



## **Workflow Analysis to Understand Ease of Preparation and Importation of 3D Exemplar Head Scan Data to 3D Modeling Software Programs for N95 Mask Sizing and Fit**

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At the height of the COVID-19 pandemic, while consulting with a local hospital regarding materials testing for N95 particulate resistance, the PI was introduced to the resident mask fitter who explained the challenges women and minorities experienced with sizing and fit. These issues have also been identified by Zhuang, Bradtmiller & Shaffer (2007) and Regli, Sommerfield & von Ungern-Sternberg (2021). With a research interest in product sizing and fit for underserved populations, the PI felt this issue was timely to investigate, to help manufacturers develop better mask patterns that considered all head shapes and provided equitable safety. A study was conducted using available CAESAR 3D scan North American dataset (2002) (due to restrictions with human subject data collection), to investigate through machine learning how 3D head data and digital modeling tools could inform future N95 mask sizing and fit.

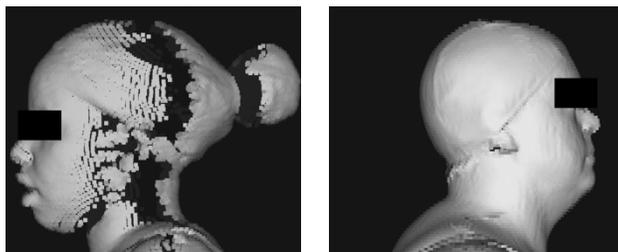
To do this work, the PI worked with a data scientist who analyzed the CAESAR dataset with an un-supervised machine learning technique called a “variational auto-encoder,” and identified three exemplar heads for each sex (male/female) and race (White, African American, Spanish/Hispanic, and Asian) combination – totaling to eight size sub-groups and 24 heads. The machine learning analysis technique used a process where facial features in each scan were simplified to a 3D number that best represented each scan and could easily be compared, grouped, and studied to identify the exemplars that best spanned the dataset. From identifying the exemplars, the research team conducted three sub-studies:

1. A statistical comparative analysis of anthropometric measures taken from the exemplar heads to validate if machine learning is a viable method of sorting large data sets to develop sizing and fit and fit systems of products.
2. A workflow analysis to understand ease of preparation and importation of 3D exemplar head scan data for use in 3D modeling programs (Browzwear and CLO), for N95 mask sizing and fit.

3. A workflow analysis to understand ease of importing, stitching, and dressing N95 mask patterns on exemplars with current 3D modeling programs (Browzwear and CLO).

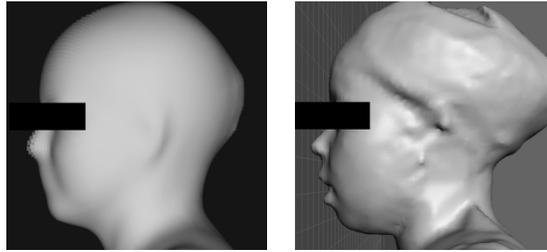
This concept abstract will discuss the challenges of preparing and importing 3D exemplar head scan data for use in 3D modeling software programs (Browzwear and CLO), for N95 mask sizing and fit analysis. Three concerns were discovered and included access to good 3D head scans, the ability to make accurate water-tight scan files, and the ability to dress scan files in modeling software programs.

The first challenge identified was the availability of good 3D head scan data. Good data includes quantity, diversity, accuracy, and completeness. The CAESAR North American data set does include 2400 accurate scans, but it is not racially diverse (Robinette & Daanen, 2006). As an example, 77% of the combined male and female scans were of White individuals. Along with diversity, another issue was data completeness. In most of the scans, the zone along the frontal plane (by the ears) was consistently missing (Fig. 1). This is a major issue for mask modeling in Browzwear and CLO. Are there are other large data sets that are of better quality? The short answer is no, unless you have a large budget to buy data (i.e., Size NA), run your own study (challenging due to COVID) or have expensive equipment to capture high-quality scans (i.e., gaming industry). Even the recent data collected for Size NA (2017) had challenges where the ears were often covered by the skull caps worn by subjects (Fig. 1). So, how could we work with this type of data, especially when developing PPE for diverse users is so critical?



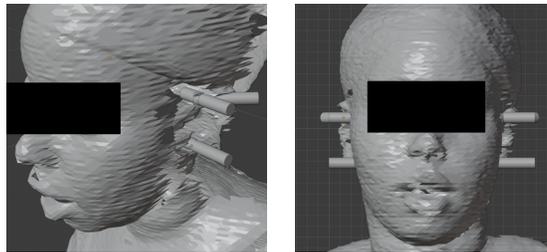
**Fig. 1.** 3D head scan challenges (left, CAESAR & right, Size NA).

In traditional full-body scanning studies, incomplete scans can be made watertight by patching them through AnthroScan or other 3D programs like Autodesk Meshmixer or Geomagic. For this study, these programs were unable to accurately patch – they augmented face shapes, along with changing race characteristics (Fig. 2). Scans could be remodeled by hand, but doing so would be costly, laborious and an artist's rendition of a head. For purposes of the work, it was deemed that the incomplete head scans were preferable because the facial characteristic were most important.



**Fig. 2.** Issues of making water-tight 3D head scan files (left AnthroScan & right Meshmixer).

Because the original, incomplete scans were determined to be better than the watertight versions, the next challenge was how to address the ear region, so that could be imported and dressed in the 3D modeling software programs. Without a proper “ear hook” the mask cannot anchor to the head and will fly away when dressing. Even with a high-end head scan this may be needed. The researchers created “surrogate ears” by bringing the exemplar heads into Blender and inserting cylinders through the top and bottom of the ear location to enable dressing (Fig. 3).



**Fig. 3.** Surrogate ear solution to dressing exemplars in 3D modeling software.

The goal of the work was to raise awareness to the ITAA community of the barriers with current data and 3D technologies for developing PPE for the head/face. It was not as easy as it should be. It is hoped this work could start a conversation with other data collectors and technology developers to share and improve tools for better efficiency and accuracy.

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