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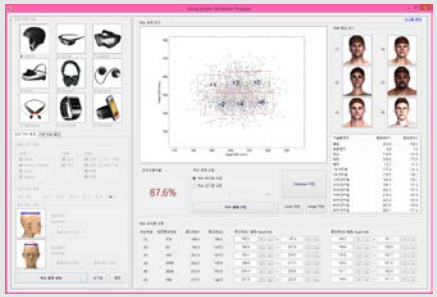
Young University Rankings

Ergonomic Design Technology Lab

# Development of Headforms and an Anthropometric Sizing Analysis System (3D-ASAS) for Head-Related Product Designs



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Global Contributor to Eco-Techno-Humanopia

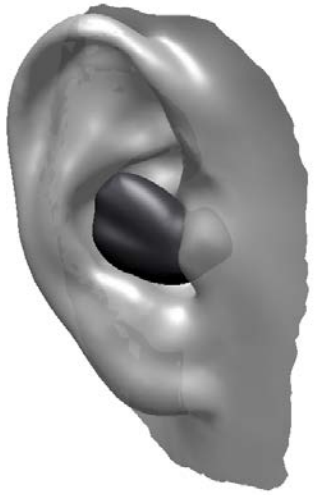
# Contents

- Introduction
  - Background
  - Objectives of the Study
- Analysis of CAESAR 3D Scan Data
- Development of 3D-ASAS
- Development of headforms
- Discussion

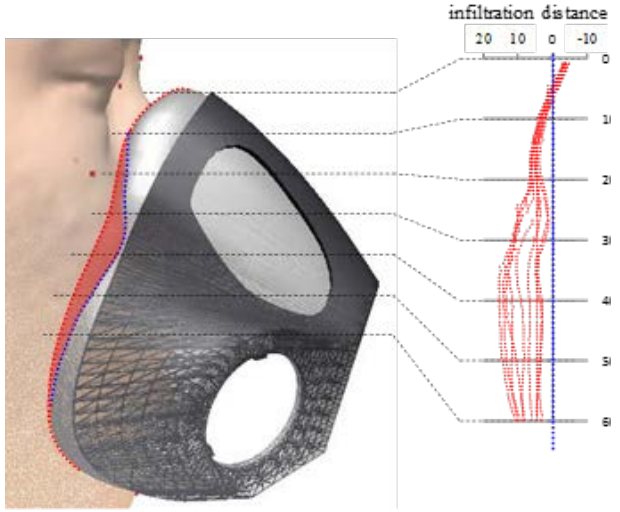
# Usefulness of 3D Body Scans for Product Design

- Support various and detailed measurements
- Support complex dimensions (e.g., curvature, shape, area, volume) which are directly applicable to product designs

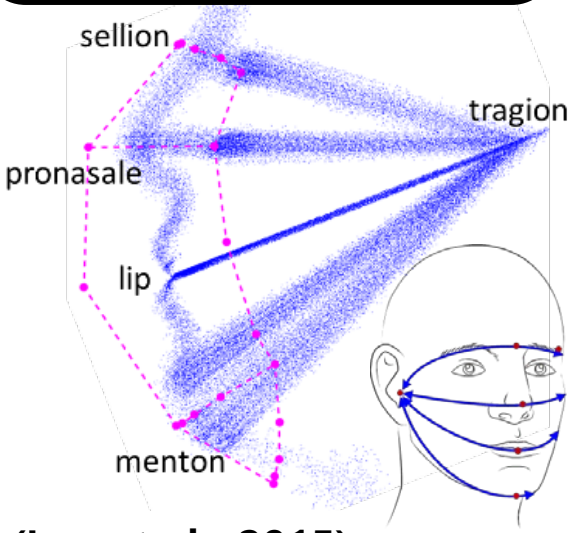
Design of earset based on size and shape of representative ear found from 300 ears



Virtual fit analysis for an optimal design of pilot's oxygen mask by applying all 336 3D facial shapes




Design of dust-proof mask based on key 3D curvatures of the face ($N$ = 336)




Application of 3D scan images to the product designs (Lee et al., 2015)

# CAESAR Database

- **Civilian American European Surface Anthropometry Resource (CAESAR)**
  - ✓ **Survey year: 1998 ~ 2001**
  - ✓ **Sample size**
    - **2,400 North Americans (USA, Canadian)**
    - **2,000 Europeans (Dutch, Italian)**
  - ✓ **Ethnicity**
    - **Caucasian (82%; *N* = 3,500)**
    - **African American (6%; *N* = 300)**
    - **others (Asian, Hispanic, and ethnic minorities; 12%; *N* = 600)**
  - ✓ **Age: 18 ~ 65**
  - ✓ **Database**
    - **3D scan images (3 postures)**
    - **80 landmarks**
    - **40 traditional measurements**
    - **60 3D measurements**
    - **demographic information**

http://www.sae.org/standardsdev/tsb/cooperative/caesumm.htm

# Needs of Post-Processing of CAESAR Image

- **Poor quality or unnatural shape in CAESAR 3D heads**
  - ✓ **Large uncaptured area on the left side of head**
  - ✓ **Lots of holes**
  - ✓ **Unnaturally volumized hair**

⇒ **Post-processing is required for better use to the product design**

# Needs of Sizing System and RHMs Analysis System

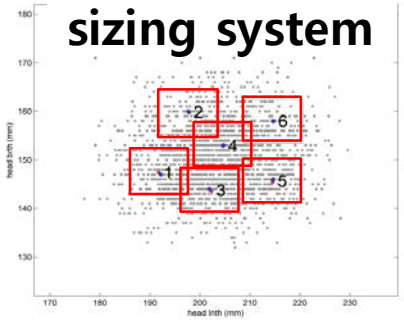
- **Sizing system** and **representative human models (RHMs)** are more useful than raw 3D scan database for product designers

Product designer

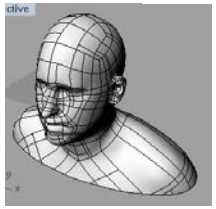
hundreds of
raw 3D scan images

Vs.

sizing system




RHMs



Product designer

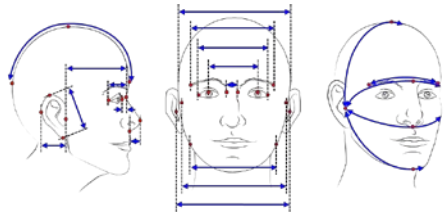
- However, **statistical analyses of sizing system and RHMs are quite complex** to be performed by product designers

⇒ **A computerized program** is required **for easy and convenient analyses of sizing system and RHMs** for PD practitioners

# Objectives

**Development of Headforms and an Anthropometric Sizing Analysis System (3D-ASAS) for Head-Related Product Designs**

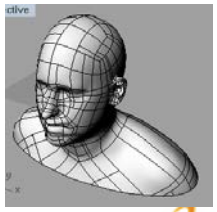
1. Identification of design dimensions and head anthropometric dimensions for head-related product designs



2. Post-processing of CAESAR 3D head images for the measurement of head dimensions

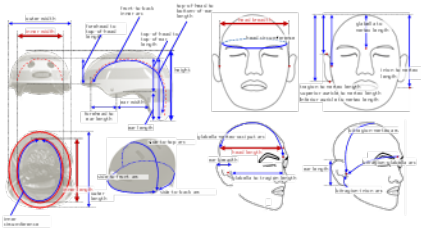
3. Development of a computerized system (3D-ASAS) which supports the product design in terms of anthropometric analysis, sizing system generation, and RHMs analysis

4. Utilization of 3D-ASAS to develop digital and physical headforms applicable to the product design

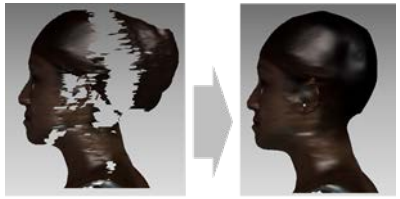


# Approach

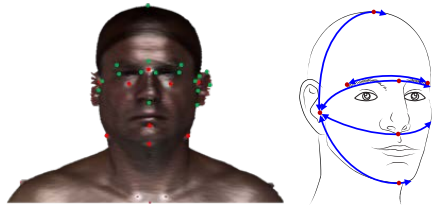
**S1** Identification of **product design dimensions** and related **head anthropometric dimensions**



**S2** **Post-processing** of CAESAR 3D heads



**S3** **Landmarking** and **anthropometric measurement** of CAESAR heads



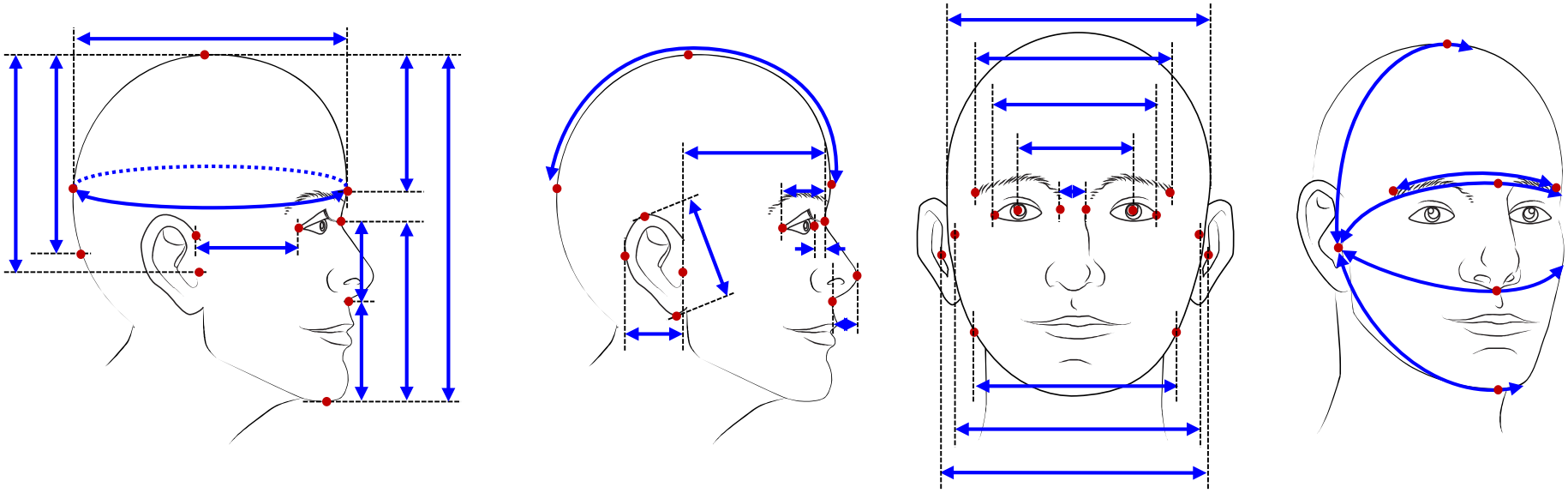
**S4** Development of **3D-ASAS**

**S5** Development of **headforms**

# S1. Identification of Head Anthropometric Dimensions

- **Identified 122 head dimensions by referring to 18 previous studies**
  - ✓ **Length dimensions: 53**
  - ✓ **Depth dimensions: 29**
  - ✓ **Width dimensions: 18**
  - ✓ **Circumference/arc dimensions: 22**

**Illustration of head and facial dimensions**



# Type of Products

- **Determined 7 head-related products through discussion of a panel of ergonomists and expert product designers**

helmet

glasses

google

HMD

headphone:
headband type

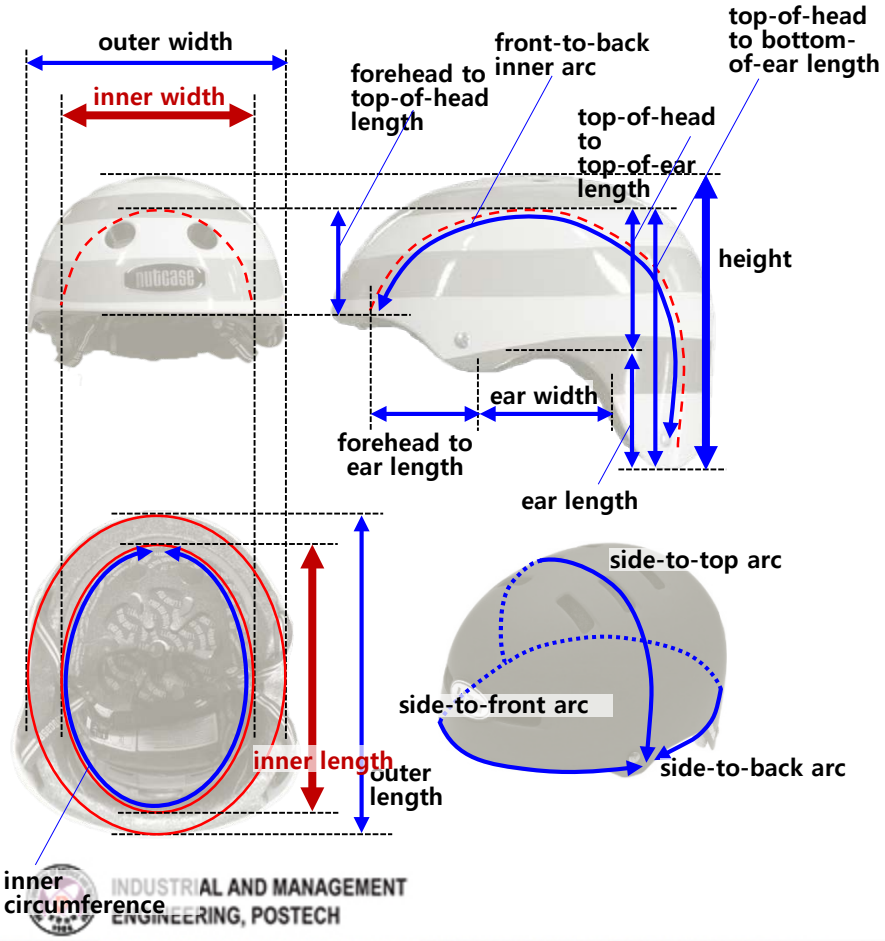
headphone:
neckband type

neckband

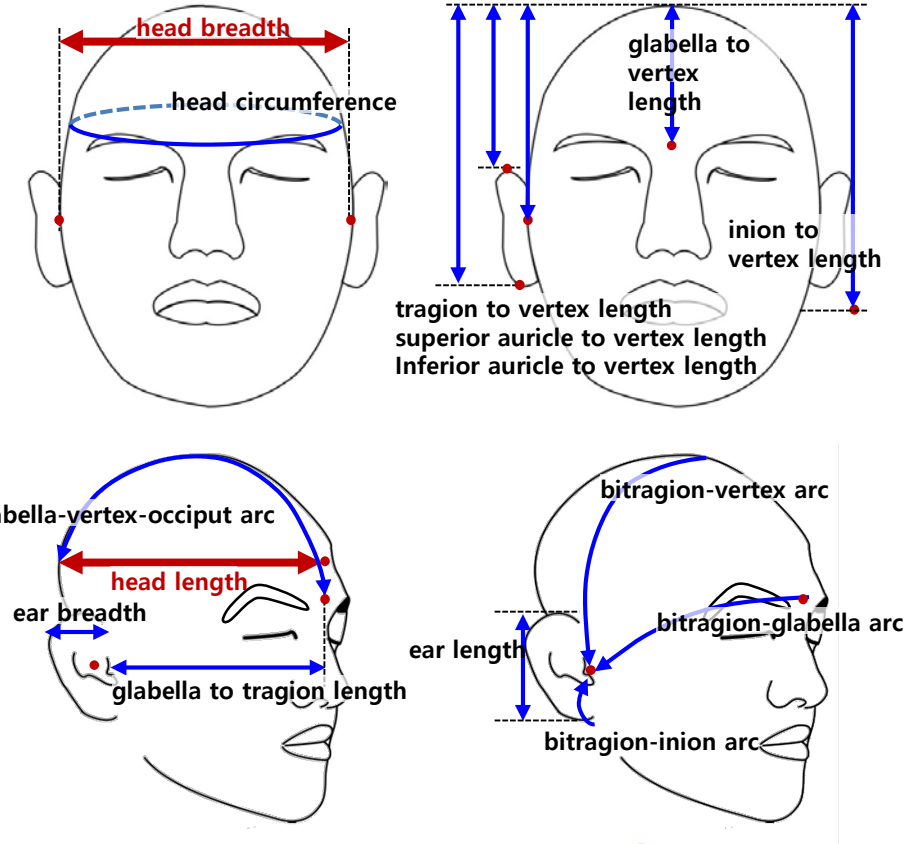
# Design Dimensions and Related Head Dimensions: Helmet

- Identified **design dimensions** and **related head dimensions** for each product

## Design dimensions (16)




## Head dimensions (18)




red: key dimensions

# Key Design & Anthropometric Dimensions

- Identified **key design dimensions** and **related key anthropometric dimensions** for each product

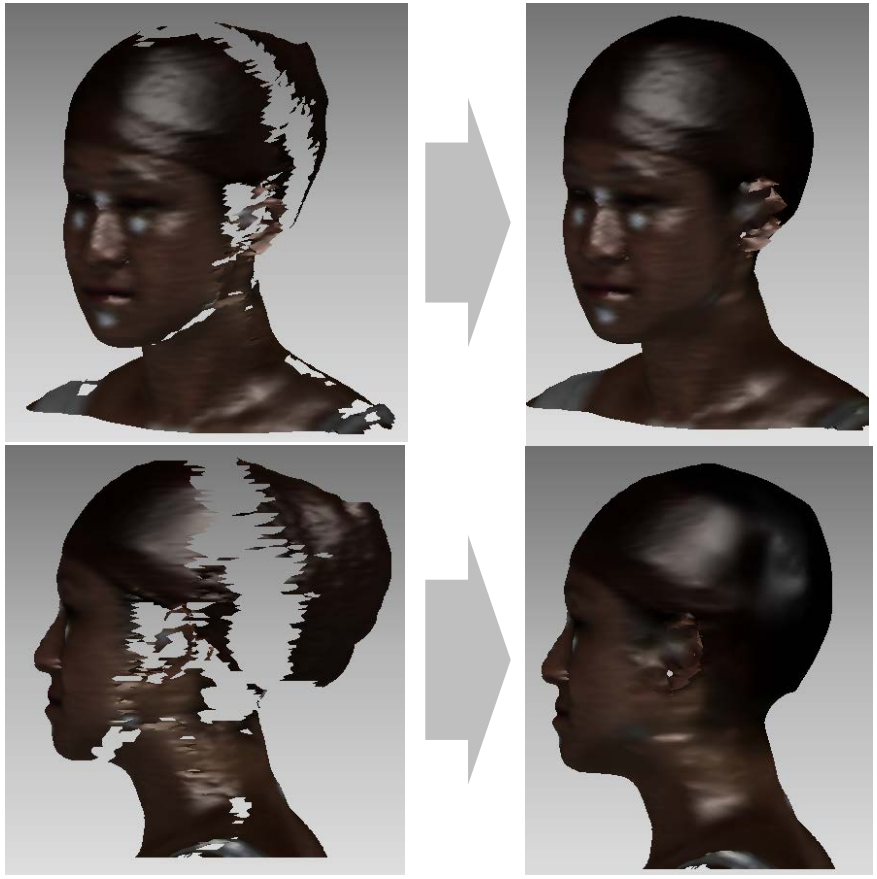
| No. | Product type | | Key design dimension | Related key anthropometric dimension |
|---|---|---|---|---|
| 1 | Helmet |  | inner length | head length |
| | | | inner width | head breadth |
| 2 | glasses |  | width | biocular breadth |
| | | | frame length | otobasion superius to ectocanthus length |
| 3 | goggle |  | glass arc | bizygofrontale arc |
| | | | frame length | otobasion superius to ectocanthus length |
| 4 | HMD |  | forehead arc | bizygofrontale arc |
| | | | zygomatic arc | bizygomatic-subnasale arc |
| 5 | headphone: headband type |  | headband length | bitragion-vertex arc |
| | | | inner width | bitragion breadth |
| 6 | headphone: neckband type |  | neckband arc | bitragion-inion arc |
| | | | inner width | bitragion breadth |
| 7 | neckband |  | circumference | neck circumference |

# S2. Sample of CAESAR Post-Processed

| No. | Category | Male | | Female | |
|---|---|---|---|---|---|
| 1 | **Used in this study (*N* = 2,299)** | **1,086** | **96.8%** | **1,213** | **96.1%** |
| | - Caucasian | 862 | 76.8% | 956 | 75.8% |
| | - African American | 111 | 9.9% | 147 | 11.6% |
| | - Asian | 81 | 7.2% | 92 | 7.3% |
| | - Hispanic | 32 | 2.9% | 18 | 1.4% |
| 2 | **Excluded samples** | **36** | **3.2%** | **49** | **3.9%** |
| | - Ethnic minorities | 23 | 2.0% | 41 | 3.2% |
| | - Heads have huge uncaptured area | 7 | 0.6% | 1 | 0.1% |
| | - Heads much deformed during scanning | 2 | 0.2% | 5 | 0.4% |
| | - Heads with no ethnic information | 2 | 0.2% | 1 | 0.1% |
| | - Inappropriate data structure | 2 | 0.2% | - | - |
| | - Head with eye patch | - | - | 1 | 0.1% |
| | **total** | **1,122** | **100%** | **1,262** | **100%** |
| | | **2,384** | | | |

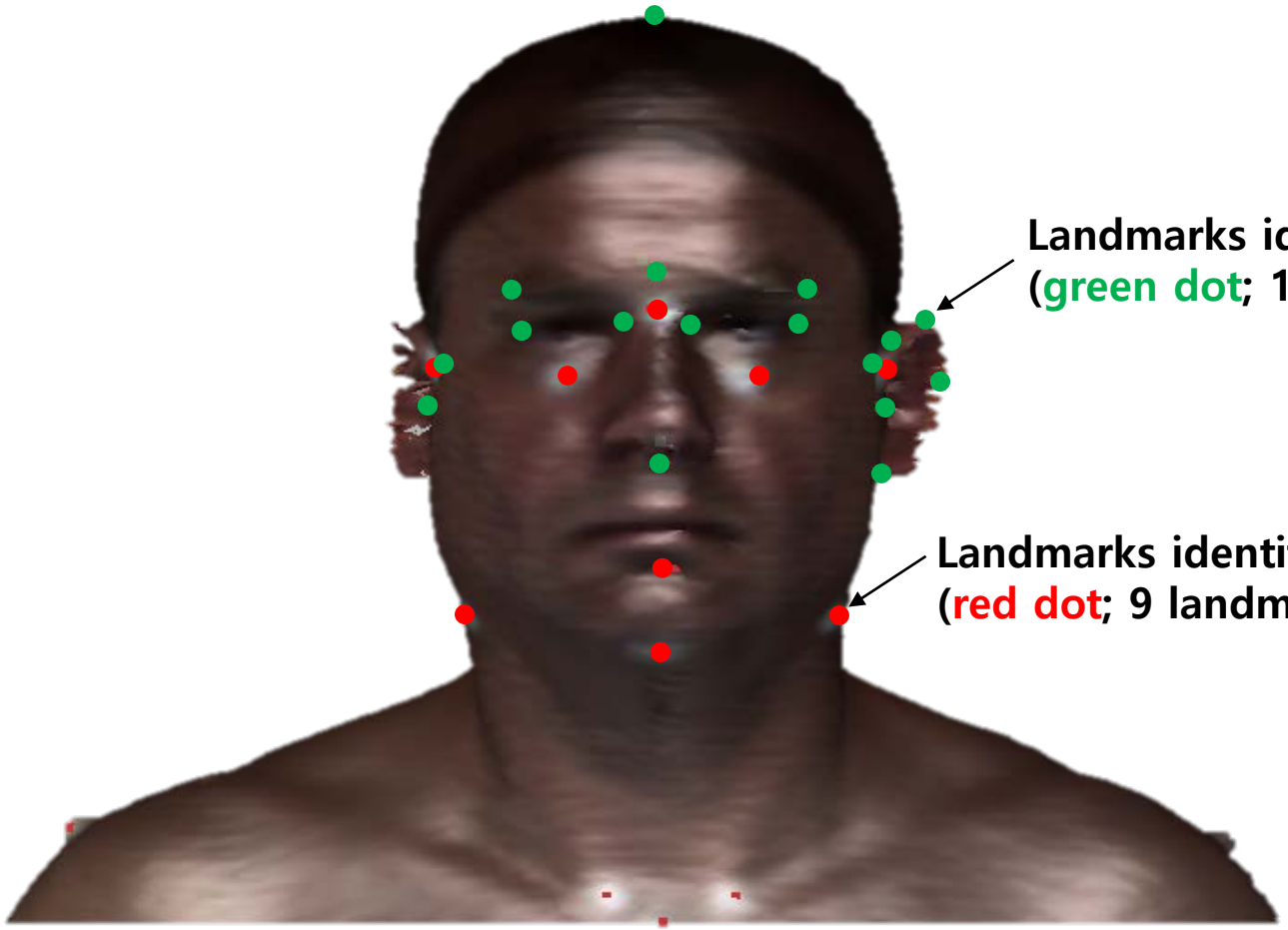
# Post-Processing of CAESAR Heads

- **Manual post-processing** of 2,299 CAESAR heads
  - ✓ Hole-filling
  - ✓ Modification of hair style
  - ✓ Smoothing
  - ✓ Elimination of unnatural features
  - ✓ Rotation of head
  - ✓ Landmarking
- Processing time: 260h



# S3. Landmarks Used in This Study

- **Manual identification of 19 additional landmarks for the measurement of 30 head dimensions**

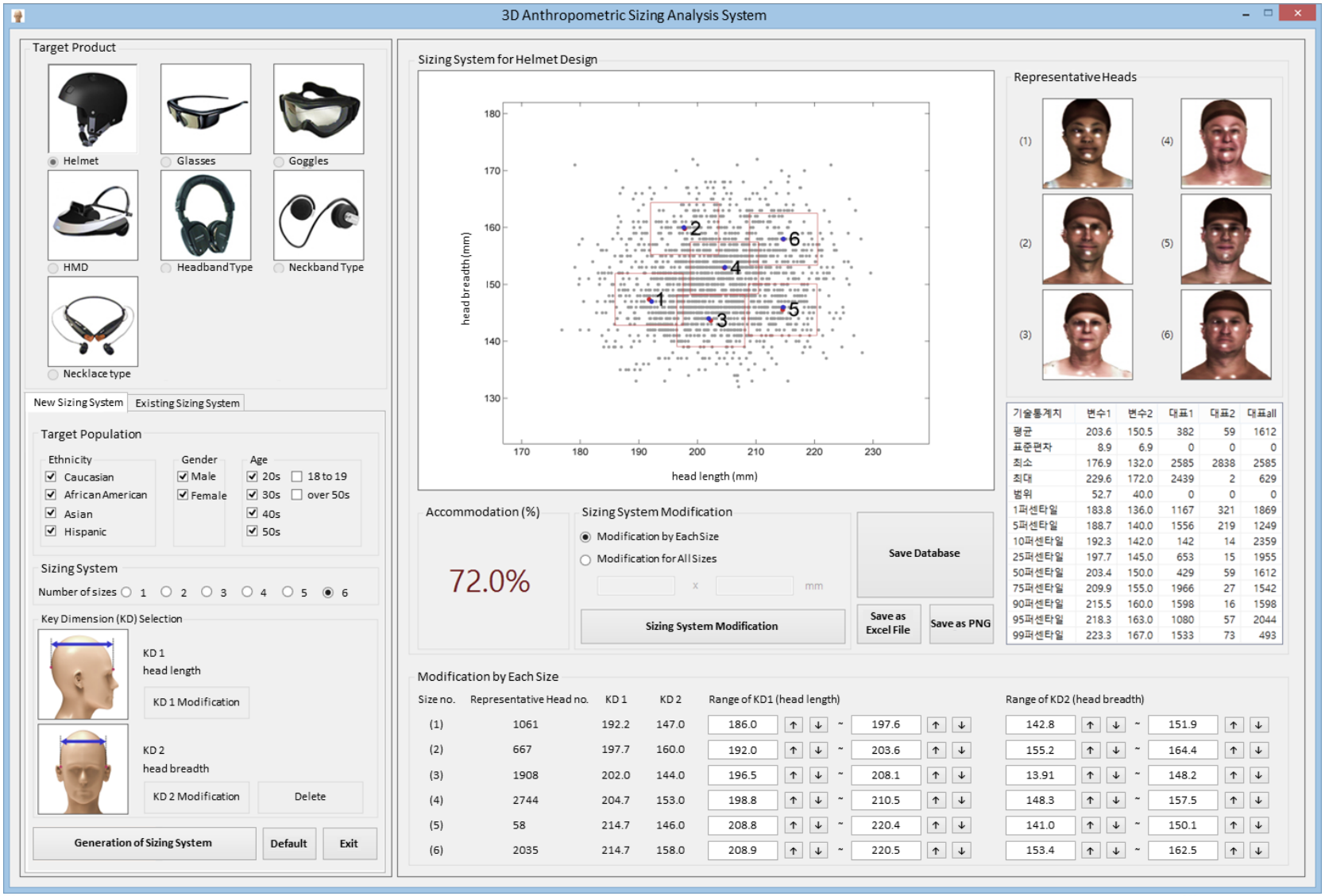


# Measurements: Caucasian Male

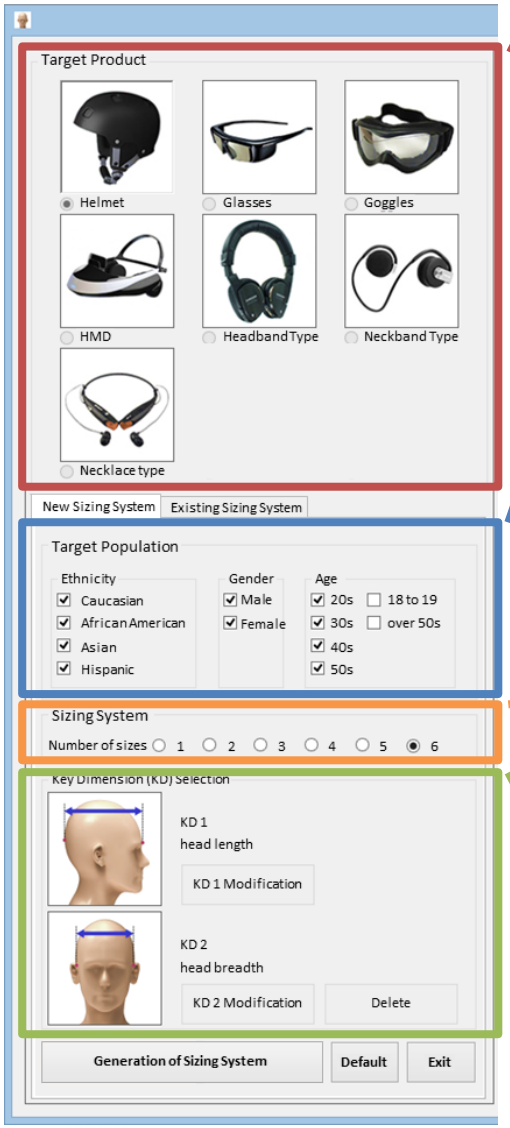
- **All head dimensions were automatically measured using a Matlab program by ethnic group**

| No. | Anthropometric dimensions | N | Mean | SD | Min | Max | Percentile | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1st | 5th | 95th | 99th |
| 1 | head height | 854 | 229.7 | 12.8 | 193.9 | 274.6 | 200.7 | 208.9 | 250.2 | 259.3 |
| 2 | head length | 862 | 195.4 | 9.3 | 169.0 | 219.0 | 174.0 | 180.0 | 210.0 | 214.0 |
| 3 | head breadth | 854 | 151.5 | 6.9 | 135.0 | 172.0 | 137.0 | 141.0 | 163.0 | 167.0 |
| 4 | head circumference | 854 | 568.1 | 20.8 | 512.0 | 622.0 | 522.0 | 534.0 | 602.0 | 613.0 |
| 5 | face length | 854 | 123.8 | 9.0 | 101.7 | 159.7 | 105.4 | 109.9 | 139.1 | 148.9 |
| 6 | face width | 862 | 144.3 | 8.8 | 119.0 | 171.7 | 126.8 | 131.1 | 159.5 | 167.5 |
| 7 | inion to vertex length | 857 | 164.3 | 10.6 | 132.9 | 195.4 | 141.6 | 147.5 | 182.6 | 188.8 |
| 8 | glabella to vertex length | 862 | 88.1 | 7.1 | 69.7 | 107.3 | 72.4 | 76.3 | 99.6 | 104.0 |
| 9 | tragion to vertex length | 859 | 141.1 | 7.1 | 120.8 | 162.2 | 125.3 | 129.8 | 153.6 | 158.8 |
| 10 | menton to subnasale length | 854 | 70.9 | 7.0 | 51.8 | 107.2 | 56.8 | 60.4 | 82.7 | 90.1 |
| 11 | ear length | 861 | 58.2 | 5.9 | 40.1 | 75.2 | 45.6 | 48.9 | 68.3 | 71.4 |
| 12 | nose length | 862 | 53.0 | 4.1 | 41.1 | 64.4 | 44.1 | 46.5 | 59.9 | 62.3 |
| 13 | sellion to ectocanthus length | 860 | 18.9 | 3.5 | 8.8 | 29.6 | 10.8 | 13.1 | 24.9 | 26.9 |
| 14 | sellion to tragion length | 861 | 93.3 | 6.0 | 75.4 | 111.2 | 80.5 | 83.6 | 102.9 | 108.0 |
| 15 | nose protrusion | 862 | 16.1 | 2.8 | 6.7 | 25.9 | 9.3 | 11.5 | 20.7 | 23.0 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

# S4. Development of 3D Anthropometric Sizing Analysis System (3D-ASAS)

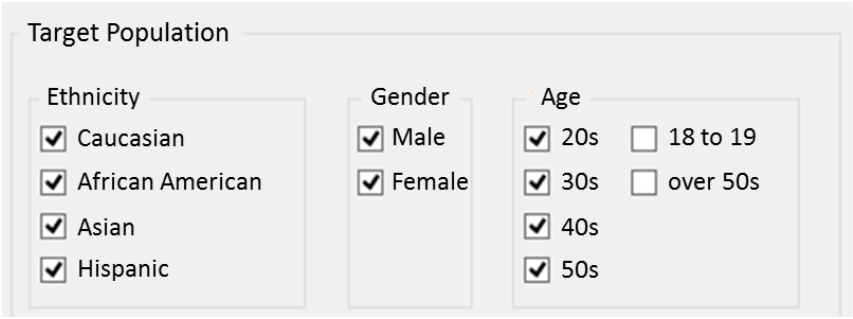


# System Interface: Input

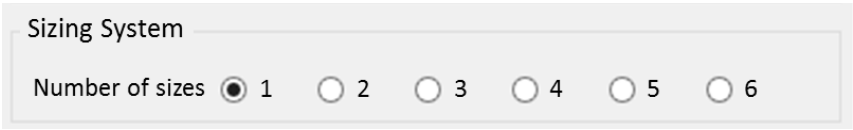



## S1. Selection of target product

## S2. Selection of target population




## S3. Selection of number of size categories for sizing system




## S4. Selection of key anthropometric dimensions

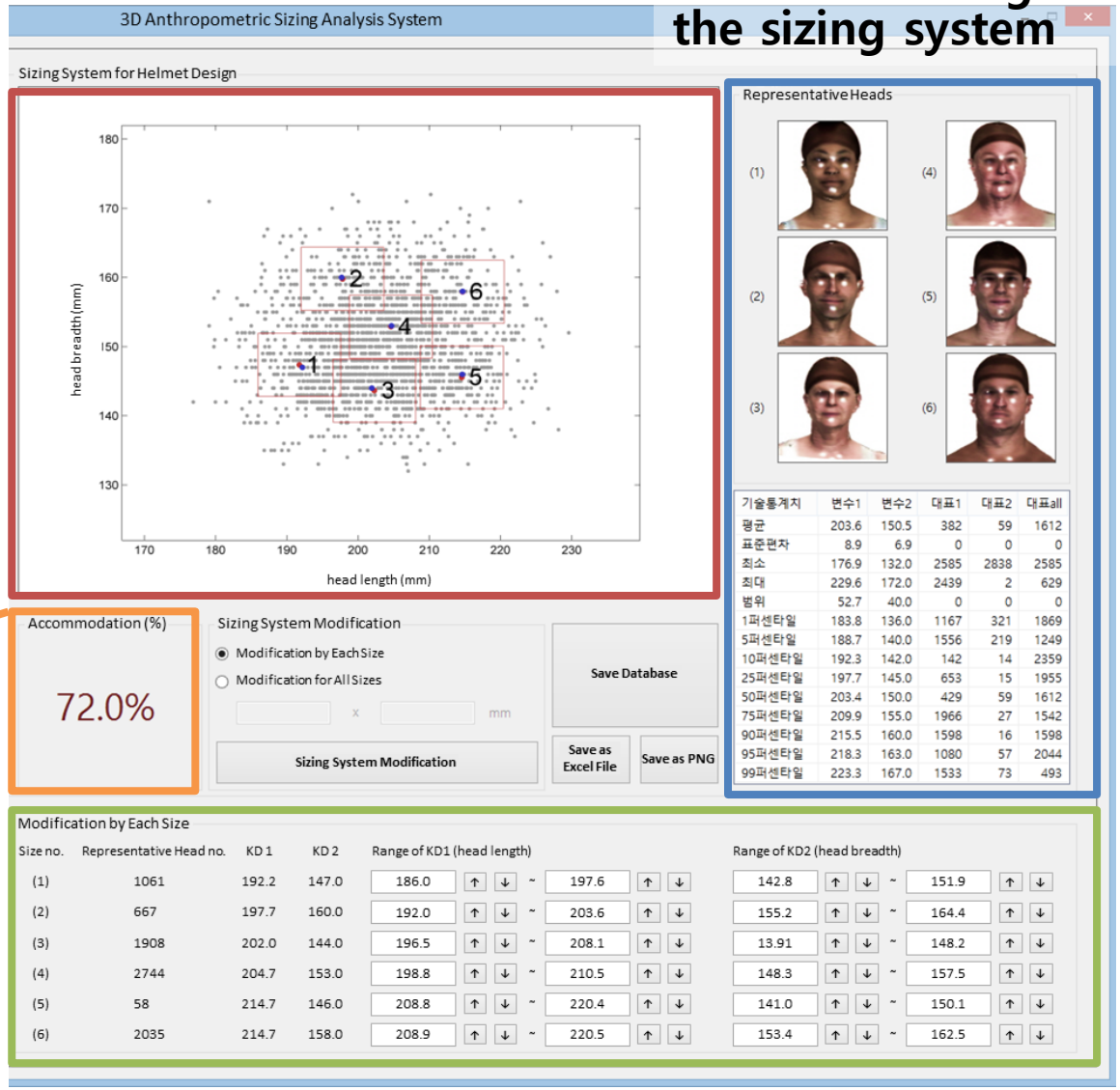
# System Interface: Output

**Representative heads according to the sizing system**

**Sizing system**

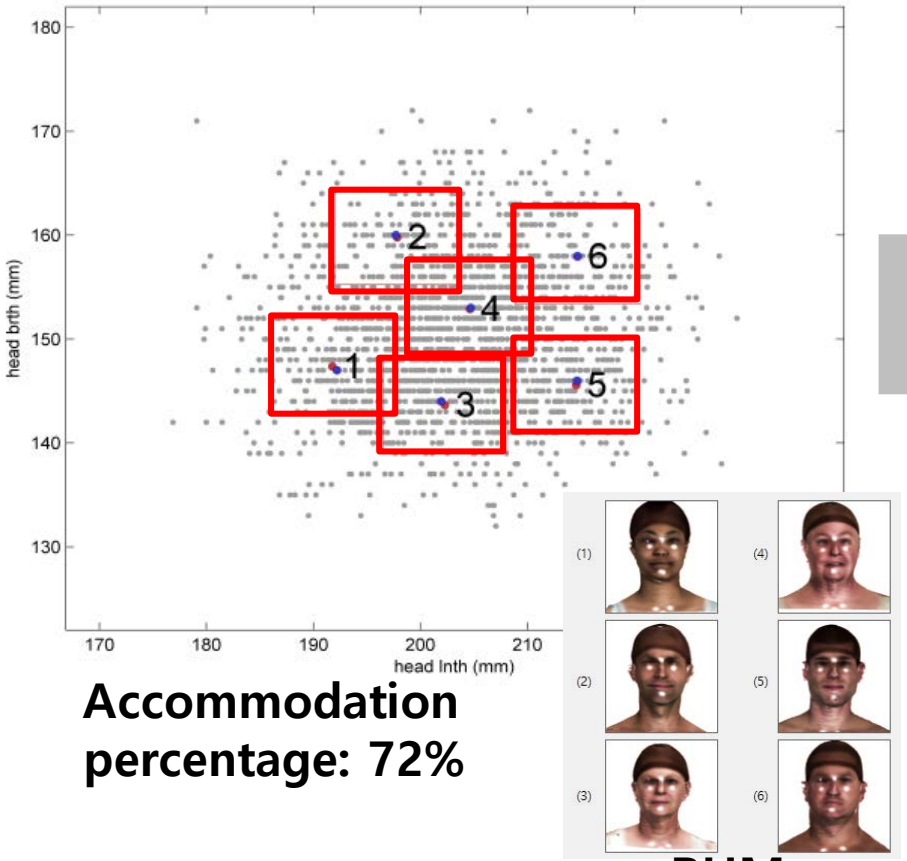
**Accommodation percentage of the generated sizing system**

**Interface for adjustment of the sizing system**



# Adjustment of Sizing System (Illustrated)

**Initial sizing system recommended by 3D-ASAS**



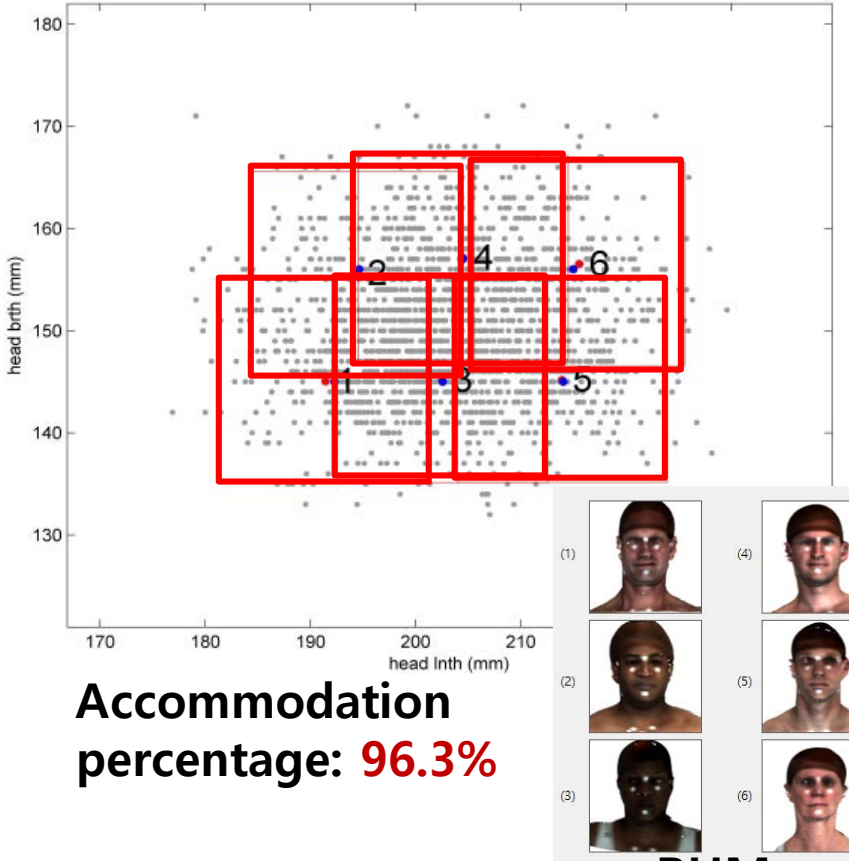




**Accommodation percentage: 72%**

**RHMs**

**Manually adjusted sizing system for better accommodation**







**Accommodation percentage: 96.3%**

**RHMs**

# Demonstration of 3D-ASAS

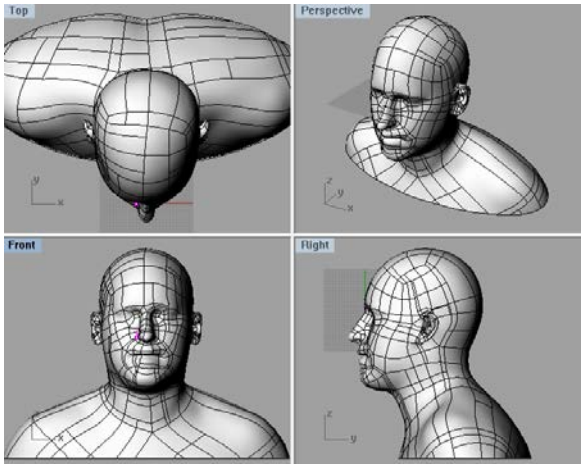
video
(https://www.youtube.com/watch?v=xZQUeWhfqXk)

# Development of Headforms

- **Digital and 3D-printed physical headforms developed based on RHMs extracted through 3D-ASAS**

**Original CAESAR scan (format: point cloud mesh)**

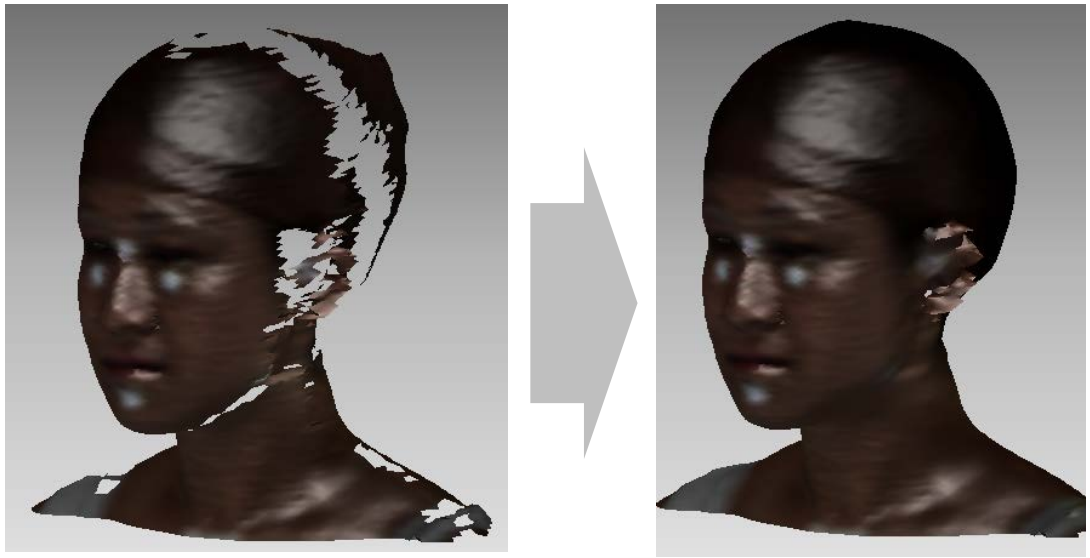
**Edited model (format: NURBS)**




**3D printed model**

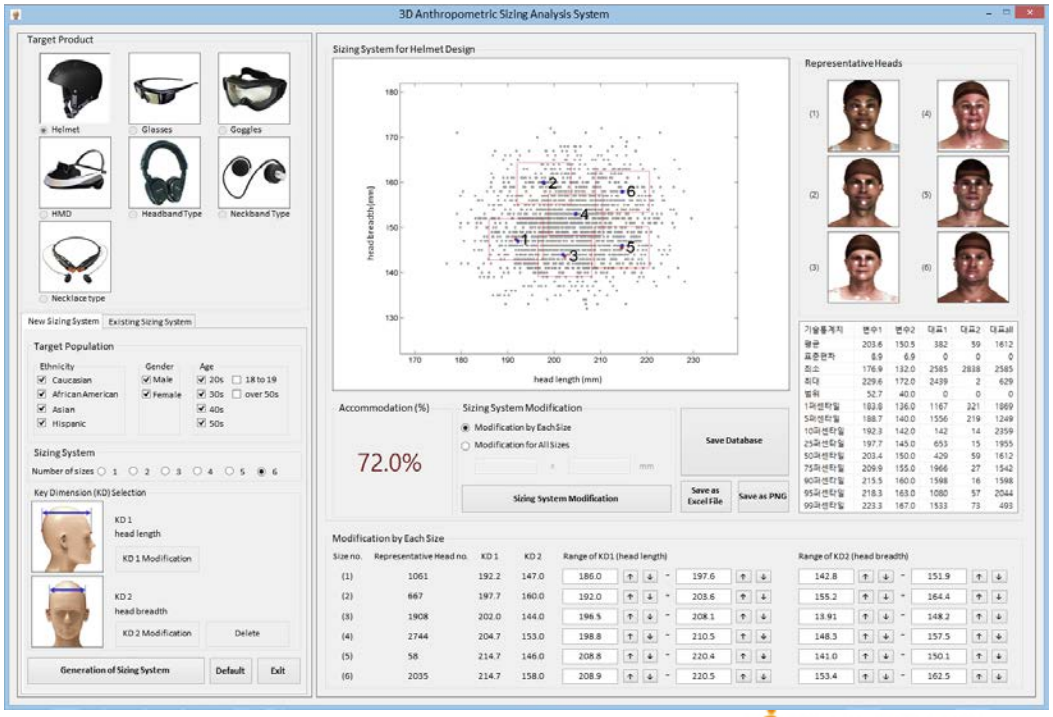
# Contribution: Improvement of CAESAR Heads

- This study devoted effort to improve quality of CAESAR 3D head images for its useful application to the head-related product designs
- Improved database (*N* = 2,299) is applicable to further head and facial anthropometric studies
  - ✓ Post measurement
  - ✓ Shape analysis
  - ✓ Virtual fitting



# Contribution: 3D-ASAS

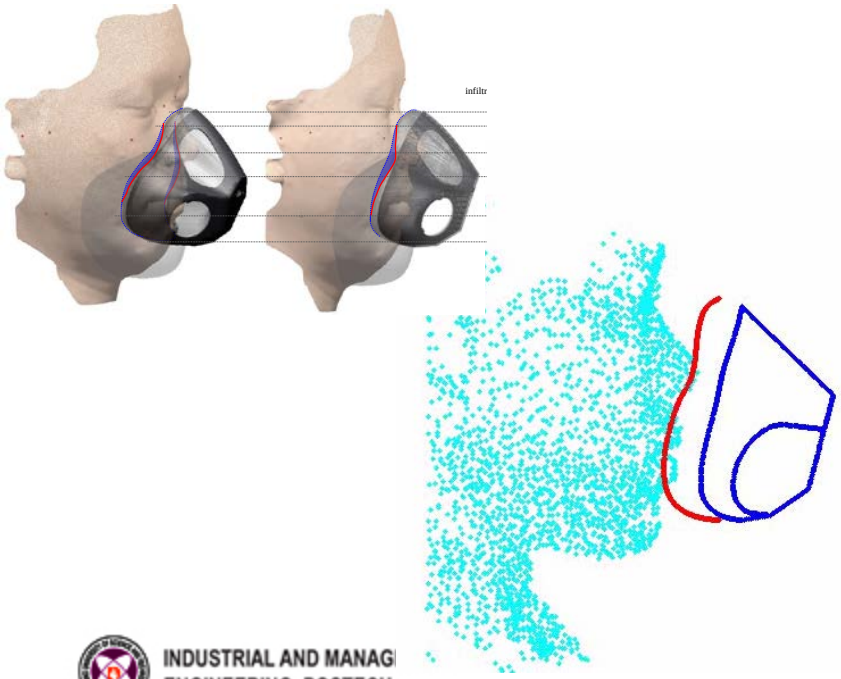
- 3D anthropometric sizing analysis system (3D-ASAS) was developed for a convenient utilization in the product design process
- System function and interface were developed based on PD practitioners' needs
  - ✓ User-friendly interface
  - ✓ Descriptive statistics of measurements
  - ✓ Statistic-based analysis
  - ✓ Generation of sizing system
  - ✓ Recommendation of RHMs
  - ✓ Save and load results



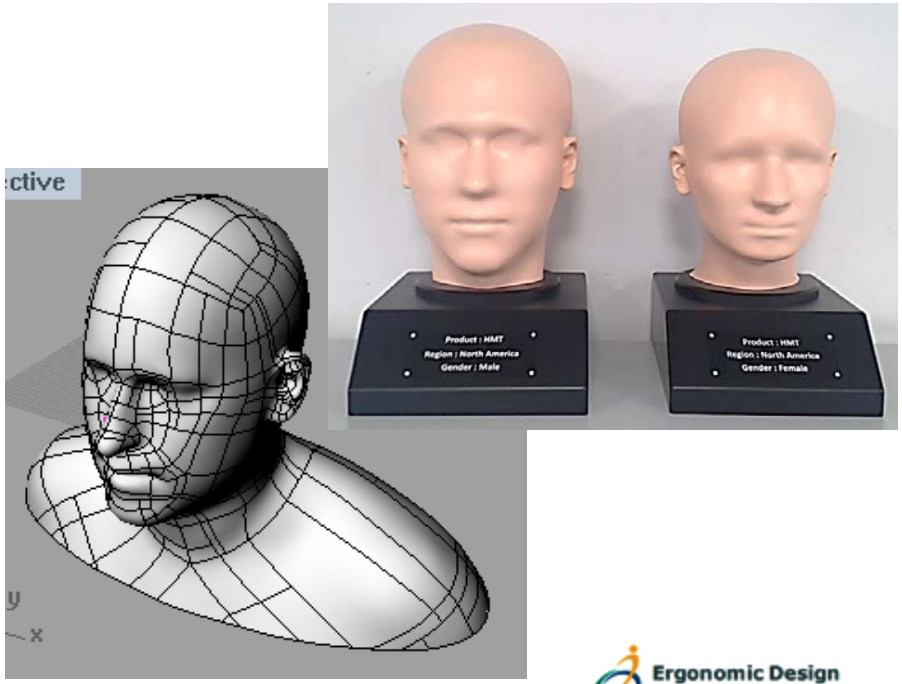
# Applications

- Improved CAESAR heads and 3D-ASAS can be applied to find an optimal shape of product through virtual fit analysis
- Digital and physical headforms can be utilized to product design and usability evaluation phases in PD process

**Illustration of the virtual fit analysis for oxygen mask design**



**Digital and physical headforms of RHMs**



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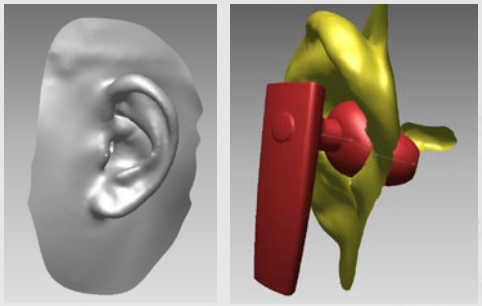
Ergonomic Design Technology Lab

# Q & A

## Ergonomic Design Technology Lab
## at Pohang University of Science and Technology
**http://edt.postech.ac.kr**

CAESAR Head Data Improvement

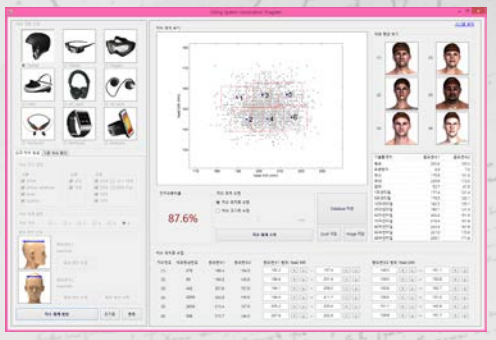


Ear Anthropometry

Hip Protector


Representative Models

Virtual Fit Analysis




Sizing Analysis System