HoBiS Human Model

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1 Introduction

MM: regular landmark
MM: inferred landmark (e.g. IM midway between MM & LM)
ST (=MM): same landmark, different papers
We only specify landmarks for one side. In reality, we add an additional R (right) or L (left) prior to the name (RMM . . .)

2 Requirements per Segment

- Several markers necessary to build the frames associated to the anatomical segment (list of markers and frame building later in the document). - Segment mass (in kg ideally) - Segment center of mass (position in the local frame, or in percent of local segment length (proximal to distal) for instance (anything goes really, as long as its mentioned and consistent)). -

3 Landmarks / Markers

3.1 ISB I – Pelvis Hip Knee

Tibia / Ankle:
MM: Tip of the medial malleolus.
LM: Tip of the lateral malleolus.
MC: The most medial point on the border of the medial tibial condyle.
LC: The most lateral point on the border of the lateral tibial condyle.
TT: Tibial tuberosity.
IM: The inter-malleolar point located midway between MM and LM.
IC: The inter-condylar point located midway between the MC and LC.

Pelvis:
ASIS: anterior superior iliac spine (Nomina anatomica: Spina iliaca anterior superior).
mASIS : middle of the **ASIS**

PSIS: posterior superior iliac spine (Spina iliaca posterior superior).
mPSIS : middle of the **PSIS**

Femur:
FEm: femoral epicondyle (Epicondylus femoris medialis)
FEl: femoral epicondyle (Epicondylus femoris lateralis).
(**HRC**: Hip rotation center if estimated, otherwise found using approximation methods)
mFE : middle of the **FEs**
mL : midway point between ***mFE*** and ***IC***

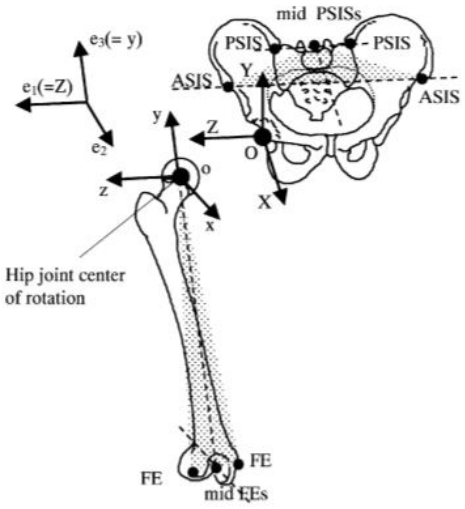

Figure 1: Pelvis and Femur according to [2]

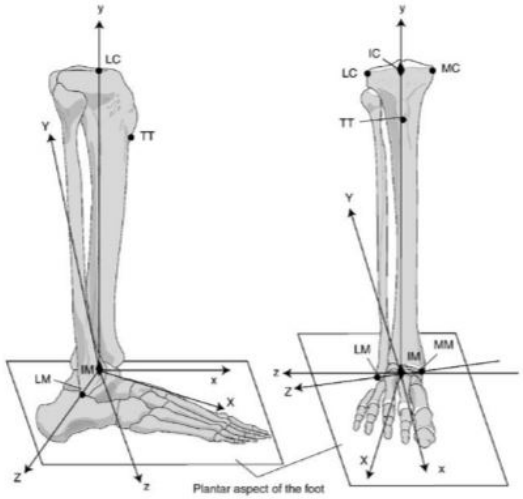

Figure 2: Tibia and ankle according to [2]

3.2 ISB II – Shoulders Elbow

Thorax:
C7: Processus Spinosus (spinous process) of the 7th cervical vertebra
T8: Processus Spinosus (spinal process) of the 8th thoracic vertebra
IJ: Deepest point of Incisura Jugularis (suprasternal notch)

Humerus:
GH: Glenohumeral rotation center (estimated by regression or motion recordings)
EL: Most caudal point on lateral epicondyle
EM: Most caudal point on medial epicondyle
ME : Mid-point between **EL** and **EM**

Forearm:
RS: Most caudal–lateral point on the radial styloid
US: Most caudal–medial point on the ulnar styloid

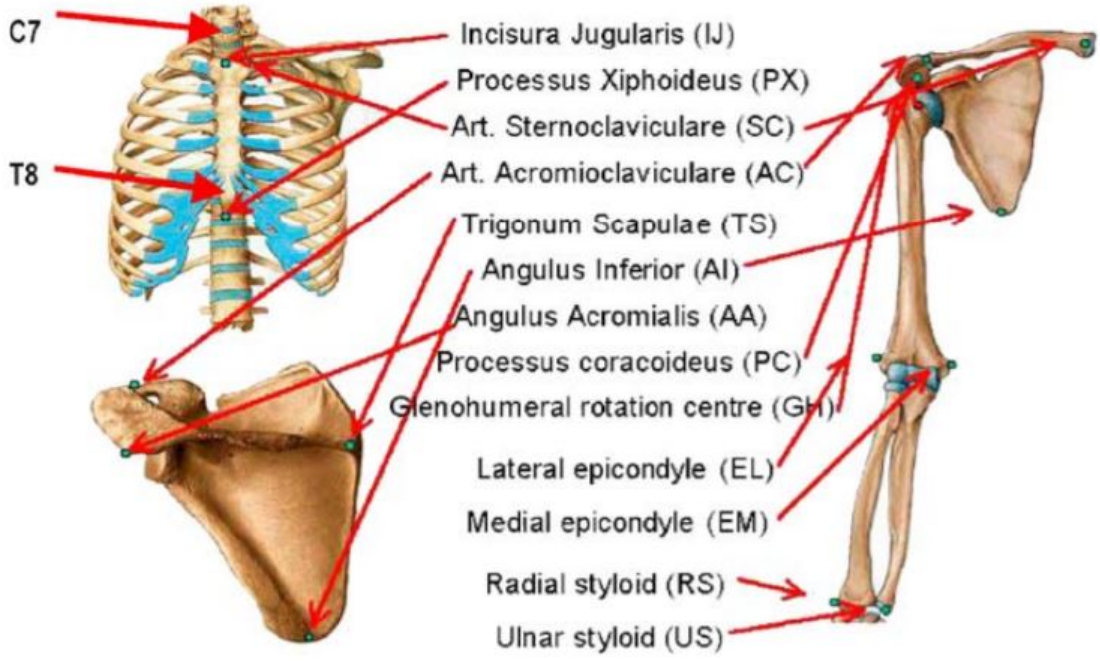

Figure 3: Arm and shoulder complex [3]

3.3 - Leardini 2007 [1] - Foot

PM: most distal and dorsal point of the head of the proximal phalanx of the hallux.

Metatarsus (Met):
FMB: base of the first metatarsal, dorso-medial aspect of the first metatarso-cuneiform joint.
FMH: head of the first metatarsal, dorso-medial aspect of the first metatarso-phalangeal joint.
SMB: base of the second metatarsal, dorso-medial aspect of the second metatarso-cuneiform joint.
SMH: head of the second metatarsal, dorso-medial aspect of the second metatarso-phalangeal joint.
VMB: base of the fifth metatarsal, dorso-lateral aspect of the fifth metatarso-cuboid joint.
VMH: head of the fifth metatarsal, dorso-lateral aspect of the fifth metatarso-phalangeal joint

Mid-foot (Mid):
TN: most medial apex of the tuberosity of the navicular.
MC: the most distal and dorsal aspect of the middle cuneiform, assumed to coincide with SMB.
TC: most lateral apex of the tuberosity of the cuboid, assumed to coincide with VMB.
ID: intermedius mid-foot, mid-point between TN and TC.

Calcaneus (Cal):

CA: upper central ridge of the calcaneus posterior surface, i.e. Achilles' tendon attachment.
PT(=LM): lateral apex of the peroneal tubercle.
ST(=MM): most medial apex of the sustentaculum tali.
IC: intermedius calcaneus, mid point between ST and PT.

Shank (Sha):
TT: most anterior prominence of the tibial tuberosity.
HF: most proximal apex of the head of the fibula.
LM: distal apex of the lateral malleolus. MM distal apex of the medial malleolus.
IM: intermedius malleoli, mid point between LM and MM.

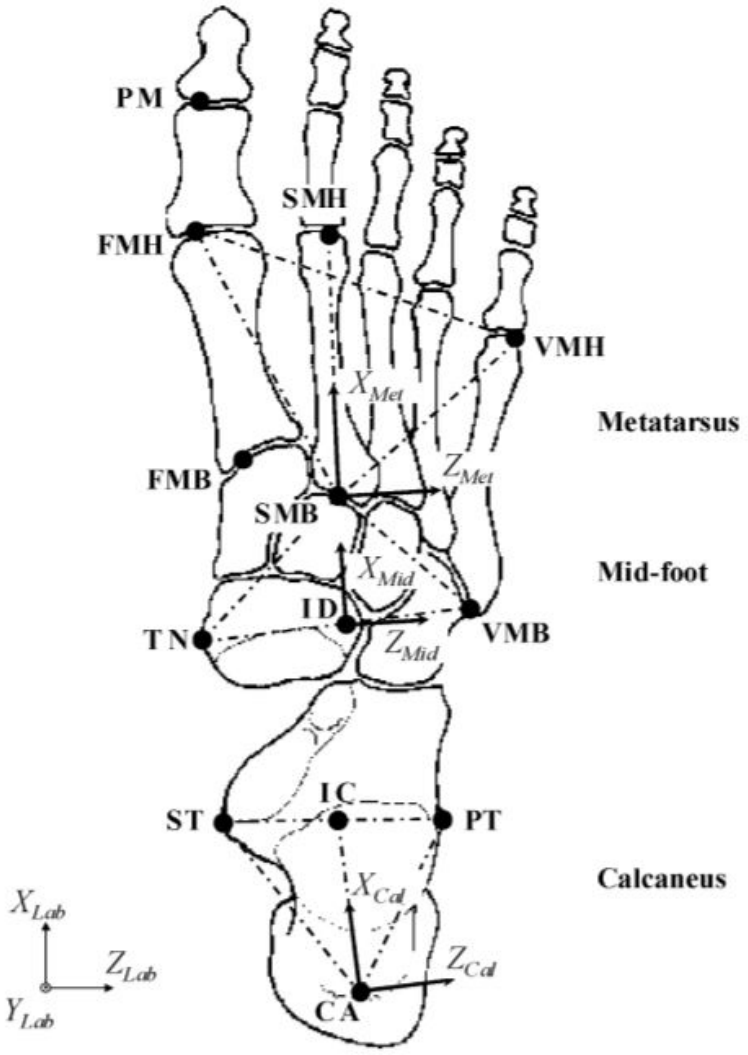

Figure 4: Foot according to [1]

4 Coordinate Systems

4.1 ISB 1 [2] - Tibia - Femur - Pelvis / Ankle - Hip - Pelvis JCS

4.1.1 Tibia CS

O_{Tib} : **IM**

Temporary vector :

$\overrightarrow{U} = \overrightarrow{MM - LM}$ pointing to the right (meaning for the left side : $\overrightarrow{U} = \overrightarrow{LM - MM}$

$\overrightarrow{Y_{Tib}} = \overrightarrow{\textbf{IM-IC}}$
$\overrightarrow{Y_{Tib}} = \overrightarrow{Y_{Tib}}/||\overrightarrow{Y_{Tib}}||$
$\overrightarrow{X_{Tib}} = \overrightarrow{Y_{Tib}} \times \overrightarrow{U}$
$\overrightarrow{X_{Tib}} = \overrightarrow{X_{Tib}}/||\overrightarrow{X_{Tib}}||$
$\overrightarrow{Z_{Tib}} = \overrightarrow{X_{Tib}} \times \overrightarrow{Y_{Tib}}$
$\overrightarrow{Z_{Tib}} = \overrightarrow{Z_{Tib}}/||\overrightarrow{Z_{Tib}}||$

4.1.2 Pelvis JCS

O_{Pel} :***mASIS***

Temporary vector:
$\overrightarrow{U} = \overrightarrow{\textbf{\textit{mPSIS-mASIS}}}$

$\overrightarrow{Z_{Pel}} = \overrightarrow{\textbf{LASIS-RASIS}}$
$\overrightarrow{Z_{Pel}} = \overrightarrow{Z_{Pel}}/||\overrightarrow{Z_{Pel}}||$
$\overrightarrow{Y_{Pel}} = \overrightarrow{Z_{Pel}} \times \overrightarrow{U}$
$\overrightarrow{Y_{Pel}} = \overrightarrow{Y_{Pel}}/||\overrightarrow{Y_{Pel}}||$
$\overrightarrow{X_{Pel}} = \overrightarrow{Y_{Pel}} \times \overrightarrow{Z_{Pel}}$
$\overrightarrow{Z_{Pel}} = \overrightarrow{Z_{Pel}}/||\overrightarrow{Z_{Pel}}||$

4.1.3 Hip JCS

O_{Hip} : **HRC**

Temporary vector :
$\overrightarrow{U} = \overrightarrow{MM - LM}$ pointing to the right (meaning for the left side : $\overrightarrow{U} = \overrightarrow{LM - MM}$
$\overrightarrow{Y_{Hip}} = \overrightarrow{\textbf{IM-IC}}$
$\overrightarrow{Y_{Hip}} = \overrightarrow{Y_{Hip}}/||\overrightarrow{Y_{Hip}}||$
$\overrightarrow{X_{Hip}} = \overrightarrow{Y_{Hip}} \times \overrightarrow{U}$
$\overrightarrow{X_{Hip}} = \overrightarrow{X_{Hip}}/||\overrightarrow{X_{Hip}}||$
$\overrightarrow{Z_{Hip}} = \overrightarrow{X_{Hip}} \times \overrightarrow{Y_{Hip}}$
$\overrightarrow{Z_{Hip}} = \overrightarrow{Z_{Hip}}/||\overrightarrow{Z_{Hip}}||$

4.1.4 Knee JCS

O_{Knee} : **mL**

$\overrightarrow{Y_{Knee}} = \overrightarrow{Y_{Tib}}$
$\overrightarrow{X_{Knee}} = \overrightarrow{X_{Hip}}$
$\overrightarrow{Z_{Knee}} = \overrightarrow{X_{Knee}} \times \overrightarrow{Y_{Knee}}$
$\overrightarrow{Z_{Tib}} = \overrightarrow{Z_{Tib}}/||\overrightarrow{Z_{Tib}}||$

4.2 ISB 2 [3] - Humerus - Radius - Thorax / Elbow - Shoulder JCS

4.2.1 Humerus CS

O_H : **GH**

$\overrightarrow{Y_H} = \overrightarrow{\textbf{ME-GH}}$
$\overrightarrow{Y_H} = \overrightarrow{Y_H}/||\overrightarrow{Y_H}||$
$\overrightarrow{X_H} = \overrightarrow{\textbf{EL-GH}} \times \overrightarrow{\textbf{EL-EM}}$
$\overrightarrow{X_H} = \overrightarrow{X_H}/||\overrightarrow{X_H}||$
$\overrightarrow{Z_H} = \overrightarrow{X_H} \times \overrightarrow{Y_H}$
$\overrightarrow{Z_H} = \overrightarrow{Z_H}/||\overrightarrow{Z_H}||$

4.2.2 Forearm CS

O_F : **US**

$\overrightarrow{Y_F} = \overrightarrow{\textbf{US-ME}}$
$\overrightarrow{Y_F} = \overrightarrow{Y_F}/||\overrightarrow{Y_F}||$
$\overrightarrow{X_F} = \overrightarrow{\textbf{US-ME}} \times \overrightarrow{\textbf{US-RS}}$
$\overrightarrow{X_F} = \overrightarrow{X_F}/||\overrightarrow{X_F}||$
$\overrightarrow{Z_F} = \overrightarrow{X_F} \times \overrightarrow{Y_F}$
$\overrightarrow{Z_F} = \overrightarrow{Z_F}/||\overrightarrow{Z_F}||$

4.2.3 Thorax CS

O_T : **IJ**

$\overrightarrow{Y_T} = \overrightarrow{\textbf{US-ME}}$
$\overrightarrow{Y_F} = \overrightarrow{Y_F}/||\overrightarrow{Y_F}||$
$\overrightarrow{X_F} = \overrightarrow{\textbf{US-ME}} \times \overrightarrow{\textbf{US-RS}}$

$\overrightarrow{X_F} = \overrightarrow{X_F}/||\overrightarrow{X_F}||$
$\overrightarrow{Z_F} = \overrightarrow{X_F} \times \overrightarrow{Y_F}$
$\overrightarrow{Z_F} = \overrightarrow{Z_F}/||\overrightarrow{Z_F}||$

4.2.4 Shoulder JCS

O_{ELb} : **GH**

$\overrightarrow{X_{Sho}} = \overrightarrow{Y_T}$
$\overrightarrow{Z_{Sho}} = \overrightarrow{Y_H}$
$\overrightarrow{Y_{Sho}} = \overrightarrow{X_H}$

4.2.5 Elbow JCS

O_{ELb} : **ME**

$\overrightarrow{X_{Elb}} = \overrightarrow{Z_H}$
$\overrightarrow{Z_{Elb}} = \overrightarrow{Y_F}$
$\overrightarrow{Y_{Elb}} = \overrightarrow{Z_{Elb}} \times \overrightarrow{X_{Elb}}$

4.3 Foot - Leardini [1]

4.3.1 Metatarsal Coordinate System (CS) - Metatarsophalangian Joint Coordinate System (JCS)

O_{Met} : **SMB**

Temporary vectors:
$\overrightarrow{U_1} = \overrightarrow{\textbf{SMB-SMH}}$
$\overrightarrow{U_2} = \overrightarrow{\textbf{SMB-FMH}}$
$\overrightarrow{U_3} = \overrightarrow{\textbf{SMB-VMH}}$

JCS:
$\overrightarrow{X_{Met}} = \overrightarrow{U_2} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_2}) + \overrightarrow{U_3} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_3})$
$\overrightarrow{X_{Met}} = \overrightarrow{X_{Met}}/||\overrightarrow{X_{Met}}||$
$\overrightarrow{Z_{Met}} = \overrightarrow{U_2} \times (1 - (\overrightarrow{X_{Met}} \cdot \overrightarrow{U_2})) + \overrightarrow{U_3} \times (1 - (\overrightarrow{X_{Met}} \cdot \overrightarrow{U_3}))$
$\overrightarrow{Z_{Met}} = \overrightarrow{Z_{Met}}/||\overrightarrow{Z_{Met}}||$
$\overrightarrow{Y_{Met}} = \overrightarrow{Z_{Met}} \times \overrightarrow{X_{Met}}$

4.3.2 Midfoot Coordinate System (CS) - Mediotarsal Joint Coordinate System (JCS)

O_{Mid} : **ID**

JCS:
$\overrightarrow{X_{Mid}} = \overrightarrow{\textbf{ID-MC}}$
$\overrightarrow{X_{Mid}} = \overrightarrow{X_{Mid}}/||\overrightarrow{X_{Mid}}||$
$\overrightarrow{Z_{Mid}} = \overrightarrow{\textbf{ID-TN}} \times (1 - (\overrightarrow{X_{Mid}} \cdot \overrightarrow{\textbf{ID-TN}}))$
$\overrightarrow{Z_{Mid}} = \overrightarrow{Z_{Mid}}/||\overrightarrow{Z_{Mid}}||$
$\overrightarrow{Y_{Mid}} = \overrightarrow{Z_{Mid}} \times \overrightarrow{X_{Mid}}$

4.3.3 Calcaneus Coordinate System (CS) - Calcaneus Joint Coordinate System (JCS)

O_{Cal} : **CA**

JCS:
$\overrightarrow{X_{Cal}} = \overrightarrow{\textbf{CA-IC}}$
$\overrightarrow{X_{Cal}} = \overrightarrow{X_{Cal}}/||\overrightarrow{X_{Cal}}||$
$\overrightarrow{Z_{Cal}} = \overrightarrow{\textbf{CA-ST}} \times (1 - (\overrightarrow{X_{Cal}} \cdot \overrightarrow{\textbf{CA-ST}}))$
$\overrightarrow{Z_{Cal}} = \overrightarrow{Z_{Cal}}/||\overrightarrow{Z_{Cal}}||$
$\overrightarrow{Y_{Cal}} = \overrightarrow{Z_{Cal}} \times \overrightarrow{X_{Cal}}$

4.3.4 Foot Coordinate System (CS) - Foot Joint Coordinate System (JCS)

O_{Foot} : **CA**

Temporary vectors:
$\overrightarrow{U_1} = \overrightarrow{\textbf{CA-SMH}}$
$\overrightarrow{U_2} = \overrightarrow{\textbf{CA-FMH}}$
$\overrightarrow{U_3} = \overrightarrow{\textbf{CA-VMH}}$

JCS:
$\overrightarrow{X_{Foot}} = \overrightarrow{U_2} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_2}) + \overrightarrow{U_3} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_3})$
$\overrightarrow{X_{Foot}} = \overrightarrow{X_{Foot}}/||\overrightarrow{X_{Foot}}||$
$\overrightarrow{Z_{Foot}} = \overrightarrow{U_2} \times (1 - (\overrightarrow{X_{Foot}} \cdot \overrightarrow{U_2})) + \overrightarrow{U_3} \times (1 - (\overrightarrow{X_{Foot}} \cdot \overrightarrow{U_3}))$
$\overrightarrow{Z_{Foot}} = \overrightarrow{Z_{Foot}}/||\overrightarrow{Z_{Foot}}||$
$\overrightarrow{Y_{Foot}} = \overrightarrow{Z_{Foot}} \times \overrightarrow{X_{Foot}}$

4.3.5 Shank Coordinate System (CS)

O_{Shank} : **IM**

Temporary vectors:
$\overrightarrow{U_1} = \overrightarrow{\textbf{IM-TT}}$
$\overrightarrow{U_2} = \overrightarrow{\textbf{IM-LM}}$
$\overrightarrow{U_3} = \overrightarrow{\textbf{IM-HF}}$

CS:
$\overrightarrow{Y_{Shank}} = \overrightarrow{U_2} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_2}) + \overrightarrow{U_3} \times (\overrightarrow{U_1} \cdot \overrightarrow{U_3})$
$\overrightarrow{Y_{Shank}} = \overrightarrow{Y_{Shank}} / ||\overrightarrow{Y_{Shank}}||$
$\overrightarrow{Z_{Shank}} = \overrightarrow{U_2} \times (1 - (\overrightarrow{Y_{Shank}} \cdot \overrightarrow{U_2})) + \overrightarrow{U_3} \times (1 - (\overrightarrow{Y_{Shank}} \cdot \overrightarrow{U_3}))$
$\overrightarrow{Z_{Shank}} = \overrightarrow{Z_{Shank}} / ||\overrightarrow{Z_{Shank}}||$
$\overrightarrow{X_{Shank}} = \overrightarrow{Y_{Shank}} \times \overrightarrow{Z_{Shank}}$

References

[1] Leardini *et al*, *Rear-foot, mid-foot and fore-foot motion during the stance phase of gait*, Gait & Posture 25 (2007) 453–462

[2] Wu *et al*, *ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human jointmotion—part I: ankle, hip, and spine*, Journal of Biomechanics 35 (2002) 543–548

[3] Wu *et al*, *ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand*, Journal of Biomechanics 38 (2005) 981–992