TPS File Measurement Software

User Guide

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Contents

1 Application Presentation

The present software application was created for the purpose of assisting the processing and extraction of data from ".tps" files, typically used in the study of cut mark and tooth mark cross section morphologies. ".tps" files are created using the tpsDig free software, and have proven highly useful in a number of different research projects [1–6]. Studies of this nature typically work from micro-topographical profiles of different bone surface modifications [1], often derived from 3D models [3–6], or powerful digital microscopes [7]. From these profiles, a series of measurements are often used to describe the nature of the bone surface modification, including the mark's width at varying intervals (surface, middle, and base), the depth of the mark, the mark's opening angle, as well as the length of each of the mark's walls [1, 2, 4]. In more later years, these measurements have also been accompanied by the use of geometric morphometric analyses [3–6], providing a different insight into the characterisation of bone surface modification morphology. To facilitate these purposes, the present application takes as input a folder with ".tps" files, each containing landmark coordinates for geometric analyses, and produces one of two different outputs; (1) the measurements used to describe each mark, of (2) a morphologika file used to carry out geometric morphometrics.

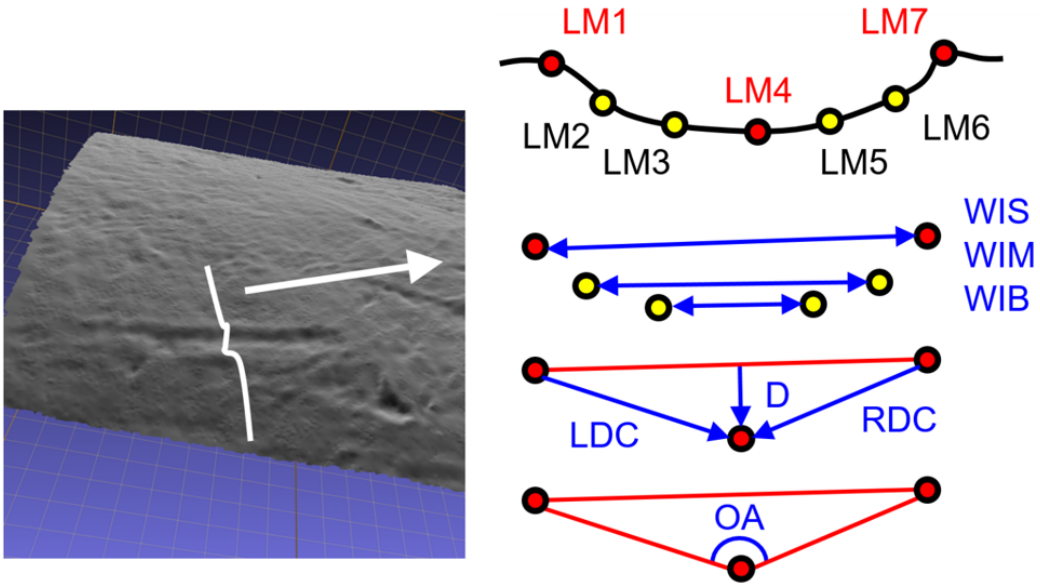


Figure 1: *Example of information that can be derived from the microtopography of bone surface modifications, including the collection of landmark data for geometric morphometric analyses, and different measurements that describe the overall metric properties of each mark. LM = Landmark. WIS = Width of Incision at Surface. WIM = Width of Incision Midway. WIB = Width of Incision at Base. LDC = Left Depth Convergent. RDC = Right Depth Convergent. D = Depth. OA = Opening Angle.*

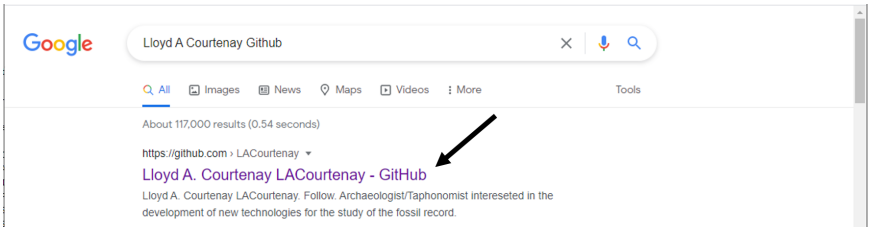
- Section two of this instruction manual describes the installation of the application (written in the C++ 17 programming language, using the Qt library for the graphic user interface).

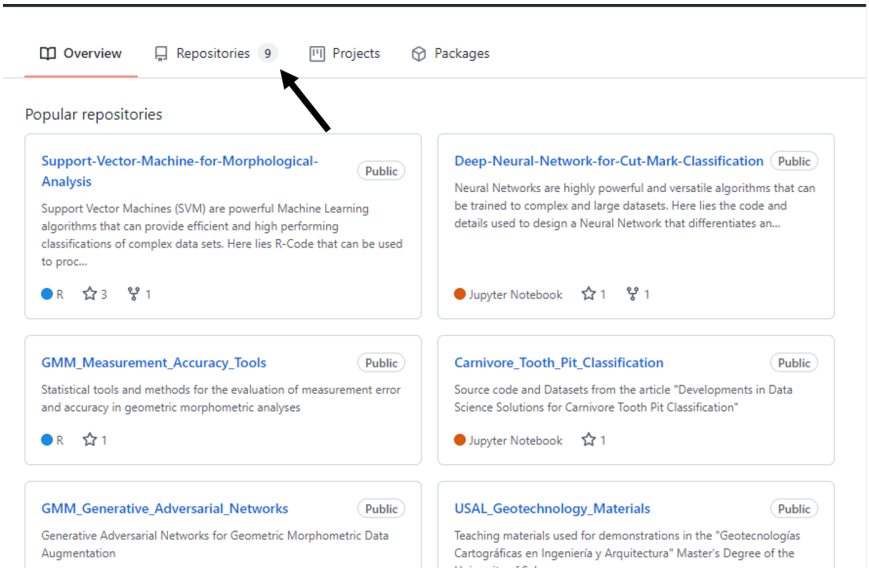
- Section three of this instruction manual describes how to obtain the ".tps" files necessary for use of the application.
- Section four describes how to use this software for the creation of ".csv" files containing measurements or morphologika files.
- Section five presents a very brief description about the application, including where to find source code and other additional information.
- The Appendix of this application presents some of the mathematical formulae used for measurements.
- Reference Section.

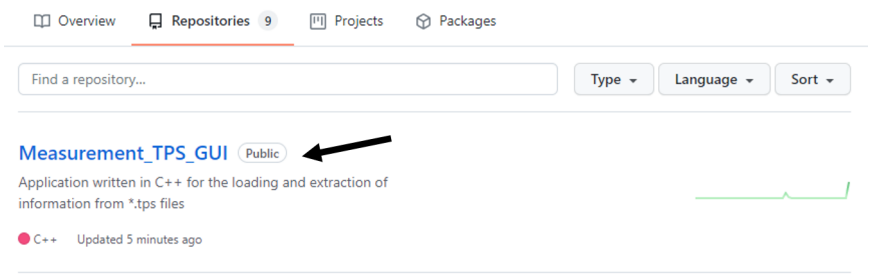
2 Installation Guide

Download installer from github profile (`https://github.com/LACourtenay`):

- Find Lloyd A. Courtenay's Github profile, and open repositories
- Search for the Measurements_TPS_GUI respository, and open the folder Application Installer
- Select the Measurement_Software_Installer.exe, and click on Download in the top right corner of the file container.
- It is very likely that the internet browser will flag the download as suspicious content, however we can overcome this by clicking on **Save** anyway.






Overview
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Application written in C++ for the loading and extraction of information from *.tps files
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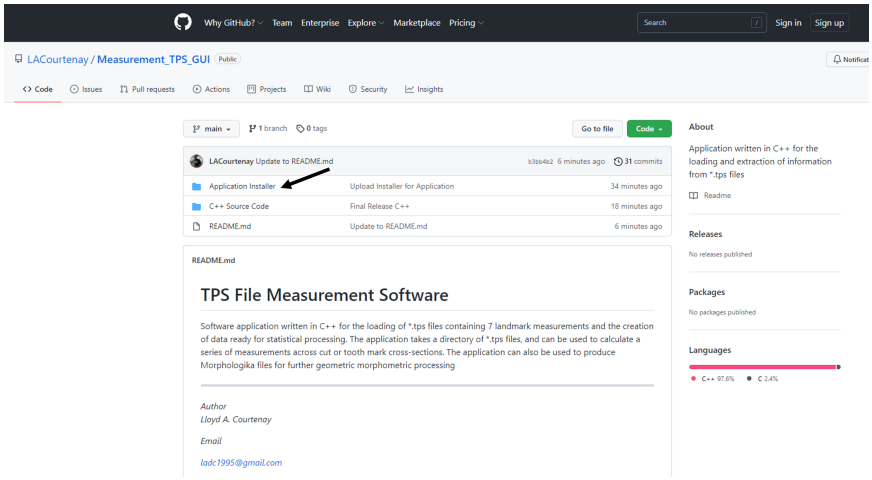
LACourtenay / Measurement_TPS_GUI
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C++ Source Code
Final Release C++
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README.md
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About
Application written in C++ for the loading and extraction of information from *.tps files
Readme
Releases
No releases published
Packages
No packages published
Languages
C++ 97.6%
C 2.4%
README.md
TPS File Measurement Software
Software application written in C++ for the loading of *.tps files containing 7 landmark measurements and the creation of data ready for statistical processing. The application takes a directory of *.tps files, and can be used to calculate a series of measurements across cut or tooth mark cross-sections. The application can also be used to produce Morphologika files for further geometric morphometric processing
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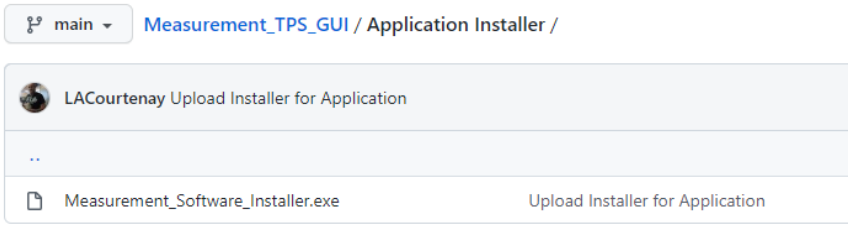
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LACourtenay Upload Installer for Application
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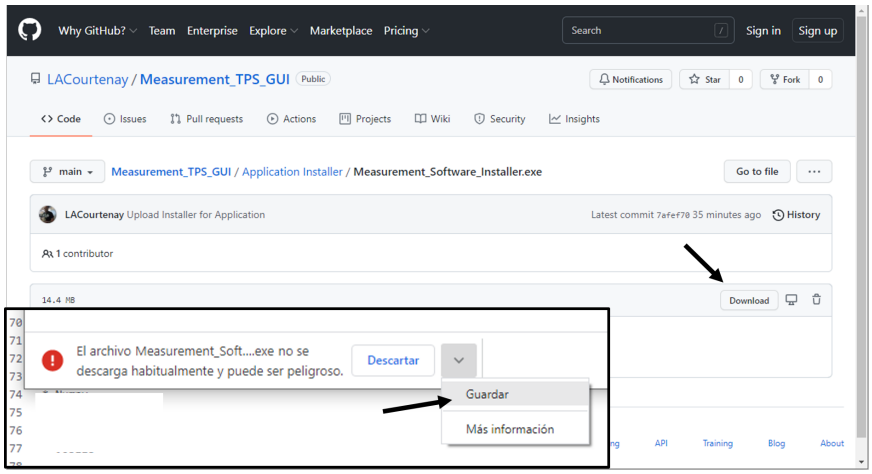
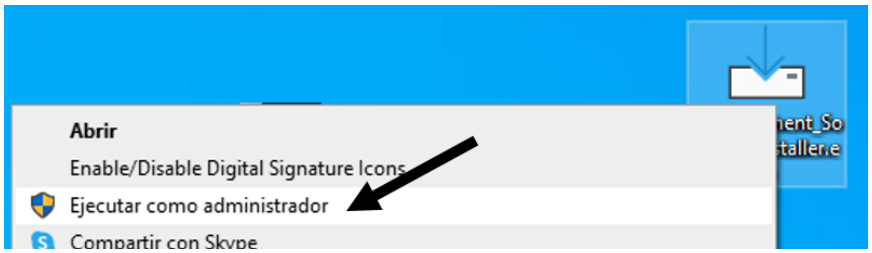
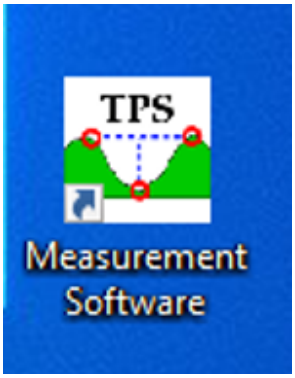
Measurement_Software_Installer.exe
Upload Installer for Application



Once the installer has finished downloading, run the executable as the Administrator and follow the instructions for installation.





3 Obtaining Landmark Data

The current version of this installation guide works with the tpsDig2 software version 2.31, by F. James Rohlf, which can be downloaded via the following link; `http://www.sbmorphometrics.org/soft-dataacq.html` [as of 08/09/2021 this link works, for any issues with the link contact ladc1995@gmail.com].

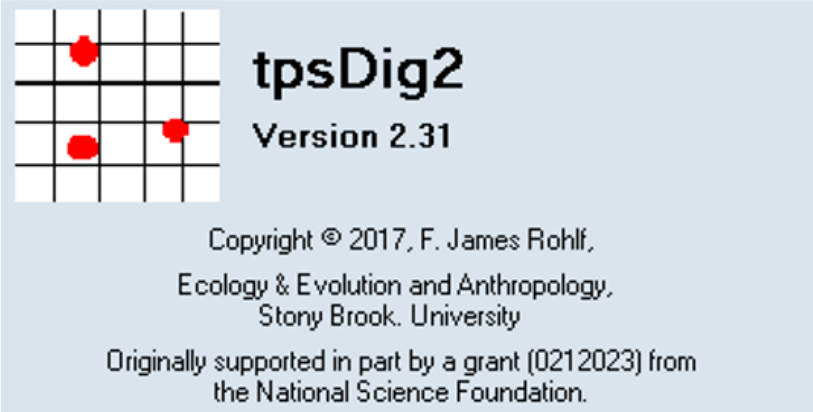


Figure 2: *tpsDig2 Software by F. James Rohlf*

To extract information from a bone surface modification profile, first load an image into the tpsDig software;

```
File >> Input source >> File...
```

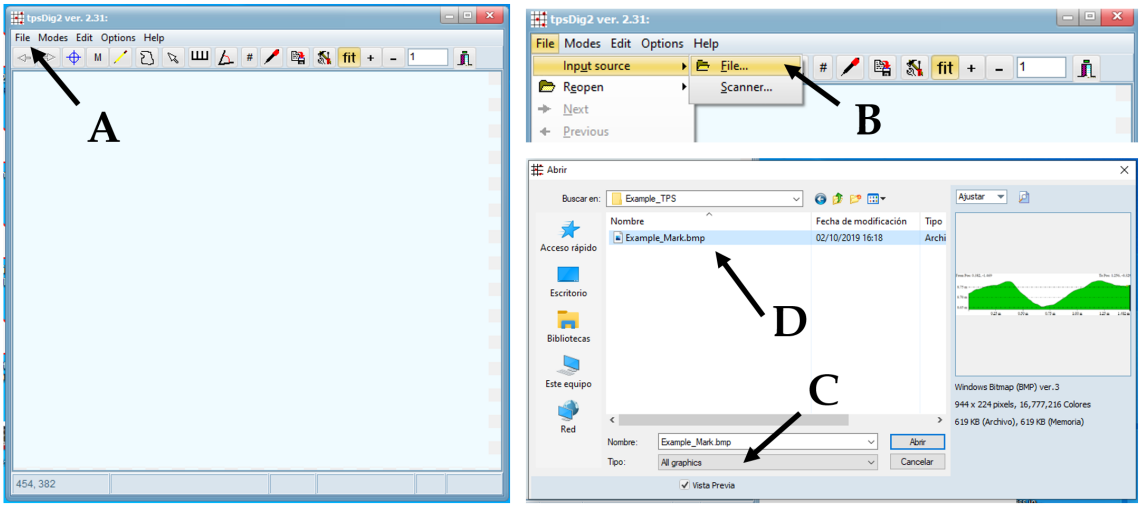


Figure 3: *(A & B) Search for file, (C) ensure that all graphics files are visible and (D) select the file of interest.*

Before proceeding, it is important to ensure that numeric values in tpsDig2 are formatted using a decimal point (.) as opposed to a decimal comma (,) (as is common in many European computers). To check this setting, the user should select the . option in;

```
Options >> Decimal character >> .
```

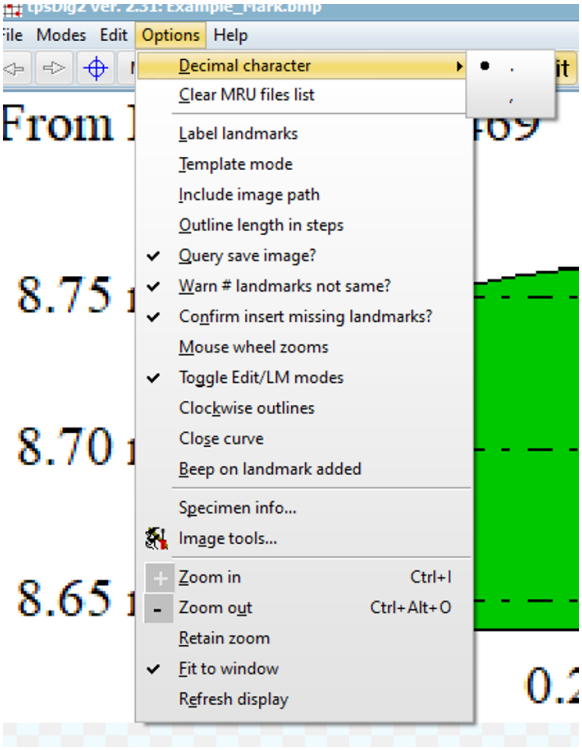


Figure 4: *Menu to change the decimal character from decimal commas to decimal points*

If this setting is not selected, then issues will occur using the Measurement Software.

3.1 Setting scale

Once the image is loaded, the first and most valuable step consists in setting the scale.

Figure 5: *Example of a carnivore tooth score's cross section*

The example presented above is the cross section of the tooth score produced by wolves [5]. The cross section was obtained from 3D models created using Structured-Light Surface scanning, while the microtopography was obtained using the Global Mapper software (although many other software can be used to obtain this information). In the present case, the image scale is represented at the bottom of the image. Despite how it may appear, the unit "m" represents millimetres as opposed to metres, with one line of the scale bar representing 0.25m (this will vary according to the way the cross-section is obtained).

To set the scale, select the **Image edit tools** in the toolbar, or;

```
Options >> Image tools...
```

Select the measure tab, and insert the **Reference length** according to the image at hand (in this case, 0.25mm). Ensure that the correct measurement unit is selected, and click on the **Set scale** button.

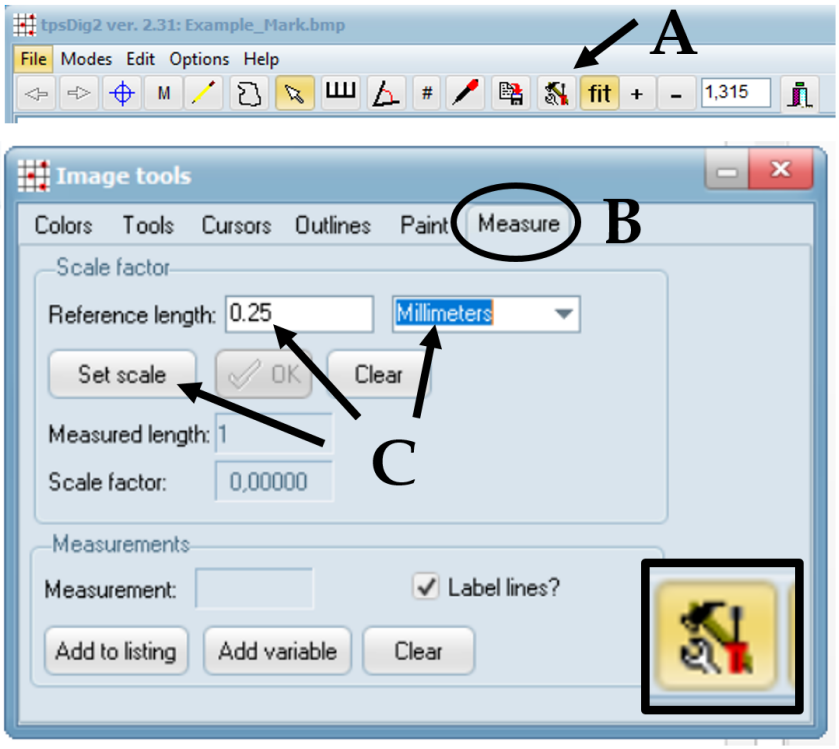


Figure 6: *(A) Image edit tools button, (B) Measurement tab, (C) controls to set image scale*

After clicking on the **Set scale** button, the scale can be established by marking on the image (left-click) the position of the beginning and end of the scale bar. Through this process, the user should observe a thin line accompanied by a small text box marking the distance (in pixels) of the scale bar;

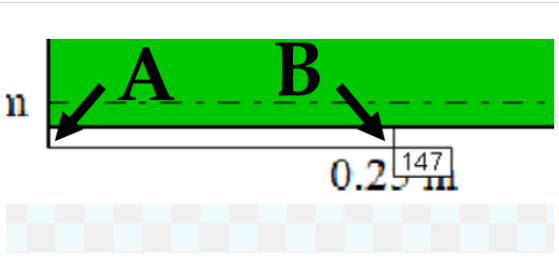


Figure 7: *(A) begining of the scale bar and (B) end of the scale bar. 147 in the present image refers to the number of pixels in the image that correspond to 0.25mm*

Once the user has established the length of the scale bar, click on **OK** in the **Image edit tools** window. If the scaling process has been successful, the **Scale factor** section of the **Image edit tools** window should contain (1) the number of pixels measured and the (2) scale factor.

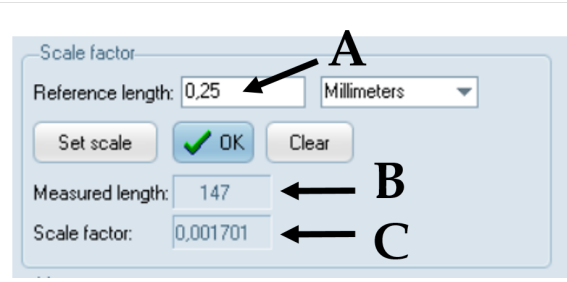


Figure 8: *(A) Length marked on the scale bar in the image, (B) the same length in pixels, and (C), the scale factor used to convert the number of pixels into the reference scale length.*

3.2 Manually placing landmarks

To place landmarks manually, select the **Digitize landmark** button on the toolbar. The user can now place landmarks by left clicking directly on the point of interest;

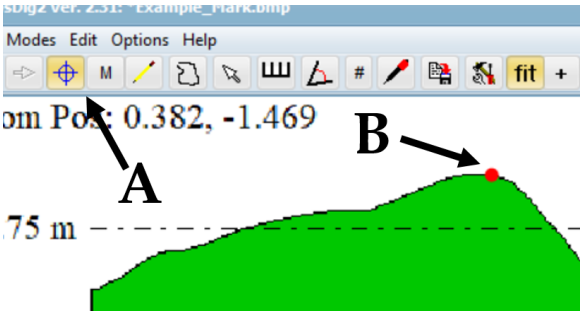


Figure 9: *(A) Digitize landmark button, and (B) a placed landmark on the image.*

To follow the methodological approach presented by [2] for cut marks, and adapted for tooth scores by [4], the user must place the following landmarks;

- Landmark 1 (LM1) - found at the beginning (top) of the left wall
- LM2 - found on the middle of the left wall
- LM3 - found approximately 10% from the base of the mark
- LM4 - at the base of the mark.
- LM5 - opposite LM3
- LM6 - opposite LM2
- LM7 - opposite LM1

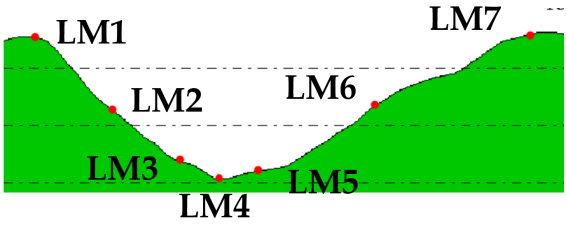


Figure 10: *Landmarks (LM) 1 to 7*

If the user wishes to adjust the position of a landmark, they can do so by selecting the **Edit landmarks & curves** tool from the toolbox. Landmarks can be deleted by right clicking over them, and selecting the **Delete landmark** option.

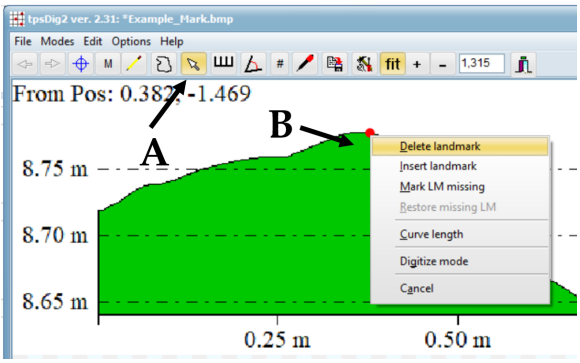


Figure 11: *(A) Edit landmarks & curves tool, and (B) delete landmark option.*

NOTE: the order of landmark placement is fundamental for these types of analyses!

3.3 Computing landmarks

Two possible methods exist for computing the position of landmarks using tpsDig. The current author recommends one method for tooth marks (where bone surface modifications are more likely to be symmetrical), and another for cut marks (where bone surface modifications are more likely to be asymmetrical). These approaches have been applied with success in [5–7], producing much less inter- and intra-observer error.

The use of this method, as opposed to using manually place landmarks, essentially converts the previously defined landmark model to the following;

- LM1 - found at the beginning (top) of the left wall
- LM2 - found midway along the left side of the wall
- LM3 - found in proximity with the base of the mark
- LM4 - at the base of the mark

- LM5 - opposite LM3
- LM6 - opposite LM2
- LM7 - opposite LM1

3.3.1 Tooth Marks

The digitisation of landmarks using more computational approaches requires use of the **Draw background curves** tool on the toolbar. This tool allows the user to trace the curve they wish to digitise, and re-sample equidistant points from this curve. For the purpose of processing tooth marks, the user should trace the entire profile using this curve;

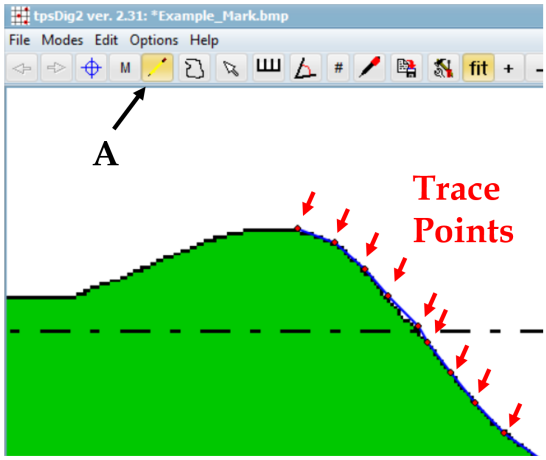


Figure 12: *(A) Draw background curves tool, and (Trace Points) use of the tool to trace the outline of the cross-section*

To sample from this curve, the user can right-click on the curve, and select the **Resample curve** option. From the pop-up window, ensure that the resampling is carried out **By length**, calculating 7 equidistant points along the entirety of the curve.

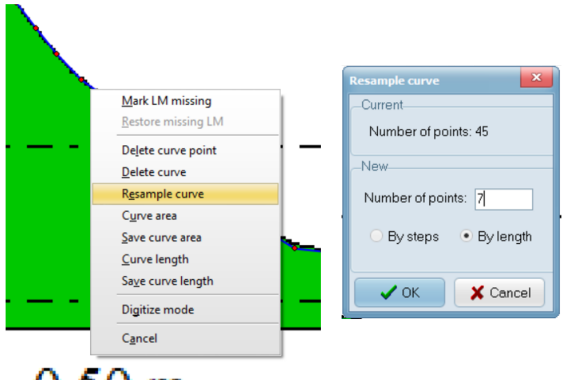


Figure 13: *Resample curve window.*

3.3.2 Cut Marks

As opposed to tooth marks [5, 6], cut marks are known for presenting an asymmetric cross-section. For this purpose, placement of landmarks should consider each of the cut mark's walls separately, sampling from two different curves.

The user should, thus, first trace the left hand side of the wall, and sample 4 equidistant points. The user should then trace the right hand side of the wall, and resample an additional 4 equidistant points. Due to the tracing of two different sides to the profile, the user must delete one of the equidistant points at the base of the mark to ensure only 7 landmarks are present.

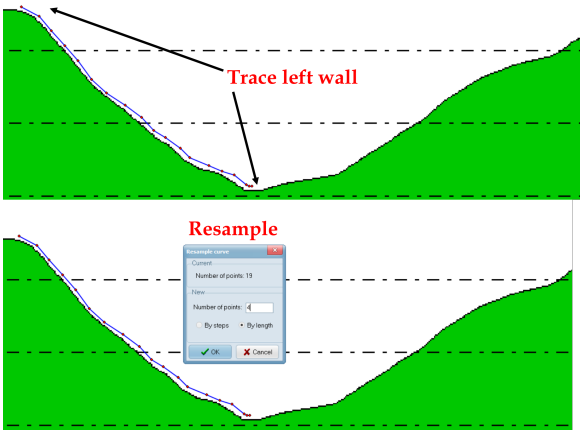


Figure 14: *Digitise left hand wall (note - for ease of visualising the curve the present example did not accurately trace each wall of the mark).*

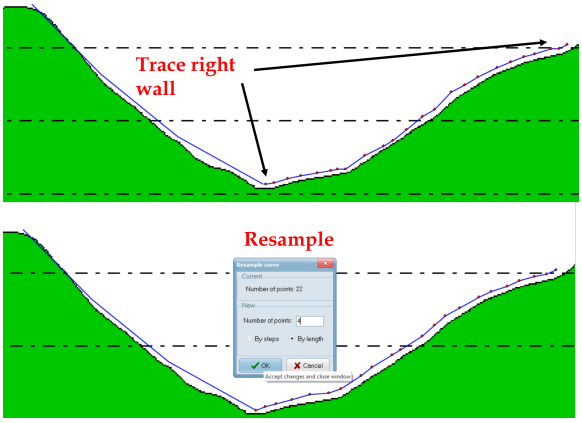


Figure 15: *Digitise right hand wall (note - for ease of visualising the curve the present example did not accurately trace each wall of the mark).*

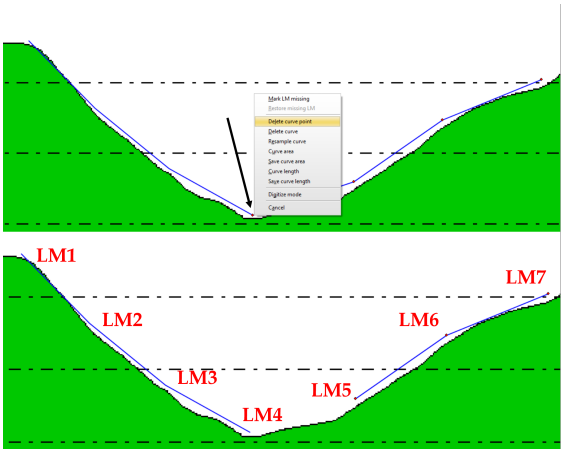


Figure 16: *Remove repeated LM4 on one of the sides (note - for ease of visualising the curve the present example did not accurately trace each wall of the mark).*

3.4 Saving landmark ('.tps') files

To save the digitised landmarks, the user should;

```
File >> Save data as...
```

When saving the file, it is important that the user include the ".tps" extension at the end of the file name.

The output files will present three different formats according to the landmark collection method used. If applying the 7 fixed landmarks presented by [2, 4], then the file will begin by specifying the contents of the file (LM=7, i.e. 7 landmarks), followed by the x and y coordinates for each of the landmarks, the name of the image landmarks were obtained from, followed by the scale factor[1]. Files created using the digitised curve method [5, 6] will present an LM count of 0, however this is because they are substituted by points (POINTS=7) on a single curve (CURVES=1). Finally, if the digitisation method samples points on each of the mark's walls separately, then two different curves will be present, with a total number of points along both curves adding up to 7 (either in the form of POINTS=3 & POINTS=4 or POINTS=4 & POINTS3).

[1]NOTE: It is very important to ensure the scale factor is included in all files

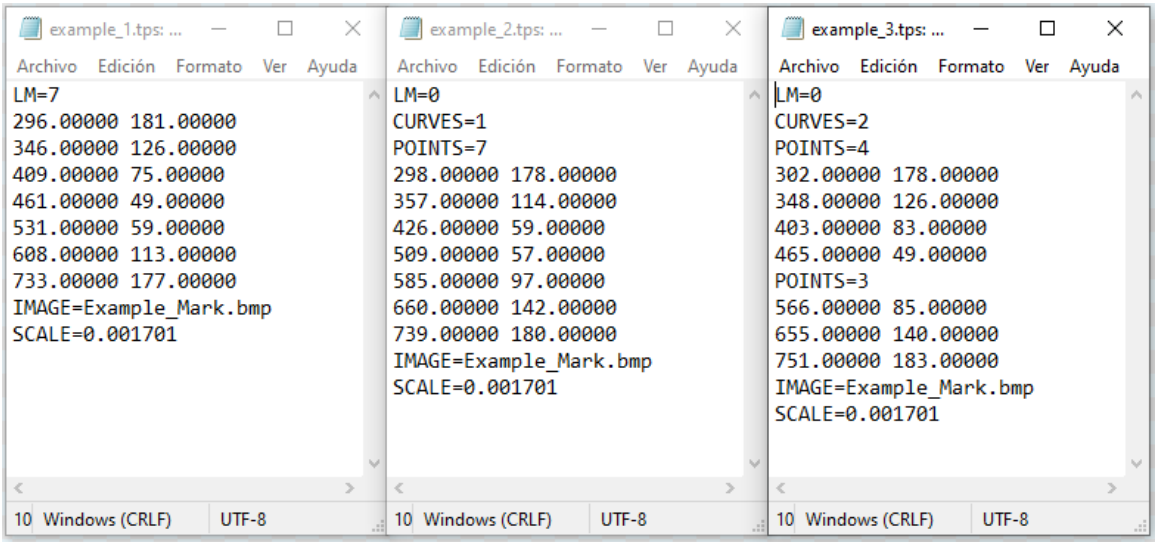


Figure 17: *Example of the three different output files that can be produced using tpsDig2*

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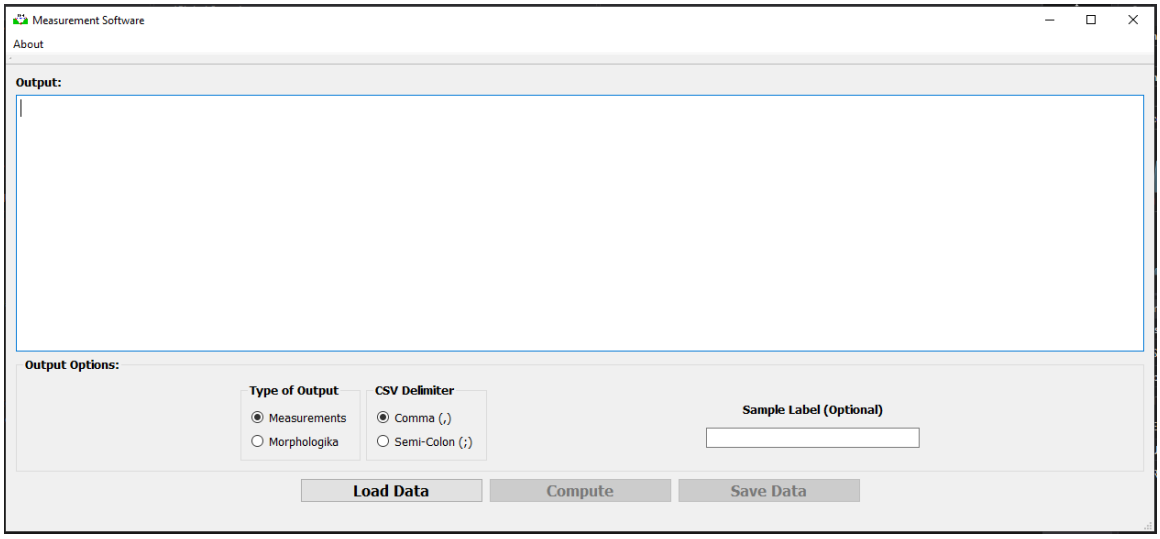

Figure 18: *Measurement Software*

When opening the measurement software the user will be presented with a window containing;

1. An empty output box where calculations and formatted landmarks will be displayed.
2. An output options box where the user can define;
   (a) The type of output information.
   (b) In the case of calculating measurements whether the ".csv" file output is delimited by commas (,) or semi-colons (;).
3. Sample labels if the user wishes this information to be included
4. Buttons to;
   (a) **Load Data**: load a directory containing ".tps" files.
   (b) **Compute**: compute the output and display in the output box.
   (c) **Save Data**: save the output.

To begin, the user must load into memory a folder containing the ".tps" files of interest, by either pressing the **Load Data** button or using the "Ctrl + L" keyboard shortcut [2]. Once the folder has been selected, the ".tps" files will now be loaded into memory. If this process was successful, the following dialogue box should appear informing the user of the number of files found within the folder;

[2] If the folder contains files other than ".tps" files this is not an issue, the software is able to filter these additional files out

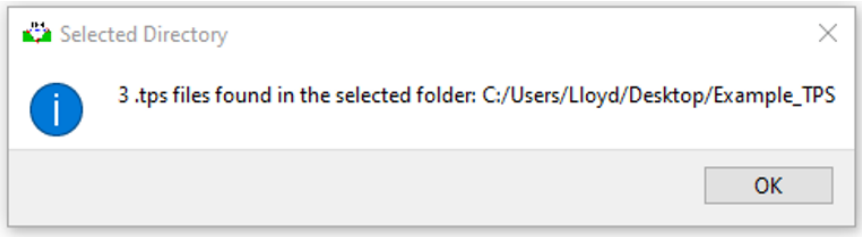

Figure 19: *Successful loading of files*

4.1 Extracting Measurements

Once the files have been loaded, the user will have access to the **Output Options** portion of the application. To extract measurements from the profile, the user must select the **Measurements** option. The output of the measurements option is a ".csv" file that can be easily opened in Excell or programming environments such as R and Python. The user must, however, define the type of delimiter to be included in the ".csv" file. For many European computers (such as in Spain), ".csv" files are saved using the semi-colon (;) delimiter, however in other countries the comma (,) is used.

If the user wishes to add a column containing a **Sample Label**, then the text box to the right can be used to specify the name of this label. **NOTE: To avoid future possible issues when working with these files in programming languages such as R or Python, it is highly recommendable to avoid the use of spaces (" ") in sample names. To avoid these issues, the present application will not allow the user to use spaces in label names.**

Once the user has selected the options of interest, they can proceed to press the **Compute** button (or the Return key on the keyboard). Upon activating the **Compute** function, the output will now be filled with the measurements defined by [1, 2, 4], with updates by [5].

The output will now display;

- The name of the ".tps" file.
- The name of the image where landmarks were sampled from.
- (Optional) The sample label.
- The Width of Incision at the Surface (WIS) - Euclidean distance (See Appendix for formulae) between LM1 and LM7.
- The Width of Incision Midway (WIM) - Euclidean distance between LM2 and LM6.
- The Width of Incision in proximity with the Base (WIB) - Euclidean distance between LM3 and LM5.
- The Left Depth Converging (LDC) - Euclidean distance between LM1 and LM4.
- The Right Depth Converging (RDC) - Euclidean distance between LM4 and LM7.
- The Opening Angle (OA) in Degrees (See Appendix for formulae).

- The Depth of the mark (See Appendix for formulae).
- A linear transformation of the Opening Angle (OA_linear), according to [5] (See Appendix for Formulae).

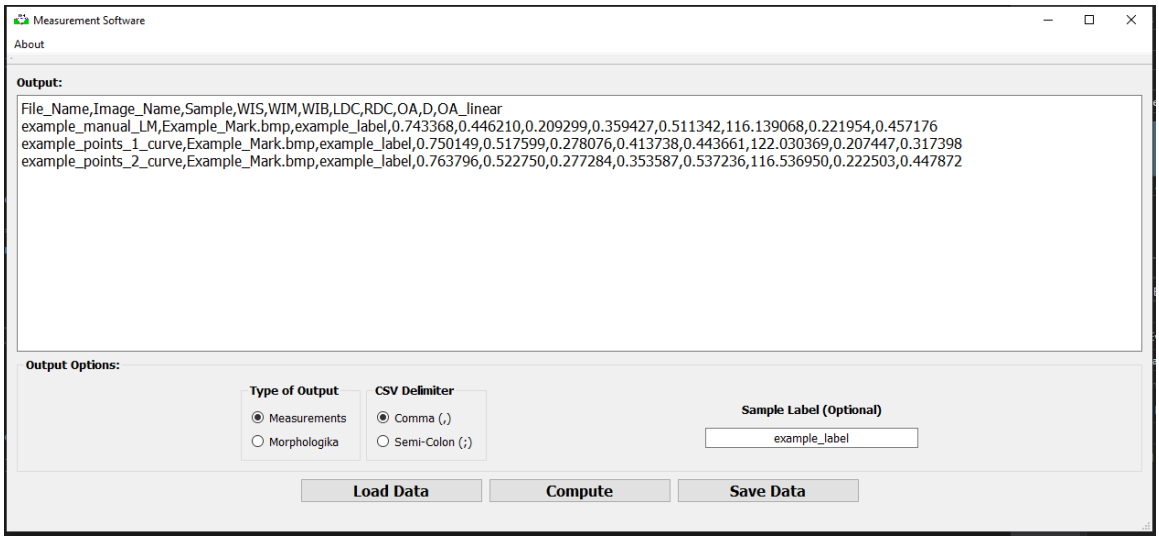

Figure 20: *Example of Measurement Output*

4.2 Creating a Morphologika File

To create a morphologika file for geometric morphometrics applications, the user can simply select the **Morphologika** option in the **Type of Output**. Upon pressing compute (or the Return key), the output will be filled with the morphologika output. If the user wishes to provide a sample label, this can once again be defined.

Morphologika files are formatted in the following way;

- Number of individuals (".tps" files).
- Number of landmarks (7)
- Dimensions (2D)
- File Names
- (Optional) Sample names corresponding to each of the files
- Scaled coordinates (or raw points) corresponding to each of the files.

4.3 Saving measurement or morphologika outputs

Once the user has generated the output, these results can be saved by pressing the **Save Data** button or using the "Ctrl + S" keyboard shortcut. According to the type of output, either a ".csv"

or a ".txt" file will be created, for measurements or morphologika data respectively. When saving, the user is not required to specify the file extension as this will be added automatically. If the user wishes to modify the output prior to saving, they can do so by directly editing the text in the **Output**.

4.4 Possible issues

The present application is designed to prevent the user from creating possibly problematic output files, especially if post-processing is performed in programming languages such as R. This section will go through the possible error or warning boxes that may be produced and how to fix these issues.

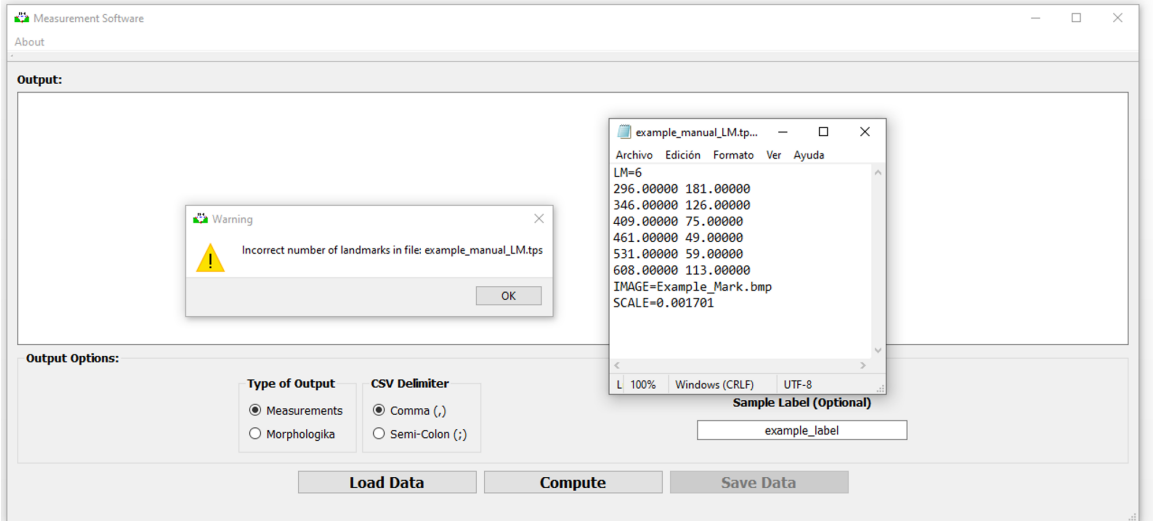

Figure 21: *If a file being processed contains to many or too few landmarks, then the following error will be produced. Within the dialogue box, however, the user will be informed as to which file contains this error. This warning will cause the entire application to close. This warning will cause the entire application to close so the user can fix the problem.*

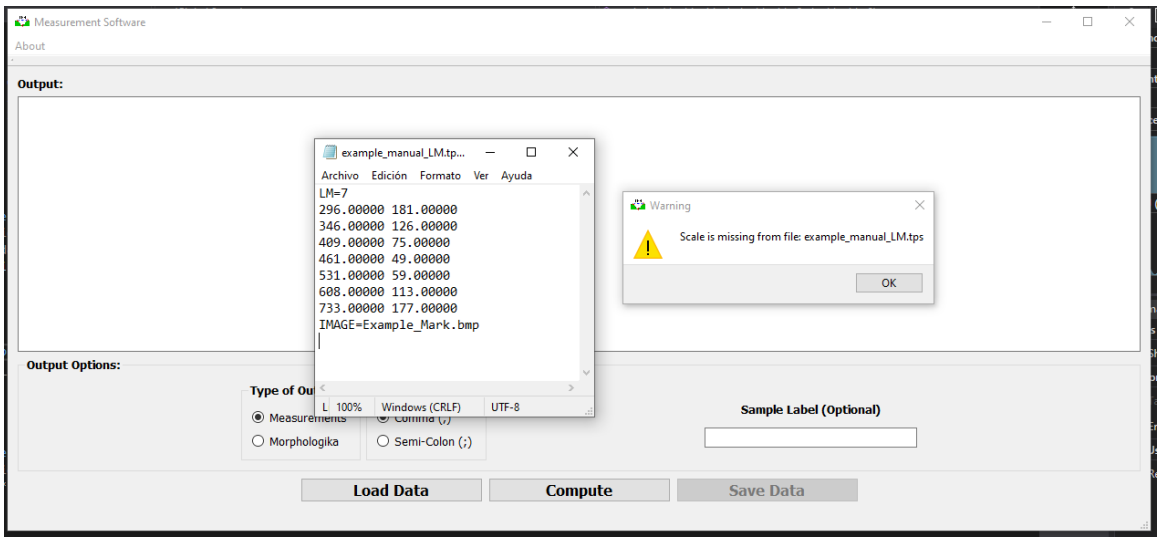

Figure 22: *If a file is missing the scale, then the following error will be produced. Within the dialogue box, however, the user will be informed as to which file contains this error. This warning will cause the entire application to close so the user can fix the problem.*

5 About this Application

This application was written in the C++ programming language (v.17), using elements of the standard C library, the Qt version 6.0.4 library, and was compiled using the Microsoft Visual Studio 2019 (v.16.9.4) compiler (Visual C++ 2019).

This application was designed and written by Lloyd A. Courtenay (ladc1995@gmail.com), of the TIDOP Research Group (`http://tidop.usal.es/`), Department of Cartographic and Terrain Engineering, Higher Polytechnic School of Ávila, University of Salamanca, Spain. All issues or suggestions are welcome contacting with the corresponding author directly.

All source code, alongside the installer, and present instruction manual, are available for free download and distribution at `https://github.com/LACourtenay/Measurement_TPS_GUI`.

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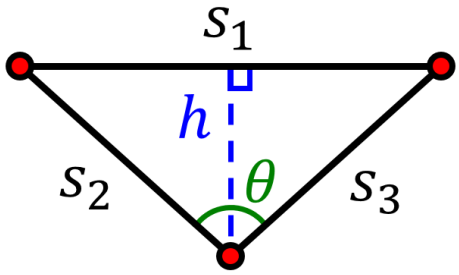
6 Appendix - Measurement Formulae

The calculation of the variables WIS, WIM, WIB, LDC, RDC, OA and D follow the rules of basic trigonometry, representing the bone surface modification's cross section as a triangle, where s_1 through to s_3 are each of the triangle's sides, h is the height of the triangle, and θ is the angle where s_1 and s_2 meet.



The calculation of values s_1 through to s_3 are simply the Euclidean distance (eq. 1) between points, where;

$$d\left(x,y\right)=\sqrt{\sum_{i=1}^{n}\left(x_i-py\right)^2} \tag{1}$$

therefore;

$$s_1=d\left(LM1,LM2\right) \tag{2}$$

$$s_2=d\left(LM1,LM4\right) \tag{3}$$

$$s_3=d\left(LM4,LM7\right) \tag{4}$$

With s_1 being analogous with WIS, s_2 with LDC, and s_3 with RDC. From this perspective, WIM and WIB are essentially $d(LM2,LM6)$ and $d(LM3,LM5)$ respectively.

From here θ (OA) can be calculated through;

$$x=\frac{s_2^2+s_3^2-s_1^2}{2s_2s_3} \tag{5}$$

$$\theta=\arccos(x)*\frac{180}{\pi} \tag{6}$$

while the linear transformation (θ_{lin}) of OA according to [5] is obtained through;

$$r=\theta*\frac{\pi}{180} \tag{7}$$

$$\theta_{lin} = cos\,(r) + sin\,(r) \tag{8}$$

Finally, h is derived in conjunction with heron's formula;

$$p = \frac{s_1 + s_2 + s_3}{2} \tag{9}$$

$$a = \sqrt{p\,(p - s_2)\,(p - s_3)\,(p - s_1)} \tag{10}$$

$$h = \frac{2 * a}{s_1} \tag{11}$$

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