Validating the accuracy of digitized head landmark data

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Student: Aylin Gunal Researcher: B-K. Daniel Park, PhD UMTRI Group: Biosciences

Introduction and Objectives

This study's purpose is to develop a systematic method of assuring the accuracy of digitized data for the UMTRI's Body Parametric Modeling Lab.

The process of digitizing landmark points leaves room for human error, as the process is completely dependent on the researcher's ability to assign landmark points as accurately as possible.This study focused on isolating outlying points as well as studying the context in which such outliers occur in order to minimize such error in the future. Some outliers may occur due to human error or abnormal head shape, but others may occur due to a pattern of variability in a particular landmark point, in which case analysis into factors including human error may be necessary.

The objectives are as follows:

- **Determine if consistently outlying landmark point values are the results of patterns, either in consistent human error, natural variability, or other factors (e.g. difference in researcher doing the digitization).**
- **Isolate individual outlying values and determine whether or not such values occurred due to human error or abnormal head shape. Fix values and resubmit into the dataset.**

Background on Landmarking

- QR Code goes to humanshape.org; see the example of a head model with landmark values in red (click "LandmarkView".

- The process of data digitization consists of scanning hundreds of digital human head scans, projecting them onto a 3D plane, and manually labeling the coordinates of 58 landmark points along the model (red dots). Examples of these landmark points include the foremost point on the nose, the corners of the eyes, the corners of the jaw, and the topmost point of the head.

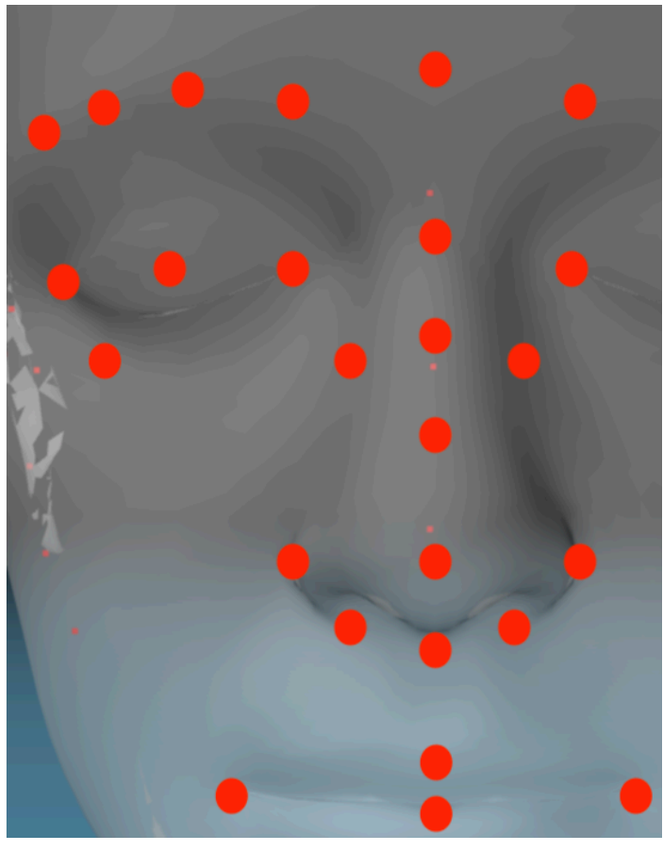
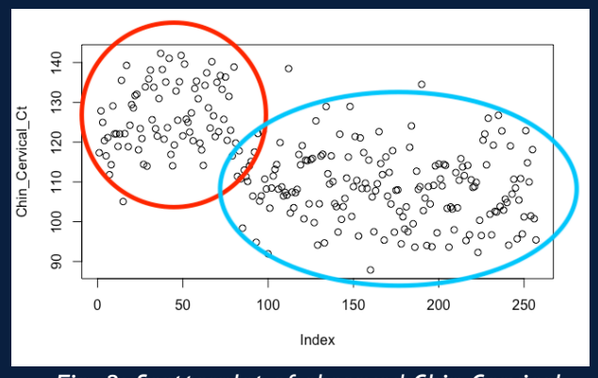


Fig. 1: Example of 3D landmarked head model.

Data Exploration

- Use RStudio to visually explore the data and observe noticeable patterns, particularly through scatterplots and boxplots.



- *Fig. 2: Scatterplot of observed Chin Cervical landmark values. Values in red digitized by Researcher 1, values in blue digitized by Researchers 2 and 3.*

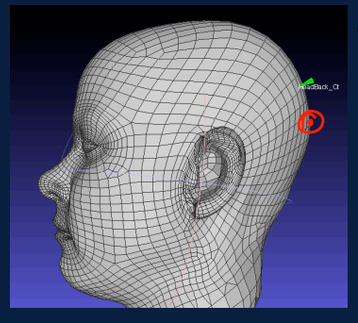
Analysis Methods

Coding in C# in VisualStudio, develop and run the following features:

- **Perform statistical analyses including multiple linear regression and variance analysis in order to study patterns in error (difference between observed and predicted values) and variance across different landmarks.**
- **Perform ANOVA tests across landmark values in order to test the significance of different researchers digitizing landmarks.**
- Isolate individual observations with outlying values from landmark points with demonstrated patterns of variability and manually check for either human error or abnormal head shape.

	HeadTop_Ct	HeadBack_Ct	Head_Occiput_Ct
Root Mean Square Error	4.26808648	4.74230749	4.959122171
R-Squared Value	0.829112994	0.758971902	0.769594451
Variance	107.0100434	93.6653382	107.1479436
ANOVA p-val	0.834774549	0.906031597	0.780792376

- *Fig. 3: Sample of error report generated through analysis methods discussed. High error and high variance values highlighted.*



- *Fig. 4: Outlier example. Outlying point (green pin) for the point farthest back on the head. The correct spot is clearly lower (red circle).*

Evaluation and Discussion

After standardizing the results, the following statistics — for the top five landmarks of their respective groups of analysis — are of interest:

- Group 1: In regards to the regression analysis, points with high margins of error between observed and predicted values coupled with high variance are of note. The relatively high residual values indicate that **other landmark points are not entirely effective in predicting these landmark points, and the high variance implies that these landmark points vary greatly from person to person.**
  Resulting landmark points: points halfway along the left and right ears, topmost point on head, back of the head, head occiput.

- Group 2: Also in regards to the regression analysis, points with relatively low error and high variance are of note. The combination suggests that that **these points are typically digitized accurately despite demonstrating natural variability from person to person.**
  Resulting landmark points: all points along the lips, all points along the chin, the corners of the jaw.

- Group 3: The ANOVA tests indicated, with significance value of .1 — significant points are those with p-values < .1 — **that several landmark values differ when digitized by different researchers.**
  Resulting landmark points: right and left ear tragus, points underneath the chin.

- Group 4: Several outliers were observed, the majority of which were the results of isolated instances of human error or abnormal head shape, and easily fixed.

The patterns present in Group 1 indicate several landmark points that are consistently digitized inaccurately, and the patterns present in Group 3 indicate particular landmark points that are consistently digitized differently by different researchers. Going forward, clear and highly detailed guidelines on how to digitize these particular points may be utilized in order to minimize the number of inaccurate digitizations.

Group 2's results open up an avenue for research into factors outside of human error and values of surrounding landmarks that cause these points to vary. For instance, gender, age, and ethnicity may be factors of note to test for significant impact on these landmark values.