al. 2010.
  - **M_x, M_y, M_z, and M_{res}**; three components and the resultant contact moment (normalized to bodyweight*m) measured by the instrumented implant and reported in CS_{JWI_TIB} as described by Kutzner et al. 2010.

- ***Joint translations and rotations according to Grood and Suntay (1983)***

- The following components are included:

Component	Description
tibial_abduction	+ abduction / - adduction of tibia. Rotation about the floating, e2, axis of Grood and Suntay.
tibial_ext_rotation	+ external / - internal rotation of tibia. Rotation about the tibial-fixed axis
knee_flexion	+ flexion / - extension of knee. Rotation about the femoral-fixed axis.
tibial_lat_translation	+ lateral / - medial tibial displacement. Medial-lateral displacement of the tibial origin with respect to the femoral origin.
tibial_ant_translation	+ anterior / - posterior tibial drawer displacement. Displacement of the tibial origin along the floating, e2, axis of Grood and Suntay (which points anteriorly).
femoral_prox_translation	+ distraction / - compression of joint. Height of the femoral origin above the tibial transverse plane.

- Offset: As described in the Stan paper supplementary materials, the tibial and femoral coordinate system origins are not coincident. In the reference position, this would produce nonzero values for tibial_ant_translation (8.26 mm) and femoral_prox_translation (19.54 mm). Consequently, these values were subtracted from the data before it was reported here and in the Stan paper. The kinematics presented here therefore present the deviation from the reference position described in the Stan paper supplementary material.
- This is the kinematics data reported in the plots of the Stan paper. It was calculated according to Grood and Suntay (1983) based on the transformation matrix of the femoral component w.r.t the tibial component in CS_{JWI} described below.
  Note that:
  1. These kinematics do **<u>not</u>** correspond to simple Euler angles and translations that can be extracted from the tibiofemoral transformation matrices.
  2. The CS_{JWI} coordinate systems and axes are implant-based. To define the joint kinematics in an anatomical coordinate system, the tibiofemoral transformation matrices described below should be shifted to physiological axes based on anatomical landmarks and the Grood and Suntay joint translations and rotations should be recalculated from that. If that is not feasible, the joint kinematics described above may be used for convenience. At the very least, however, the flexion angle should be shifted by Stan's posterior tibial slope given in the Stan paper.

- **Transformation matrix of the femoral component w.r.t the tibial component**

- $T_{11\_JWIfem\_JWItib}$ ... $T_{44\_JWIfem\_JWItib}$; the sixteen elements of a 4x4 transformation matrix describe the translation and rotation from the tibial component $CS_{JWI,tib}$ into the femoral $CS_{JWI,fem}$:

$$T_{JWI,fem \to JWI,tib} = \begin{bmatrix} T_{11\_\mathrm{JWIfem\_JWItib}} & \cdots & T_{14\_\mathrm{JWIfem\_JWItib}} \\ \vdots & \ddots & \vdots \\ T_{41\_\mathrm{JWIfem\_JWItib}} & \cdots & T_{44\_\mathrm{JWIfem\_JWItib}} \end{bmatrix}$$

The tibial coordinate system is the base. The columns of the 3x3 rotation matrix are the unit vectors of the femoral frame expressed in the tibial frame. The translation vector is the coordinates of the femoral origin expressed in the tibial frame.

References:

Dreyer, M.J., et al. "European Society of Biomechanics S.M. Perren Award 2022: Standardized tibio-femoral implant loads and kinematics." *Journal of Biomechanics* 141 (2022): 111171.

Grood, E.S. and Suntay, W.J. "A Joint Coordinate System for the Clinical Description of Three-Dimensional Motions: Application to the Knee." *Journal of Biomechanical Engineering* 105.2 (1983): 136-144.

Kutzner, I., et al. "Loading of the knee joint during activities of daily living measured in vivo in five subjects." *Journal of biomechanics* 43.11 (2010): 2164-2173.

Taylor, W.R., et al. "A Comprehensive Assessment of the Musculoskeletal System: The CAMS-Knee Data Set. Journal of Biomechanics (2017), pre-print: DOI: 10.1016/j.jbiomech.2017.09.022

Terms and conditions:

1. The data may be used only for scientific purposes without any commercial benefit
2. The data may be used only at the registered institute or facility and may not be passed on to third parties
3. In any scientific publication (e.g. journals, conference abstracts, poster, or oral presentation) reporting use of the data, the CAMS-Knee database must be cited as follows: CAMS-Knee (2017): 'filename', retrieved from https://CAMS-Knee.orthoload.com, 'Date of access (day, month, and year)'

and

Taylor W.R., Schütz P., Bergmann G., List R., Postolka B., Hitz M., Dymke J., Damm P., Duda G.,Gerber H., Schwachmeyer V., Hamed Hosseini Nasab S., Trepczynski A., Kutzner I.; "A Comprehensive Assessment of the Musculoskeletal System: The CAMS-Knee Data Set"; Journal of Biomechanics 2017; http://dx.doi.org/10.1016/j.jbiomech.2017.09.022; https://cams-knee.orthoload.com

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Contact:

A user forum has been created on the SLACK platform (www.slack.com) with a workspace-URL at https://cams-knee.slack.com. Please feel free to join in discussions, propose changes, add information or associated models, or ask questions.

For questions regarding possible collaborations or sponsorship: contact@cams-knee.orthoload.com

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Supplementary Material: Coordinate Systems and Transformations in the Stan Dataset

Nomenclature, Transformation Definitions, CAMS-Knee Coordinate Systems, Transformations

Please see CAMS documentation.

CAMS-Knee Examples

Ex1: Find the relative tibio-femoral kinematics transforms for a single trial from the original CAMS-Knee dataset.

We start with the data given in the original CAMS-Knee dataset:

$\boldsymbol{T}_{LMB,fem\rightarrow LAB}$ = Transformation matrix of the femoral component from the CAMS dataset

$\boldsymbol{T}_{LMB,tib\rightarrow LAB}$ = Transformation matrix of the tibial component from the CAMS dataset

$\boldsymbol{T}_{LAB\rightarrow LMB,tib} = \boldsymbol{T}_{LMB,tib\rightarrow LAB}{}^{-1}$

We then find the tibio-femoral transform in CS_{LMB} relative to the tibia, i.e. we calculate $\boldsymbol{T}_{LMB,fem\rightarrow LMB,tib}$:

$$\boldsymbol{T}_{LMB,fem\rightarrow LMB,tib} = \boldsymbol{T}_{LAB\rightarrow LMB,tib}\boldsymbol{T}_{LMB,fem\rightarrow LAB}$$

Ex2: Find Stan's relative tibio-femoral kinematics in expressed in the LMB coordinate systems CS_{LMB}.

We start with $T_{JWI,fem\rightarrow JWI,tib}$, which is given as part of the Stan dataset. We also need the transformations $\boldsymbol{T}_{JWI,tib\rightarrow LMB,tib}$ for the tibia and $\boldsymbol{T}_{JWI,fem\rightarrow LMB,fem}$ for the femur, which are constant and can be found in Table 3 of the CAMS documentation:

$$\boldsymbol{T}_{JWI,tib\rightarrow LMB,tib} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 72.1100 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\boldsymbol{T}_{JWI,fem\rightarrow LMB,fem} = \begin{bmatrix} 0 & -1 & 0 & 2.3724 \\ 0 & 0 & 1 & -0.4520 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

We can now express the tibio-femoral kinematics in the CS_{LMB} reference frames as follows:

$$\boldsymbol{T}_{LMB,fem\rightarrow LMB,tib} = \boldsymbol{T}_{JWI,tib\rightarrow LMB,tib}\boldsymbol{T}_{JWI,fem\rightarrow JWI,tib}\boldsymbol{T}_{LMB,fem\rightarrow JWI,fem}$$

Where $\boldsymbol{T}_{LMB,fem\rightarrow JWI,fem} = \boldsymbol{T}_{JWI,fem\rightarrow LMB,fem}{}^{-1}$.

The same procedure can be used to transform Stan's kinematics into any other coordinate systems if you have the transformations from CS_{JWI} to the new coordinate systems.