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

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  - 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.

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.
• Identified design dimensions and related head dimensions for each product
Key Design & Anthropometric Dimensions

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Product type</th>
<th>Key design dimension</th>
<th>Related key anthropometric dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Helmet</td>
<td>inner length</td>
<td>head length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inner width</td>
<td>head breadth</td>
</tr>
<tr>
<td>2</td>
<td>glasses</td>
<td>width</td>
<td>biocular breadth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>frame length</td>
<td>otobasion superius to ectocanthus length</td>
</tr>
<tr>
<td>3</td>
<td>goggle</td>
<td>glass arc</td>
<td>bizygofrontale arc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>frame length</td>
<td>otobasion superius to ectocanthus length</td>
</tr>
<tr>
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<td>HMD</td>
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<td>bizygofrontale arc</td>
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<tr>
<td></td>
<td></td>
<td>zygomatic arc</td>
<td>bizygomatic-subnasale arc</td>
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<td>bitragion-vertex arc</td>
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<td></td>
<td>headband type</td>
<td>inner width</td>
<td>bitragion breadth</td>
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<td>6</td>
<td>headphone:</td>
<td>neckband arc</td>
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<td>neckband type</td>
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<tr>
<td>7</td>
<td>neckband</td>
<td>circumference</td>
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## S2. Sample of CAESAR Post-Processed

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<th>Female</th>
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<td>1,213</td>
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<tr>
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<td>- Caucasian</td>
<td>862</td>
<td>956</td>
</tr>
<tr>
<td></td>
<td>- African American</td>
<td>111</td>
<td>147</td>
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<tr>
<td></td>
<td>- Asian</td>
<td>81</td>
<td>92</td>
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<tr>
<td></td>
<td>- Hispanic</td>
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<td>2</td>
<td>Excluded samples</td>
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<td>49</td>
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<tr>
<td></td>
<td>- Ethnic minorities</td>
<td>23</td>
<td>41</td>
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<tr>
<td></td>
<td>- Heads have huge uncaptured area</td>
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<td></td>
<td>- Heads much deformed during scanning</td>
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<td>- Heads with no ethnic information</td>
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<td>1</td>
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<tr>
<td></td>
<td>- Inappropriate data structure</td>
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<td>-</td>
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<td>- Head with eye patch</td>
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<tr>
<td></td>
<td>total</td>
<td>1,122</td>
<td>1,262</td>
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</table>

**total** 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

Landmarks identified in CAESAR database (red dot; 9 landmarks on the head)

Landmarks identified in this research (green dot; 19 landmarks on the head)
Measurements: Caucasian Male

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Anthropometric dimensions</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
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<th>5th</th>
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<td>face width</td>
<td>862</td>
<td>144.3</td>
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<td>83.6</td>
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<tr>
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<td>25.9</td>
<td>9.3</td>
<td>11.5</td>
<td>20.7</td>
<td>23.0</td>
</tr>
</tbody>
</table>

...
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

Sizing system

Representative heads according to the sizing system

Accommodation percentage of the generated sizing system: 72.0%

Interface for adjustment of the sizing system
Adjustment of Sizing System (Illustrated)

Initial sizing system recommended by 3D-ASAS

Manually adjusted sizing system for better accommodation

Accommodation percentage: 72%

Accommodation percentage: 96.3%
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
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
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