Accessing the database from Python

The simplest way to utilize this database is to access it from the associated Python code. The code implements the spatial and temporal syncing described below. Anaconda must be installed beforehand to setup the environment necessary for the associated Python code.

1. `cd code`
2. `conda env create --file environment.yml`
3. `conda activate kinematics-db`
4. `python -m test_db`

The `demo_notebook.ipynb` notebook showcases how to utilize the included code/framework to perform custom transformations and analyses. The simplest way to run this notebook is to install `jupyter` and `numpy-stl` in the environment created above via `pip install jupyter numpy-stl`. Then (with the environment still active) run the `jupyter notebook` command, and browse to `demo_notebook.ipynb`.

Subjects

Each subject has the following naming scheme: `{O45 | U35}_{Ordinal}_{F | M}_{Age}_{R | L}`.

- O45 or U35 indicates whether the subject is in the over 45 or under 35 age group.
- Ordinal is a number from 1-10 indicating the subject's identifier within an age group.
- F for Female and M for Male indicates the subject's gender.
- Age indicates the subject's age.
- R for Right and L for Left indicates the subject's dominant arm. This particular study only recruited right hand dominant subjects.

For each subject coronal plane abduction (**CA**), scapula plane abduction (**SA**), forward elevation (**FE**), external/internal rotation in 90° of abduction (**ERa90**), and internal/external rotation in adduction (**ERaR**) trial motion files are provided.

Trial Files

For each trial, the kinematic trajectories of the humerus (`_humerus_biplane.csv`), scapula (`_scapula_biplane.csv`), and torso (`_torso.csv`) are provided. The kinematic trajectories of the humerus and scapula are derived from biplane fluoroscopy recordings, therefore are expressed in the biplane fluoroscopy reference frame. The kinematic trajectory of the torso is derived from skin-marker recordings therefore it is expressed in the Vicon reference frame. Each kinematic trajectory is specified by its position (`pos_x`, `pos_y`, `pos_z`) and a scalar-first quaternion (`quat_w`, `quat_x`, `quat_y`, `quat_z`). The coordinate system of the humerus, scapula, and torso were established according to standards set forth by the International Society of Biomechanics (https://pubmed.ncbi.nlm.nih.gov/15844264/) with the exception that the glenoid center specifies the origin and lateral direction of the scapula.

Additional Trial Files

The `_humerus_biplane_avgSmooth.csv` and `_scapula_biplane_avgSmooth.csv` files contain humerus and scapula (respectively) kinematic trajectories that have been smoothed using a 9-frame average smoothing algorithm (see Averaging Quaternions). The `_torso_v3d.csv` file contains torso kinematics where the torso coordinate system has been established according to an alternative definition that accounts for the position of the greater trochanters. See the `code/torso_cs_v3d.py` file for a code implementation of this definition.

Time Syncing

For the humerus and scapula trajectories associated capture frame numbers are provided in the `frame` column. For the torso, capture frame numbers implicitly start at 1 and increase monotonically. The `_vicon_endpts.csv` file specifies the temporal syncing between biplane fluoroscopy and Vicon. The `startFrame` parameter specifies the frame number in the torso trajectory that corresponds to frame 1 of the humerus and scapula trajectory. The `stopFrame` parameter specifies the frame number in the torso trajectory that corresponds to the last frame of the humerus and scapula trajectory. Note that some humerus and scapula trajectories start at a frame number other than 1, so the torso trajectory must be further cropped to account for this. Assuming that 0-based stop-index exclusive indexing (Python-style) is utilized then to crop the torso trajectory so it conforms to a humerus trajectory:

```
torso[startFrame-1:stopFrame][humerus.frame-1]
```

Spatial Syncing

For each subject, under its `Static` directory the `_F_T_V.csv` file contains the rigid body transformation (scalar-first quaternion and translation) between the Vicon and biplane fluoroscopy coordinate system. Given a vector in the Vicon coordinate system ${}^{V}v$, and a homogeneous transformation created from the `_F_T_V.csv` file, ${}^{BF}T_V$, then the corresponding vector in the biplane fluoroscopy coordinate system can be computed as: ${}^{BF}v = {}^{BF}T_V \cdot {}^{V}v$.

STL files and anatomical landmarks

For each subject, under its `Static` directory, the smoothed humerus and scapula 3D models (derived from a CT scan) are provided in `_Humerus_smooth.stl` and `_Scapula_smooth.stl`. For the humerus, the position of the humeral head center (**HHC**), lateral epicondyle (**LE**), and medial epicondyle (**ME**) are provided in `_humerus_landmarks.csv`. For the scapula, the position of the glenoid center (**GC**), inferior angle (**IA**), trigonum spinae (**TS**), posterior lateral acromion (**PLA**, also known as acromial angle), and acromioclavicular joint (**AC**) are provided in `_scapula_landmarks.csv`. Note that the mesh points within each STL and the humerus/scapula landmarks - utilized to establish anatomical coordinate systems - are all expressed in the same underlying CT scanner coordinate system. Finally, the CT scanner coordinate system can vary by subject. To ease the use of computational modeling tools, such as OpenSim, an additional set of STL files ending in `_anatomical_cs.stl` have been created. For these STL files, the mesh points have been expressed in the humerus/scapula anatomical CS (see **Trial Files** above for CS definitions).

Subject Anthropometrics

Subject anthropometrics are contained in the `Subject_Anthropometrics.csv` file. Height is expressed in cm, weight in kg, armpit thickness in mm, and hand thickness in mm.