HFValid collection

General information

Data Set Title: "HFValid collection: Hip-Fracture validation collection".

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Dataset description

The HFValid dataset is composed of 101 anonymized calibrated CT scans of whole femurs, the corresponding segmentations, and selected anatomical landmarks. In the `Subjects\` folder one folder for each subject (`Subjects\PatXXX`) is available, containing the CT scan (`Subjects\PatXXX\PatXXX.nrrd`), the segmentation (`Subjects\PatXXX\PatXXX.stl`), and the anatomical landmarks coordinates file (`Subjects\PatXXX\PatXXX_palp.inp`). The CT scans were collected at Rizzoli Orthopaedic Institute (IOR) from 1999 to 2016 for surgical planning of hip arthroplasty at the contralateral femur.

All the necessary Ethical committee authorisation documents have been obtained and are available (in Italian) upon request.

Inclusion and exclusion criteria

The criteria for the CT scans selection were the following:

- Female biological sex
- Age over 55 years

- Resident in the Emilia Romagna region (required to follow-up occurrence of fractures)
- Alive for at least 5 years after the CT scan, or fractured within 5 years
- No autoimmune (e.g., rheumatoid arthritis) or metastatic pathologies
- No prosthetic implants or metal artifacts
- No hip deformities in the modelled side

Images calibration

The CT scans were asynchronously calibrated by using a set of European Spine Phantom (ESP) CT scans collected at IOR, choosing for each subject the phantom scanned with the most similar acquisition parameters. A descriptive file containing detailed information about the Phantom can be found at the following link.

A total of seven different scans of the phantom were used to calibrate the CT images. The CT acquisition parameters for each scan are reported in the file `CTcalibrationPhantom\PhantomScans.csv`, where also the coefficients of the corresponding calibration line are reported according to the following relation: *Density* (mg/cm3) = $a + b * HU$.

In addition, means and standard deviations of Hounsfield Unit values of the three spongious inserts and the two cortical segments of each ESP scan are provided in a dedicated CSV file (`CTcalibrationPhantom\ScanJ_HU.csv`, J referring to the J-th scan).

Data management and workflow

The original CT scans were interpolated using Matlab (release R2019b, The Mathworks Inc) in order to have uniform spacing between slices, and were successively anonymised using Synedra View Personal (version 19.0.0.3, Synedra Information Technologies GmbH); eventually, residual identifying fields in the DICOM files were removed or overwritten with a custom Matlab script. As a result, in the date fields, the only reliable information was the year, while months and days were set to the 1st of July for all the records. Also, all the time fields of the study were set to 15:00:00.

Only one of the two femurs (right or left) was selected as the side of interest to be analysed. For the fractured subjects, the chosen side was the one where the fracture would occur; for the non-fractured subjects the healthiest-looking side was chosen. The HFValid dataset is composed of subjects who were CT scanned prior to a total hip replacement arthroplasty, which explains why one of the two femurs was commonly found to be in worse conditions. The full CT scans were cropped and saved in NRRD file format with a custom Python script. The CT scans are made available in the NRRD format.

Subsequently, the CT scans were segmented with a homemade semiautomatic tool, and the resulting segmentation was inspected and manually corrected with the open-source software 3DSlicer (version 4.11.20210226, Slicer Community). The final segmentations were exported as STL files.

Some anatomical landmarks were identified from the CT scans, namely: femur head centre, rear distal epicondyles, and knee rotation centre (calculated as the mean point between the furthest points of the distal epicondyles in the mediolateral direction). These anatomical points were employed to define a standardised local reference system in the Finite Element (FE) analyses. In particular, the origin of the local reference system is positioned at the head centre, the X-axis direction is along the line joining the femur head centre and knee rotation centre, pointing towards the subject's head, and

the Y-axis is pointing towards the greater trochanter, parallel to the line joining the two rear distal epicondyles (orthogonalised with respect to the X-axis); Z-axis direction automatically descends as cross product between X- and Y-axes.

A FE model of each femur was developed. Starting from the STL geometry, a 10-nodes tetrahedral mesh (2 mm edge size, Octree algorithm) was obtained with Ansys ICEM CFD (release 2019R3, Ansys Inc), and material properties were assigned elementwise with Bonemat (build 152, developed by Bioengineering and Computing Laboratory of IOR) [Taddei2007]. Each FE model was simulated 28 times with different load and boundary condition orientations and, for each simulation, the critical load that would cause a fracture was calculated; the minimum critical load over the 28 orientations is referred to as the *Minimum Sidefall Strength* (MSF) [Altai2019]. The FE model was also coupled with a multiscale falling model to estimate the *Absolute Risk of Fracture at time 0* (ARF0), as reported in [Bhattacharya2019]. Some results of the above-mentioned subject-specific FE simulations are also reported for each femur, namely Minimum Sidefall Strength (MSF) and Absolute Risk of Fracture at time 0 (ARF0). Together with the MSF also the corresponding intra-extra rotation and add-abduction angles are reported.

Data formats

For each subject (`Subjects\PatXXX\`) the following data are given, using the specified formats:

- CT scans: NRRD file (`Subjects\PatXXX\PatXXX.nrrd`) containing the volume of the modelled femur (right or left) as indicated in `HFValid_Metadata.csv` file.
- Segmentation: binary STL file (`Subjects\PatXXX\PatXXX.stl`)
- Anatomical landmarks: TXT file (`Subjects\PatXXX\PatXXX_palp.inp`) with the X, Y, and Z coordinates of the landmarks (in the CT reference system) necessary to build the standard local reference system. The coordinates are given for: femurHead (origin), headDir (X axis direction), greatTroch (Y axis direction, to be orthogonalised), and kneeCentre (hinge location).

A CSV file with subject cohort data (`HFValid_Metadata.csv`) is also provided besides the dataset. For each subject, the file reports the following data:

- Subject's ID from 1 to 101
- Subject's sex
- Subject's year of birth
- Subject's age at the time of the CT scan
- Subject's height (in cm)
- Subject's weight (in kg)
- Modelled femur side (R: Right; L: Left)
- Subject's fracture status (0: Non-ractured; 1: Fractured)
- Time interval (in days) between the CT scan and the fracture (only for fractured subjects)
- Subject's ARF0 (in %)
- Subject's MSF (in N)
- Intra-extra rotation where the MSF was identified, expressed as Intra XX or Extra XX (XX being the angle in degrees)
- Abduction angle where the MSF was identified (in degrees)
- Calibration coefficients a & b to obtain the radiological density from the HU as *Density* (mg/cm3) = $a + b * HU$

In addition, also some details about the subject's CT scans are reported:

- Pixel spacing (in mm)
- Spacing between slices (in mm)
- Slice thickness (in mm)
- KVP (in kV)
- X-ray tube current (in mA)
- CT scanner manufacturer
- CT scanner model

Licensing