**2.2 Definition of user Specification – exporting landmarks, distance measurements and osteometric board**

**EXPORTING LANDMARKS and COMMON COORDINATE SYSTEM**

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

The majority of anthropological work uses geometric morphometrics (GM). I am not sure that the scope of this project is to provide geometric morphometrics tools within lhpFusionBox as open source software exists which allow you to conduct the analysis already (i.e. MorphoJ, or Past 3) but data exported from ALs should be in a format that can be analysed using systems commonly used by paleoanthropologists The key criteria to analysing 3D landmarks with each other is that all the landmarks should be in the same coordinate system. Therefore each object should be able to be placed in the same position in the same local coordinate system.

Specimens should go in different rows and landmarks in each row. You need to have the x, y, z coordinates of the landmarks (as follows is a format commonly used for geometric morphometrics.

**Example 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  x1 | y1 | z1 x2 | y2 | z2 x3 | y3 | z3 x4 | y4 z4 |
|  x1 | y1 | z1 x2 | y2 | z2 x3 | y3 | z3 x4 | y4 z4 |
| x1 | y1 | z1 x2 | y2 | z2 x3 | y3 | z3 x4 | y4 z4 |

**2) Methods and algorithms (with bibliographic references) to produce these results must be detailed.**

XYZ coordinates should be known and be able to be defined in relation to the origin of the coordinate system (i.e show where 0,0,0 is (lower left frontal corner, or centroid, or …). Then coordinates should then be able to exported in relation to the origin of the coordinate system (currently can export landmark positions *Export-Motion Analysis – Landmark* but if you don’t know the origin then you cannot compare these to other bones).

There is currently an operation called : ‘Operations – Modify-Fuse- Represent in RefSys’ which enables you to place the bone in a reference system. This then places the object in the reference system which you chose. (please note that I cannot make this work but perhaps Serge you can advise on this). As all bones need to be in the same place to make the GM analysis work then we need to have a way to do this. This could be ‘Operations – Modify-Fuse-Represent in 0,0,0’. Then you can chose to move the anatomical reference frame attached to the object and all bones will then be in the same position.

The most straight and clear approach for GM bone evaluation is based on palpable ALs (three and more). Preferably these ALs must be selected using ISB recommendations for LCS definition (these definitions are available in lhpFusionBox). If these ALs are not labelled than its must be palpated and stored in the same order (as “dimension” see Ex\_1). Indeed, after bone LCS definition all palpated and supplementary (e.g. derived) ALs together with bone vertices (if surface data are available) must be converted into the bone LCS.

Another option is based on surface vertices availability and LCS derivation from principal axis (PA) evaluation. In this approach LCS origin will be in barycentre and LCS axis orientation must be corrected using example data for each type of bone. The advantage of PA approach is not necessary using any ALs for bony shape evaluation (e.g. bending, twisting etc.). The disadvantage is, that method is sensitive to surface data resolution, which may lead to error in LCS pose.

**3) User interface and user actions required to inject INPUT data into the algorithms.**

This could be done by highlighting a group and then it automatically exports all landmarks in cloud in the format shown in 2.

Three palpable ALS must be placed on each object according to ISB recommendations.

**Distance Measurements**

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

Physical measurements in FusionBox are made from previously located landmark locations. The development strategy in the previous lhp consortium was that no predefined “application specific” functions was implemented in order to keep lhp applications as generic as possible. Therefore, measurements from anatomical landmarks must be performed manually by 1) selecting the operations; 2) selecting relevant landmarks that have been previously located; 3) displaying the results. However, this is difficult in practice when you need to perform lots of measurements on lots of bones and it is therefore currently very laborious in lhpFusionBox. Therefore a way to facilitate this would be useful.

For anthropological purposes, measurements are much simpler in other systems. For example in MESHLAB, you can choose the measurement tape option, do a simple click on the object (which places a second landmark on the object) and the second click elsewhere on the object also automatically places a line which displays the distance between the two landmarks. If you did not place a landmark correctly then you can click on the landmark itself and move it on the object very easily (It stays automatically on the surface of the object). Landmarks are however not labelled like in FusionBox and automatically have names.

There are several ways distance measurements could be improved.

A. In lhpFusionBox you have to go into ‘add landmark’ then choose a dictionary (which is very useful) but there is no way to just add a couple of landmarks easily and there is a difficulty when adding a ‘new landmark’ rather than a dictionary, as you can type different names for the ‘new’ landmark and it says that the landmark has already been added. CTRL A adds a landmark. The dictionary of points works well but there is often a problem when you try to add a ‘new landmark’ therefore this needs to be improved.

B. As part of the project RBINS will set up dictionaries in lhpFusionBox for all the major bones based on the measurements of Martin. It would be useful to have a way to also have automated distance measurements (i.e. if you create a dictionary – you could also ask for the distance between two landmarks or the angle between 3 landmarks. It would be useful to have this as an option (in a menu or as part of a dictionary) and have it so that it can be changed as other people may want other distances between landmarks. This can be a script or plug in.

C. When moving prepalpated landmarks, surface snap should also be the default when moving landmarks on objects (as this has to be changed each time you move a landmark on an object). This is done when pressing CTRL T.

D. In relation to 2, it would also be useful to be able to export distance measurements and angles as a group. This is a feature that would also be useful for the analysis of the centre line of an object and quadric surfaces (see later tasks).

**2) Methods and algorithms (with bibliographic references) to produce these results must be detailed.**

A. the problem (add landmark) is not really a bug; it is rather a badly implemented request. It is probably a good idea to rewrite the ‘add landmark’ function in the following way: 1) user is selecting a landmark cloud; 2) user is entering a landmark name in a tick box; 3) if the landmark name does not exist in the current cloud, then and only then the user can set a new landmark at the surface of the currently selected surface.

B. Specific high-end applications should be developed (plug in or script). For example, a “measurement operation” that would ask user to choose 2 landmarks (linear measurements); C. landmarks (angular measurements, or shortest distance to a line); 4 landmarks (angle between lines, distance between lines), distances to planes and lines.

A script system could be associated. The script would include all measurements to be performed through various AL clouds.

For example:

CLOUD1 AL2 CLOUD4 AL6 LINEAR

CLOUD1 AL2 CLOUD4 AL6 CLOUD4 AL3 ANGLE

Etc…

Obviously the script must still be constructed, but this would give a lot of flexibility because the specific measurements will not be hard-coded.

Note that this script and AL selection already exists but is not currently associated to measurements (it is in AF definition).

Operations needed for script

2 landmarks

* Line
* Distance (AB)

A

B

Landmark (s)

3 landmarks ABC

* Lines AB, BC, CA
* Average of two/or more landmarks (AB) to another landmark (C)
* 2 perpendicular lines
* Angle between two lines
* Plane

 Distance between Average of two landmarks (AB) to another landmark (C)

C

B

B

A

 Angle between two lines

C

A

B

B

Plane defined by three landmarks

**More than 3 landmarks**

A set of landmarks to define a surface area

2 planes

Creation of automatic planes from manually defined plane (see above)

a)Perpendicular plane:

(i.e. create automatic perpendicular plane through one landmark (in this case the centre landmark) in relation to other two (from the manually defined plane above)

b)Parallel plane: to be automatically created (distance should then be able to be measured between two planes)

c) Oblique plane: with user defined angle (distance should then be able to be measured between two planes)

1 plane, 1 point

Perpendicular line from landmark (either on or off the surface) to plane showing distance



**1 line, 1 landmark**

Distance between a landmark (C) to a plane (perpendicular 90degree angle) defined by two landmarks (A and B)

C

B

B

B

A

**1 plane, 2 landmark**

landmark (C) to a plane defined by two landmarks (A and B)

1 plane, 2 points. Interpolation of landmarks from two specified landmarks on the surface of the bone (to analyse curvature)

B

B

A

Results of distance meters and positions of landmarks in relation to the origin of the coordinate system should then be able to be exported in a file in a way to enable comparisons with other results (i.e. a horizontal or vertical column) (landmark positions are currently able to be exported *Export-Motion Analysis – Landmark*). (See above EXPORTING LANDMARKS)

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

There needs to be a series of scripts which make the creation of distances between landmarks and planes more easy.

Script creation:

**2 landmarks**, distance measurement between two landmarks (can currently manually do in *Operations – Create – Derive – Meter- mode-point distance*) (also derive distance measurement from average of landmarks to landmarks or average of landmarks aswell). (note there is also something in *Operations- Measure-2D measure* but it doesn’t work)

**3 landmarks**, angle (can currently manually do in *Operations – Create – Derive – Meter- mode- line angle*, average of two or more landmarks (AB) to another landmark (can currently manually do in *Operations – Create – Derive – Average landmark* ), creation of a plane from three manually defined landmarks

**More than 3 landmarks**, this is a set of landmarks created to define a surface area (mm and cm) which can be exported.

**2 planes**, creation of an automatic plane from the plane from three manually defined landmarks which can be a) perpendicular, b) paralell, c) oblique. Distance should then be able to measured between two parallel planes

**1 line, 1 landmark,** perpendicular line from landmark (either on or off the surface) to plane showing distance (distance should be measured)

**1 plane, 1 landmark,** perpendicular line from landmark (either on or off the surface) to line defined by two landmarks(distance should be measured)

**1 plane, 2 landmarks,** Interpolation of landmarks between the two defined landmarks (in set distances, 1mm, 3mm etc)**.**

XYZ position in relation to origin of the coordinate system.

Distance in units (um, mm, cm, m)

Angle (degree, radian)

Volume

Surface area (defined by manually defined landmarks)

**3) User interface and user actions required to inject INPUT data into the algorithms**

***Osteometric board - Measures of Martin***

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

Anthropology and paleoanthropology have focused on measurements on specimens for many years. Measurements are largely used to differentiate between species and populations and large databases exist with measurements all taken in the same way. It would be a very useful tool if measurements can be taken in the same way as previously to allow comparisons between datasets. The majority of measurements are taken with a calliper or with an osteometric board and follow a guideline produced by Martin (1928) (Original in German). The two papers described above detail how they devised a virtual osteometric table (Lee et al., 2017; Reynolds et al., 2017). The way they devised this table is described below.

Reynolds et al. (2017) created a protocol for conducting linear measurements of postcranial skeletal elements using three-dimensional (3D) models from CT scans in ‘Geomagic Design X’. A posterior base plane was generated using three manually placed points on the posterior part of the bone (3 landmarks: medial and lateral condyle and posterior part of greater trochanter). An external contour of the distal bone and tangent vector were obtained from these landmarks and then a rotational plane was generated (perpendicular to the base plane). The proximal boundary of the femoral head was used to define other plane. There is an automated placement of extreme position planes in Geomagic Design X. Reynolds (2017) stated that alterative software to Geomagic could do some steps (Reynolds quotes lhpFusionBox as one of these softwares).

Sookyoung et al. (2017) analysed femora by placing them on an object on a horizontal coronal plane in MIMICS (then confirmed the object was on the plane by checking the three lowest points of the femur were on that plane). They then created a centre line in the same software and this was projected on the horizontal plane. Two additional planes (vertical axial planes) were added that were perpendicular to the projected centre line and to the horizontal coronal plane. The vertical planes were added by locating the most proximal and distal points of the femur uinsg ‘Create datum plane’ and ‘create extreme analysis’ functions in MIMICS. Maximum length of femur was then analysed by looking at distance between vertical axial planes

LhpFusionBox can currently create planes in lhpFusionBox *Options – Create – New – Parametric Surface,*  as well as other parametric objects but they are not stable. A way needs to be found to define the external boundaries of the bone with planes. Could lhpFusionBox recognise extreme positions of a bone or surface outline? Is this the boundary box? This is similar to the method in Reynolds et al. (2017) that the boundaries of the object were able to be recognised.

Once a virtual geometric board was created, Reynolds et al. (2017) also used Geomagic to cut bones. This is similar to Victor’s cutting planes. This would enable AP and ML diameters of the diaphysis shaft to be taken (which is v. useful in anthropology)

The virtual osteometric board should therefore have planes that are parallel or perpendicular to each other otherwise it won’t work. It would be most advantageous to create a best fit box (with edges that are moveable). The best way could possibly be to create one plane manually and then to create extreme reference planes automatically. Automated plane to plane measurements (midshaft, length) should then be taken (these measurements should also be easily moveable – i.e so that maximum condylar length can be easily taken on the femur for example). It may be useful to define where the bottom plane is placed manually to ensure that the planes were placed in a good position. Standardised ALs are used to create anatomical reference planes – could these ARFs be used to define where the plane is placed with the planes being placed on the extremes of the bone. This may be complicated as the pelvis has four ALs for the reference plane whilst the femur has three.

Measurements should be easy to take between planes. I.e. should be able to click on a plane and then do a second click on the other side of the plane.

A. Define the best way to make a virtual osteometric board. This should be done so that planes can be created and placed that are parallel or perpendicular to each other. The boundary box should be investigated in lhpFusionBox.

B. Planes should be opaque or see through so that you are able to see the bone.

C. Insert a function to take automated plane to plane measurements. This should be as simple as possible and the distance line between planes should be able to be moved easily (this should be done as above).

D. Investigate if it possible to ‘cut’ objects in lhpFusionBox. This would enable cross section diameters to be taken. It is important however, that the object is cut in the right place (i.e. It could be done within the osteometric box.

**2) Methods and algorithms (with bibliographic references) to produce these results must be detailed.**

**3) User interface and user actions required to inject INPUT data into the algorithms**

This should be something similar to ‘Create-new-osteometric board’

**REFERENCES**

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