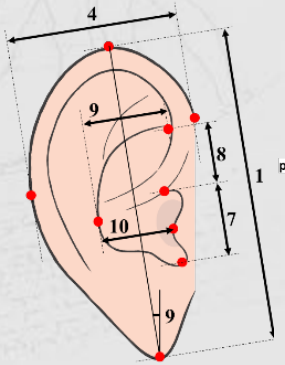
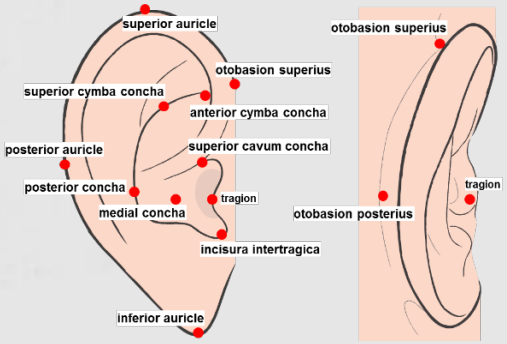
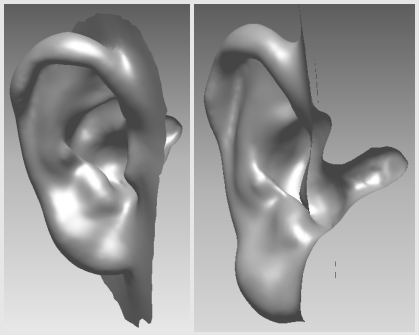
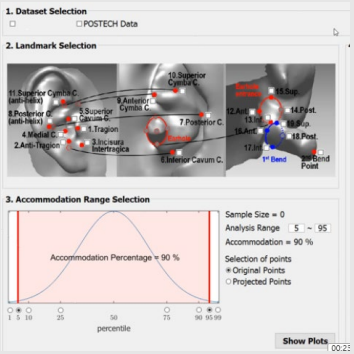
Development of a System for Anthropometric Ear Size and Shape Analysis









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2016년 추계 대한인간공학회

Contents

1. **Research background**
2. **Objectives**
3. **System development method**
   - Landmark & ear dimension selection
   - Landmarking of 3D ears
   - Extraction of measurements
   - Ear Size & Shape Analysis System
4. **Discussion**

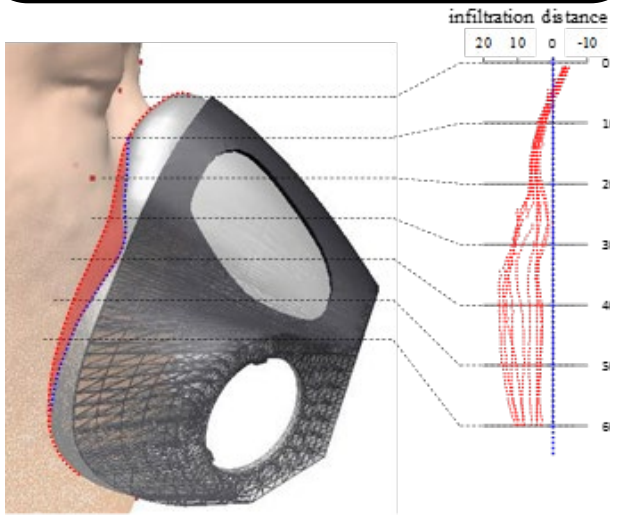
Usefulness of 3D Body Scans in Product Design

- Provide detailed measurements of complex dimensions (e.g., curvature, area, and volume) of the human body applicable to various product designs

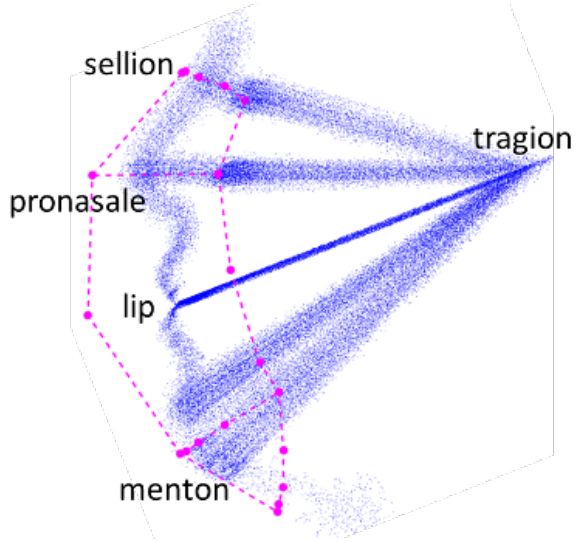
Application of 3D scan images to product design

Representative head form analysis of 2,300 head images for head wearable products

Virtual fit analysis for design of pilot's oxygen mask by applying 3D facial shapes of 336 Korean pilots



3D shape analysis of 300 Korean faces for design of dust-proof mask

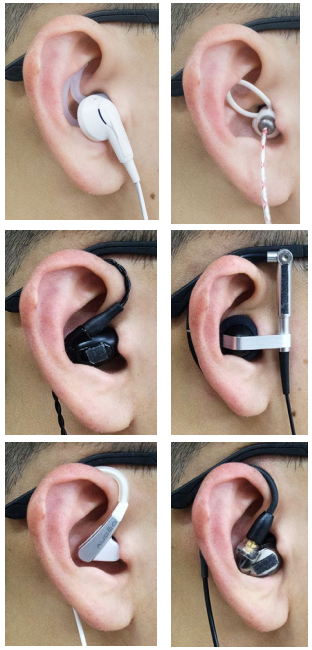


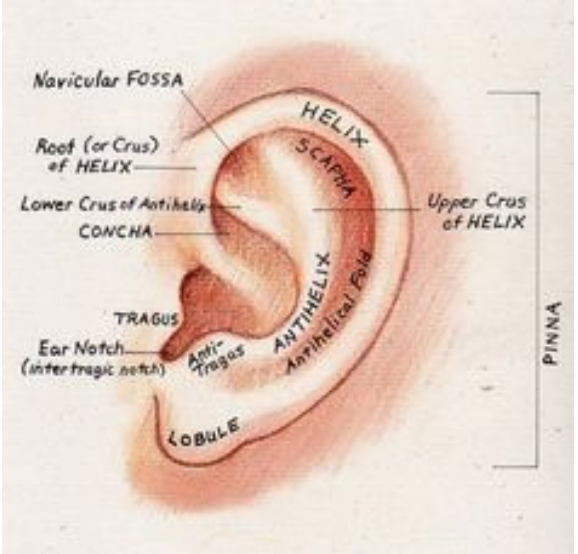
Needs of 3D Ear Anthropometry

- Diversity & complexity of earphone types and designs
  ⇒ Require detailed measurements of the ear for earphone design
- Little information of 3D ear shapes is available

⇒ Need to identify detailed ear dimensions which is significantly related to earphone design

⇒ Need to collect 3D ear scans including the pinna and earhole

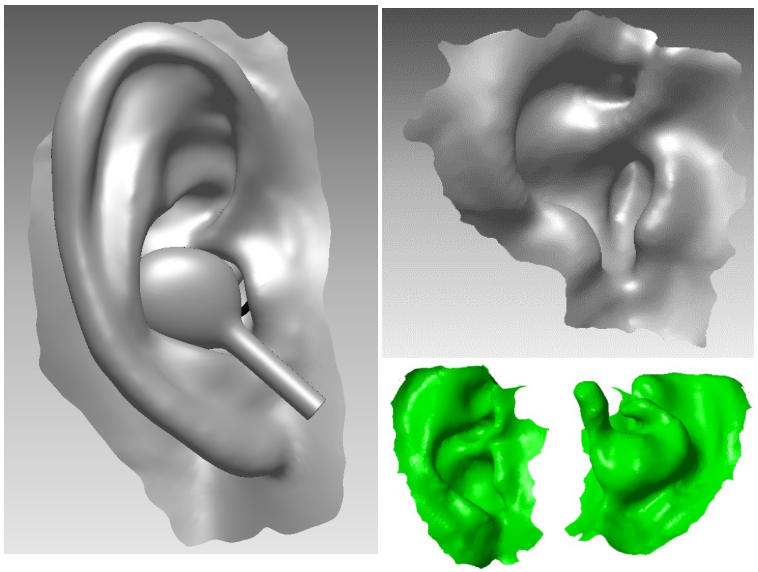




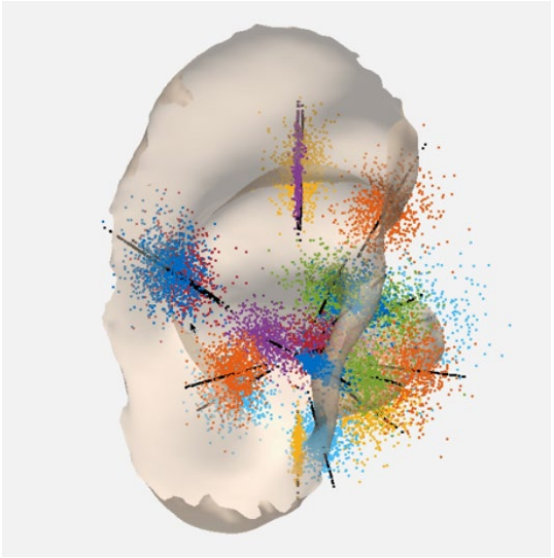
Needs of 3D Ear Visualization

- 3D ear has complex & detailed information (curvature, volume, landmark location) of ear shape → Engineer or designer need to check individual 3D character of ear
- To provide better application to ear product, 3D ear shapes need to be visualized with ergonomically designed system.

Complex shape of ear



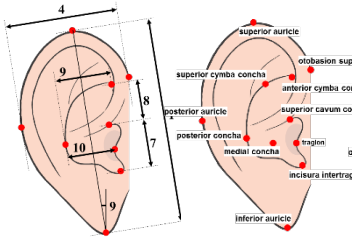
Ear landmark visualization



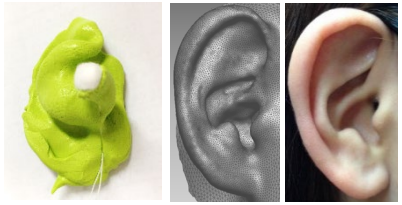
Objectives of the Study

Development of a System for
Anthropometric Ear Size and Shape Analysis

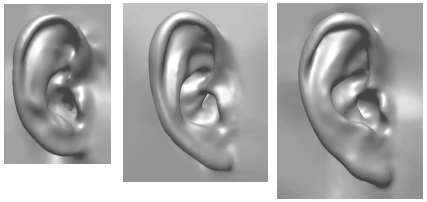
1. Identification of ear dimensions and landmarks related to earphone



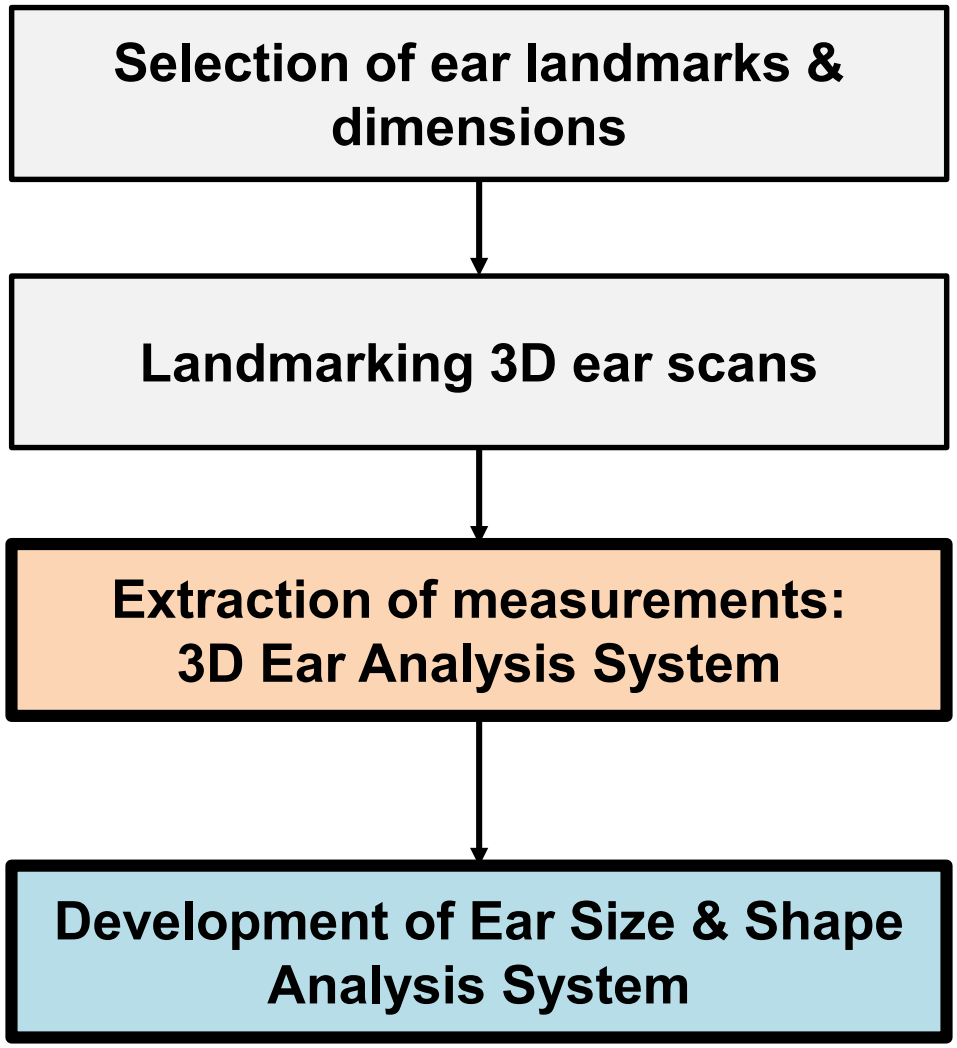
2. Collection of 3D ear scans and measurements: scanning, editing, landmarking, and measurement



3. Analysis of the size, shape, volume of the ear using system



Approach

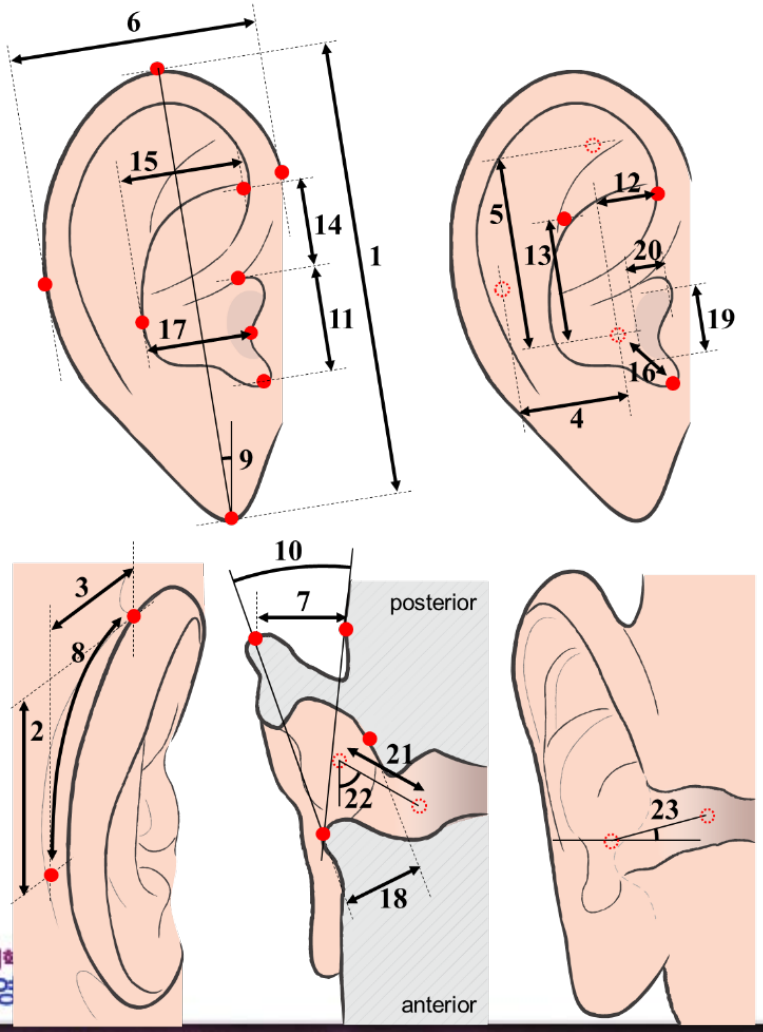


1. Landmark identification
2. Alignment
3. Ear dimension measurement
4. Ear curvature extraction
5. Concha volume extraction

1. Landmark visualization module
2. Representative earbud shape and volume analysis module

Identification of Ear Dimensions

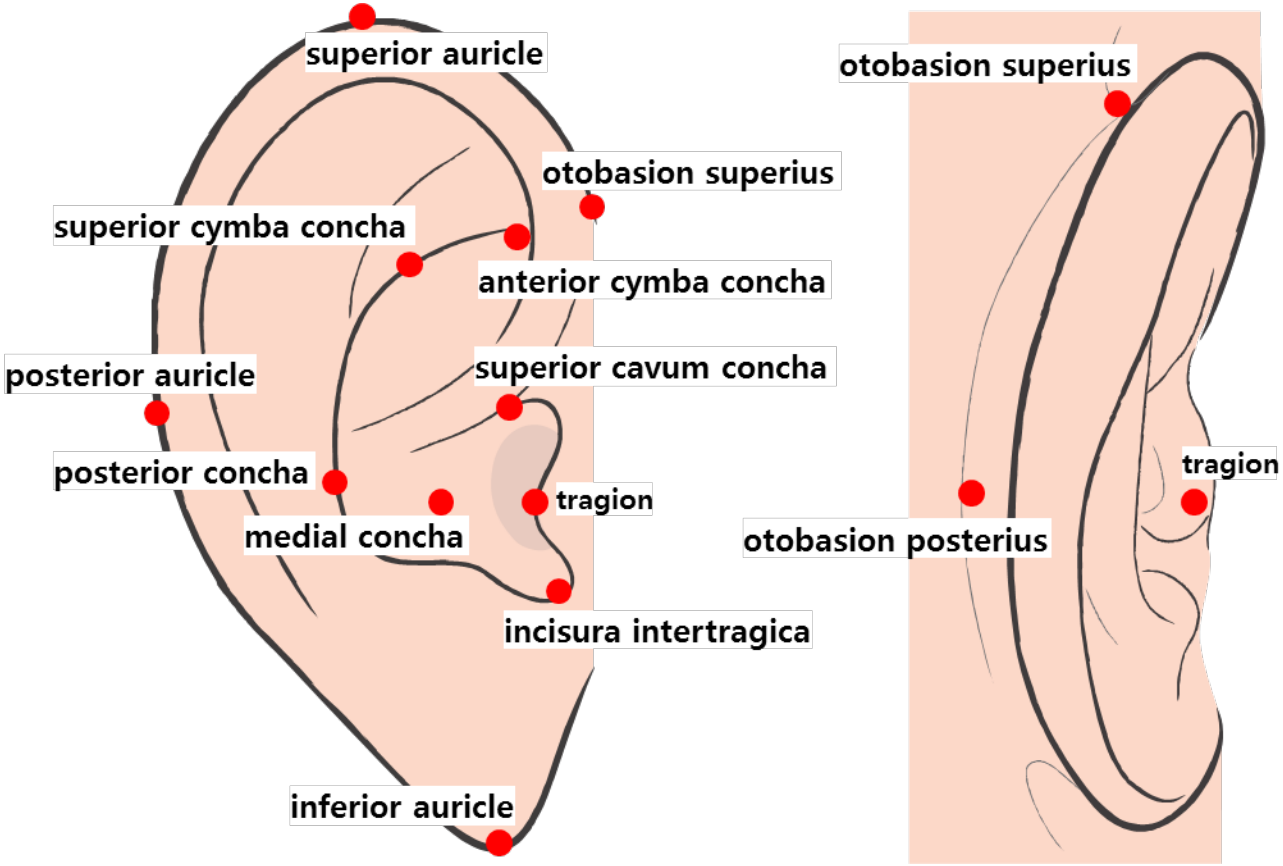
- Selected 9 ear dimensions out of 22 dimensions found from 22 papers
- Defined 14 new dimensions which are highly relevant to earphone design



Category		No	Ear dimensions
Ear dimensions	Length	1	ear length
		2	otobasion superius to otobasion posterius horizontal length
		3	otobasion superius to otobasion posterius vertical length
		4	center of concha to otobasion posterius length
		5	center of concha to otobasion superius length
	Width	6	ear breadth
		7	ear protrusion
	Arc	8	upper otobasion arc
	Angle	9	ear angle
		10	pinna flare angle
Concha dimensions	Length	11	cavum concha length
		12	center of concha to anterior cymba concha length
		13	center of concha to superior cymba concha length
		14	superior cavum concha to anterior cymba concha length
		15	posterior concha to anterior cymba concha length
		16	center of concha to incisura intertragica length
	Width	17	cavum concha width
	Depth	18	cavum concha depth
Ear canal dimensions	Length	19	ear canal length
	Width	20	ear canal width
	Depth	21	ear canal depth
	Angle	22	ear canal azimuth angle
		23	ear canal elevation angle

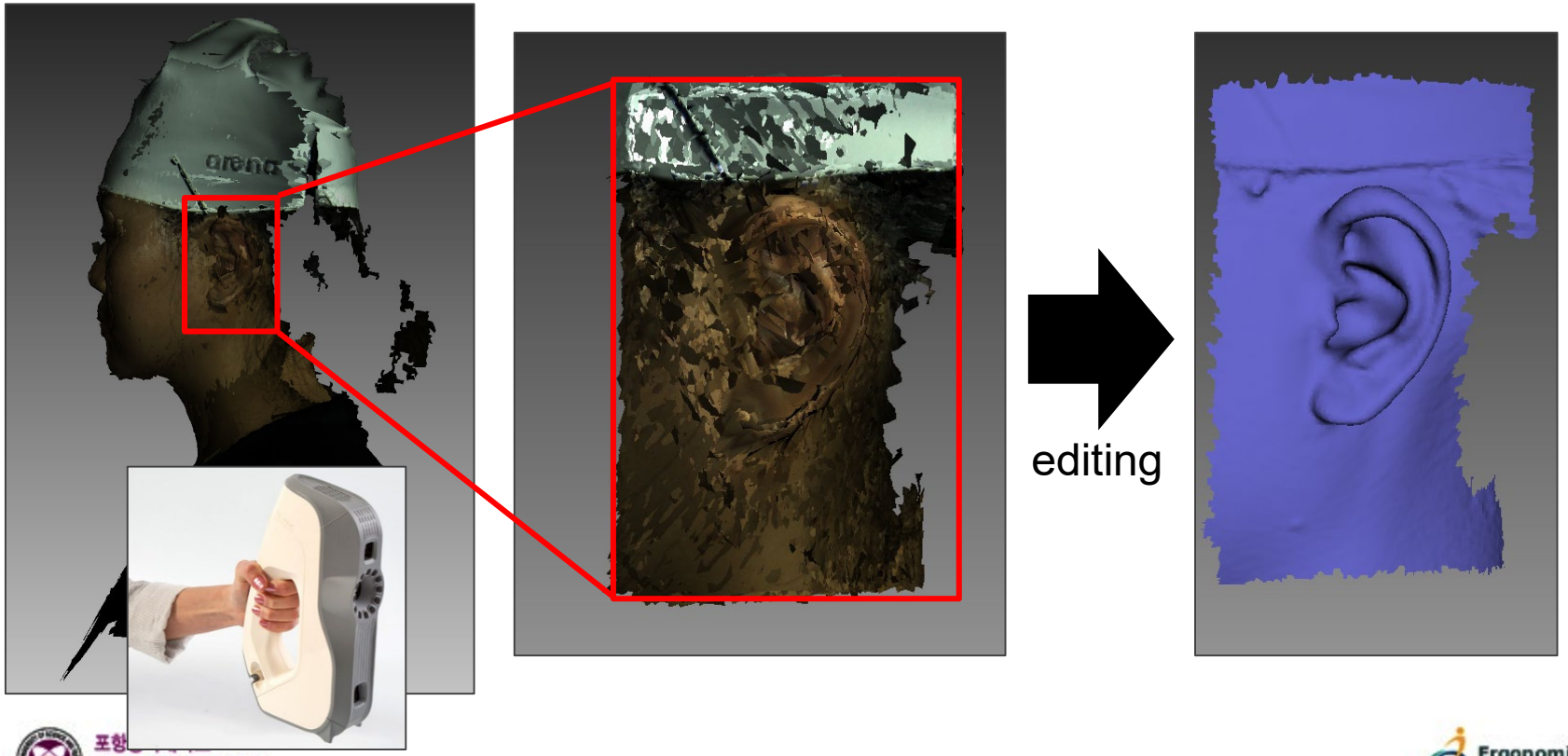
Determination of Ear Landmarks

- Identified 18 landmarks for measurement of the 23 ear dimensions selected in the study for ear phone design



3D Scanning of the Outside Ear (Pinna)

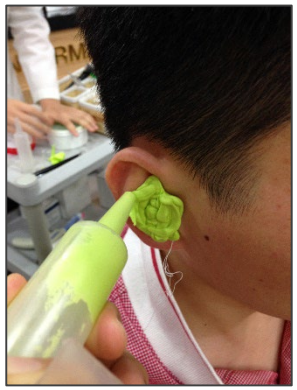
- Scanned the outside of the ear (pinna) using an Artec Eva 3D scanner for 296 participants in 20s to 50s
  - ✓ 200 Koreans: 100 males and 100 females
  - ✓ 96 Caucasians: 50 males and 46 females

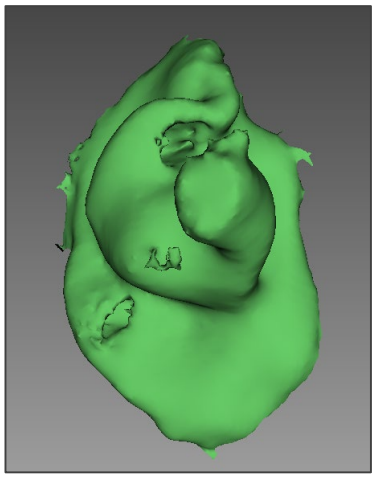
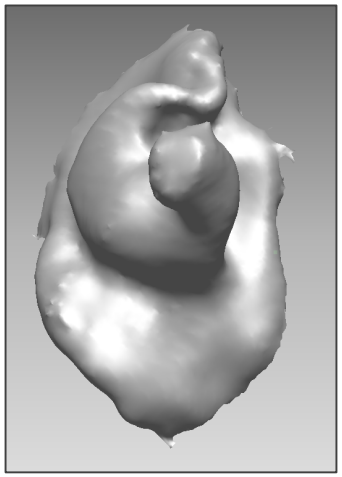
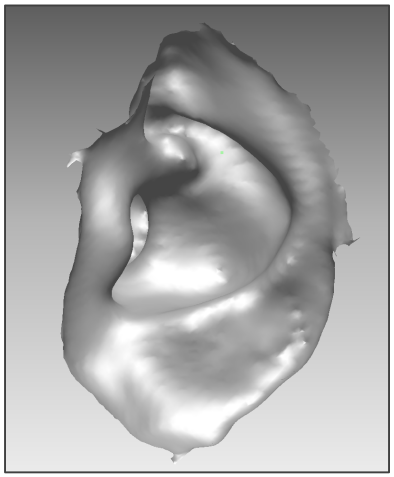


Scanning of the Concha & Earhole

- Applied casting materials to obtain the shape of the concha and ear hole
- Scanned the cast using the Artec Eva 3D scanner

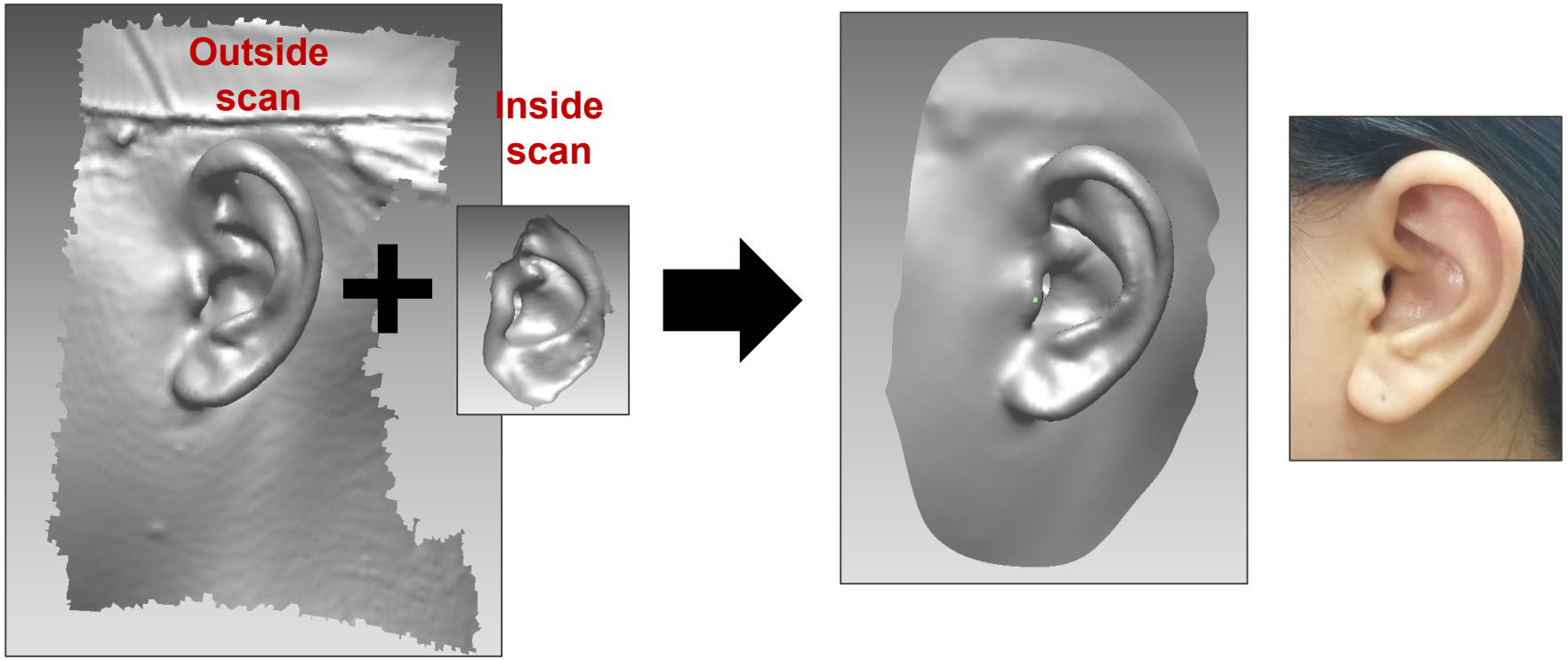


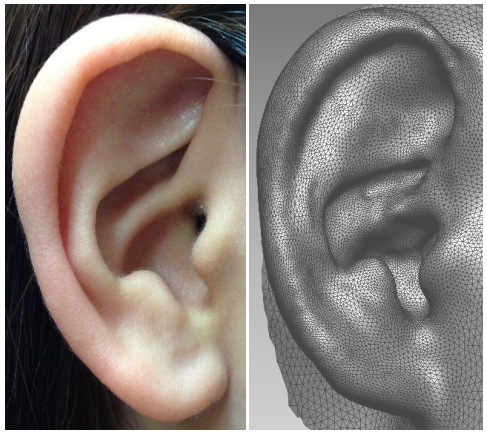
Merging Outside and Inside Ear Scans

- Acquired an complete 3D ear scan by merging outside and inside ear scans



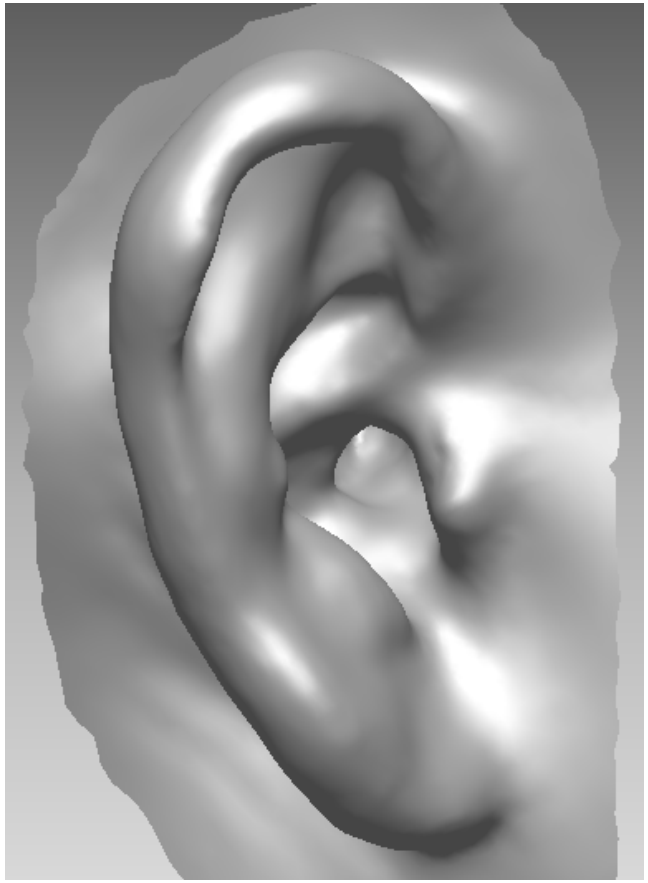
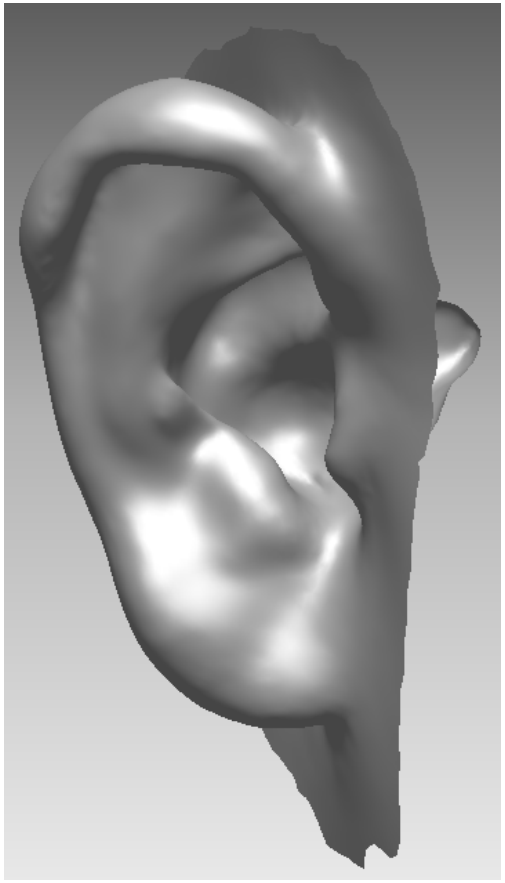
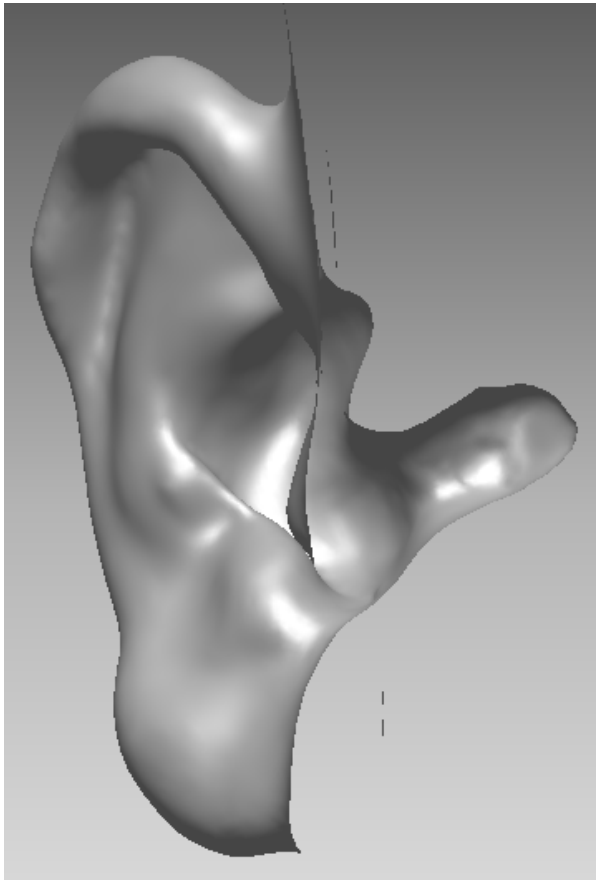
3D Ear Scans (1/2)



3D Ear Scans (2/2)

- Acquired 3D ear scans including the ear-hole part

Measurement: Composite Data (*N* = 836)

code	category	dimension name	mean	SD	SE	min	0.01	0.05	0.25	0.5	0.75	0.95	0.99	max
D1	Concha length dimensions	concha length	27.4	2.3	0.1	19.5	22.2	23.9	25.9	27.2	28.8	31.4	33.3	35.4
D2		cavum concha length	17.2	2.2	0.1	9.7	12.3	13.7	15.7	17.0	18.5	21.1	23.4	26.2
D3		lower cymba concha length	6.2	2.6	0.1	0.1	0.7	1.8	4.3	6.2	8.0	10.6	12.3	14.3
D4		upper cymba concha length	4.0	1.7	0.1	0.2	0.7	1.4	2.8	3.9	5.2	7.1	8.4	9.9
D5		cymba concha length	10.2	2.2	0.1	3.9	5.3	6.7	8.8	10.2	11.7	13.6	15.3	18.1
D6	Concha width dimensions	earhole entrance to central concha length	2.8	1.7	0.1	0.0	0.1	0.3	1.6	2.7	4.0	5.7	7.3	9.3
D7		anterior cymba concha to central concha length	8.6	2.1	0.1	1.2	3.8	5.4	7.2	8.5	9.9	12.2	14.2	16.6
D8		posterior concha to central concha length	11.6	1.8	0.1	5.0	7.3	8.8	10.4	11.6	12.7	14.4	15.7	16.6
D9		cavum concha width	14.3	2.2	0.1	6.3	9.3	10.7	12.9	14.3	15.8	18.0	19.6	20.8
D10		cymba concha width	20.2	2.9	0.1	11.8	14.3	15.5	18.2	20.1	22.1	25.2	27.5	29.6
D11	Intertragic notch dimensions	posterior part	6.6	1.5	0.1	2.5	3.5	4.1	5.5	6.5	7.6	9.1	10.1	12.2
D12		anterior part	2.3	1.1	0.0	0.0	0.2	0.6	1.5	2.3	3.0	4.2	5.2	6.1
D13		superior part	1.6	0.8	0.0	0.0	0.1	0.4	1.0	1.5	2.0	2.9	3.8	4.9
D14		inferior part	7.7	1.2	0.0	1.9	4.9	5.8	6.9	7.6	8.4	9.6	10.7	12.9
D15		tragion to anti-tragion length	8.9	1.9	0.1	4.5	5.2	5.9	7.5	8.8	10.1	12.1	13.5	16.0
D16		center of concha to incisura intertragica length	9.2	1.4	0.0	4.0	6.2	7.1	8.3	9.1	10.0	11.6	12.7	14.6
D17	Concha depth dimension	concha depth	12.0	1.4	0.1	6.0	8.6	9.8	11.1	12.0	12.9	14.5	15.4	16.2
D18	Earhole dimensions	earhole entrance major axis length	14.1	1.6	0.1	7.9	10.7	11.7	13.0	14.1	15.1	16.6	18.2	19.3
D19		earhole entrance minor axis length	7.5	1.2	0.0	4.3	5.0	5.6	6.6	7.5	8.3	9.6	10.4	11.5
D20		earhole entrance circumference	36.6	3.5	0.1	24.6	29.2	31.1	34.1	36.5	38.9	42.5	45.1	48.6
D21		1st bend major axis length	9.7	1.5	0.1	3.8	6.1	7.3	8.8	9.7	10.7	12.4	13.3	14.6
D22		1st bend minor axis length	7.7	1.3	0.0	3.7	4.7	5.6	6.8	7.7	8.5	9.8	10.7	11.6
D23		1st bend circumference	29.3	3.6	0.1	17.7	21.0	23.4	26.9	29.2	31.6	35.3	37.5	41.7
D24		center of earhole to 1st bend length	7.5	1.9	0.1	3.2	3.9	4.7	6.1	7.3	8.6	10.6	12.8	17.3
D25	Angle dimensions	earhole elevation angle	98.9	11.9	0.4	69.4	76.9	81.1	90.8	97.9	106.0	120.0	132.0	149.8
D26		earhole azimuth angle	156.1	24.8	0.9	3.7	50.2	106.4	149.1	162.9	171.5	178.7	179.8	180.0
D27		1st bend elevation angle	151.3	22.3	0.8	64.0	89.4	105.5	138.9	157.1	168.8	177.1	179.3	179.9
D28		1st bend azimuth angle	43.2	32.7	1.1	0.0	1.2	5.1	18.6	37.6	59.0	109.5	149.4	179.2

Ear Size and Shape Analysis: System Flow Chart

Ear Landmark Visualization Module

S1. Analysis condition setting

- Select dataset (1. Korean, 2. Caucasian, 3. Both)
- Select landmarks
- Select accommodation percentage

S2. Results confirming and exporting

- Visualize landmarks in the designated accommodation percentage
- Export results
- Send results to the following module

Representative Concha Shape & Volume Analysis Module

S3. Analysis condition setting

- Receive information from the previous module
- Select the number of size categories and representative points
- Select size analysis options

S4. Results confirming and exporting

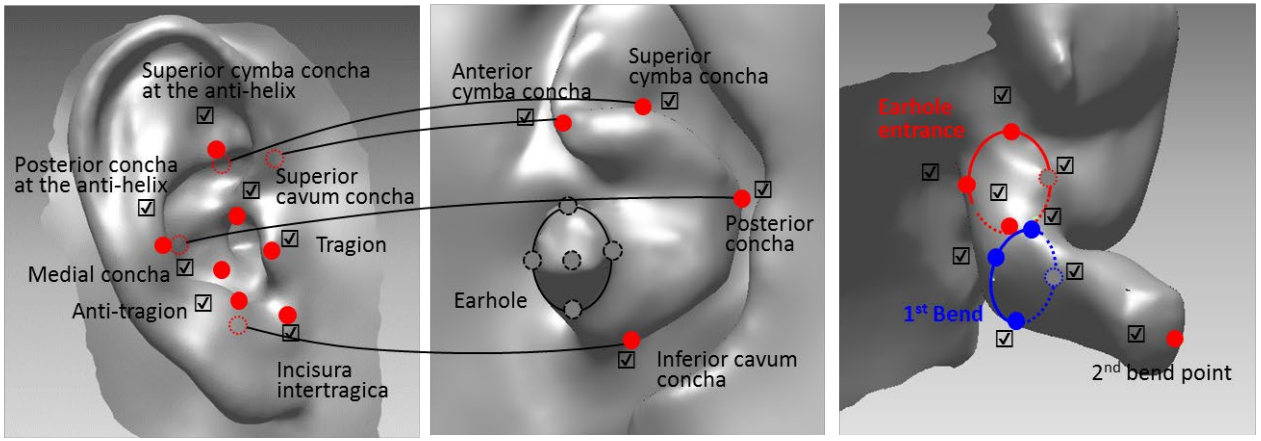
- Visualize 3D curvature and concha shape by size category
- Export results: curvature, volume, concha shape, plate shape

Ear Landmark Visualization Module: Planned

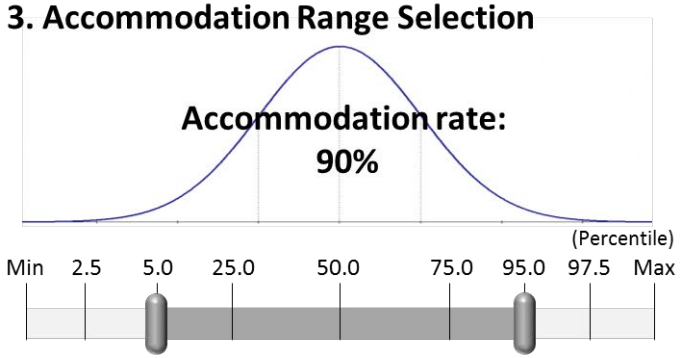
3D Landmark Plots Visualization System — Next

1. Dataset Selection ☑ Caucasian ☑ Korean — Reset — Save — Load

2. Landmark Selection



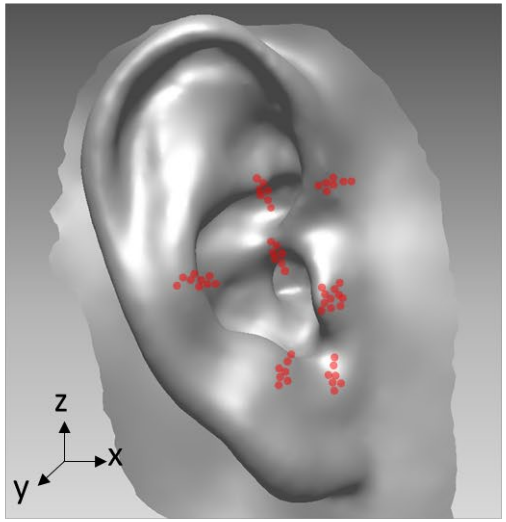
3. Accommodation Range Selection



# of Sample (*n*)	355		
Range (%ile)	5	~	95
Coverage Rate	90 %		

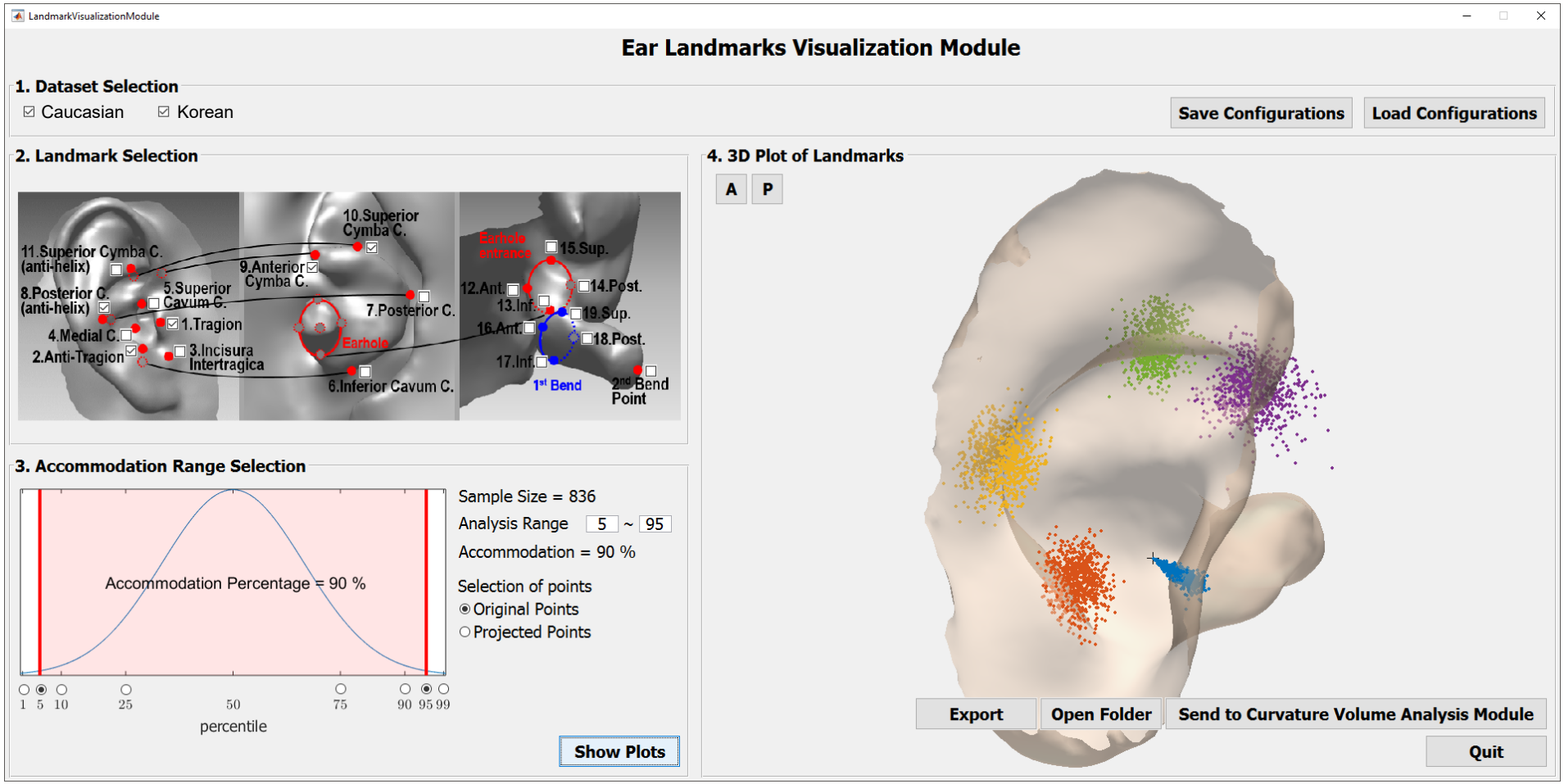
Show Plots

4. 3D plots of Landmark



S L A R P I — Export — Exit

Ear Landmark Visualization Module: Developed



∗ The system was developed using Matlab.

Representative Concha Shape & Volume Analysis Module: Planned

Concha Shape & Size Design System

Previous

1. Sizing category options

- Coverage range (%ile): 5 ~ 95
- Accommodation rate: 90 %

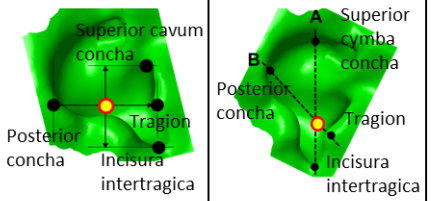
# of Sizing category	○ 1	○ 2	◉ 3	○ 4	○ 5

		Small	Medium	Large		
Representative point	Min	○	○	○	○	○
	Average	◉	◉	◉	○	○
	Max	○	○	○	○	○

Overlap area (%)	10	Size increment (%)	5

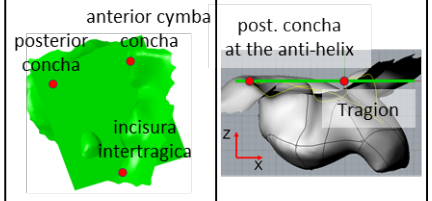
2. Shape analysis standard

Center of concha



○ ◉

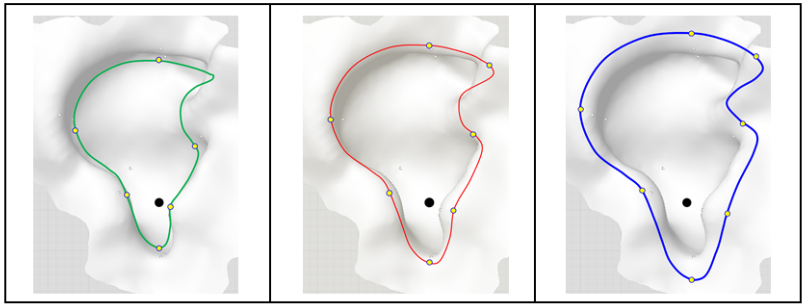
Reference plane



○ ◉

3. Concha shape design

Small	Medium	Large



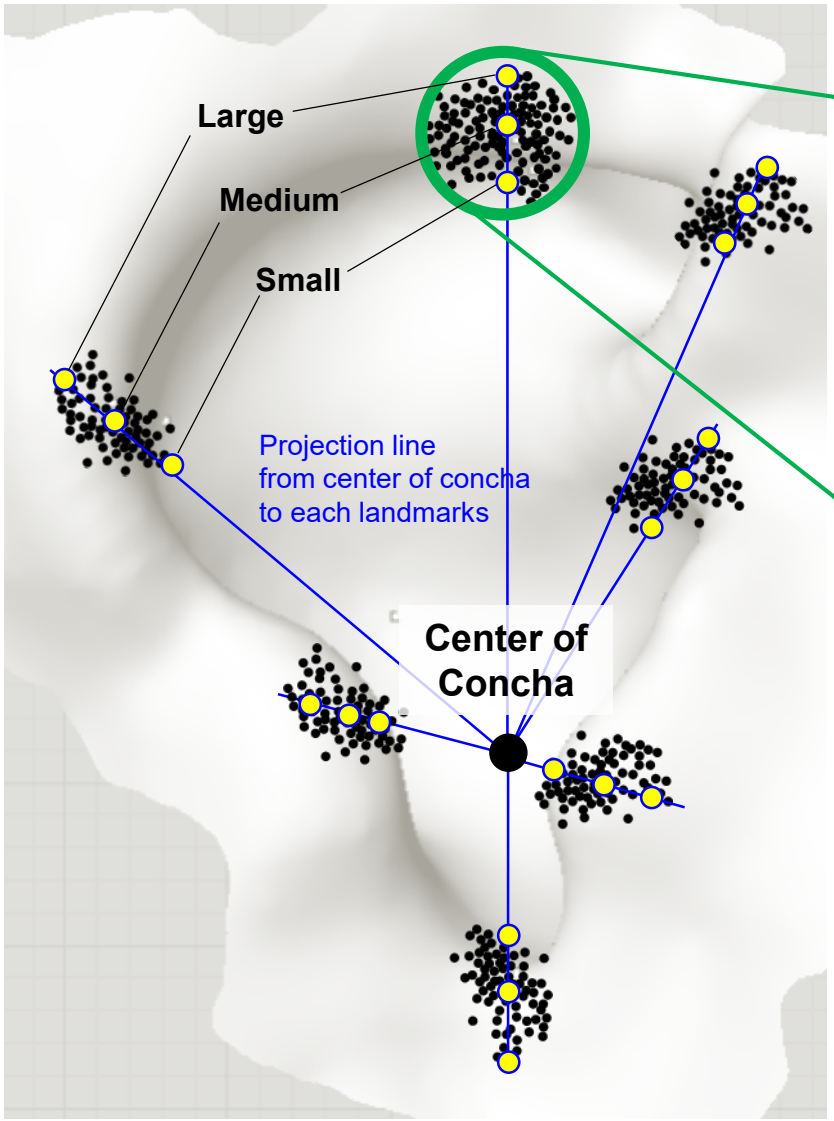
Export

4. Concha Volume analysis

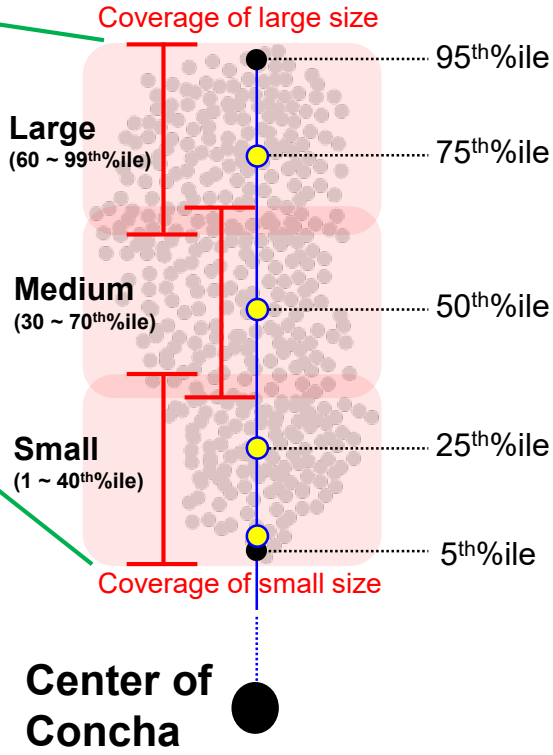
	Small	Medium	Large
Cymba concha	15 ml	17 ml	18 ml
Cavum concha	30 ml	42 ml	55 ml
Tail	5 ml	7 ml	7 ml

Exit

Representative Landmark Selection

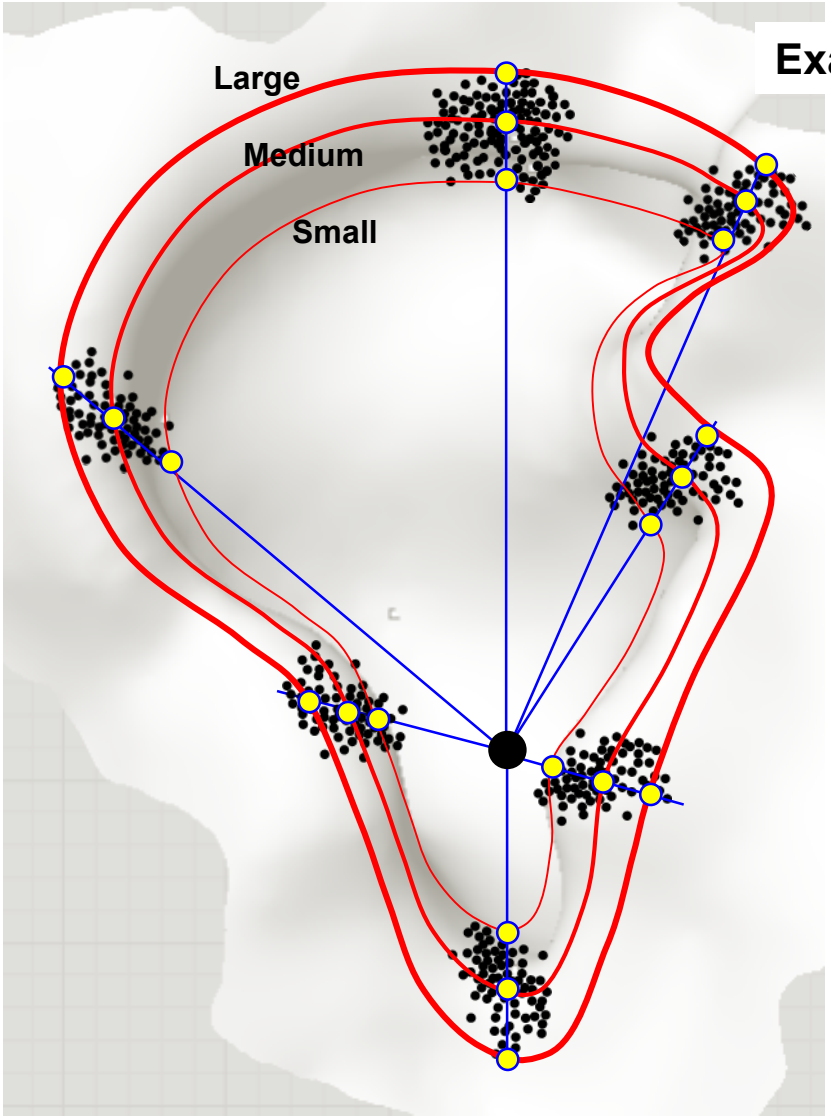


Examples of Sizing Category Analysis

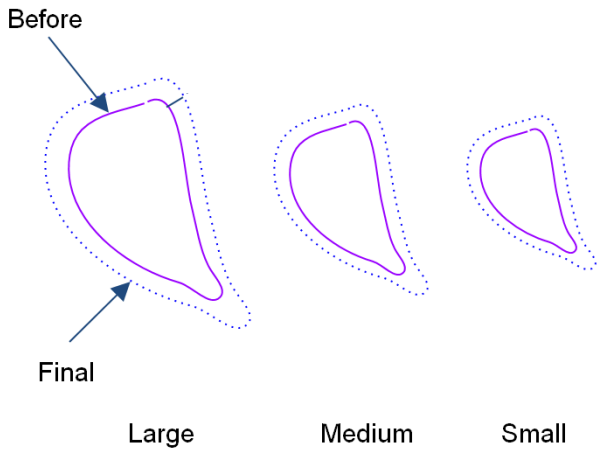


⇒ Select representative ears

Analysis of Representative Concha Profile

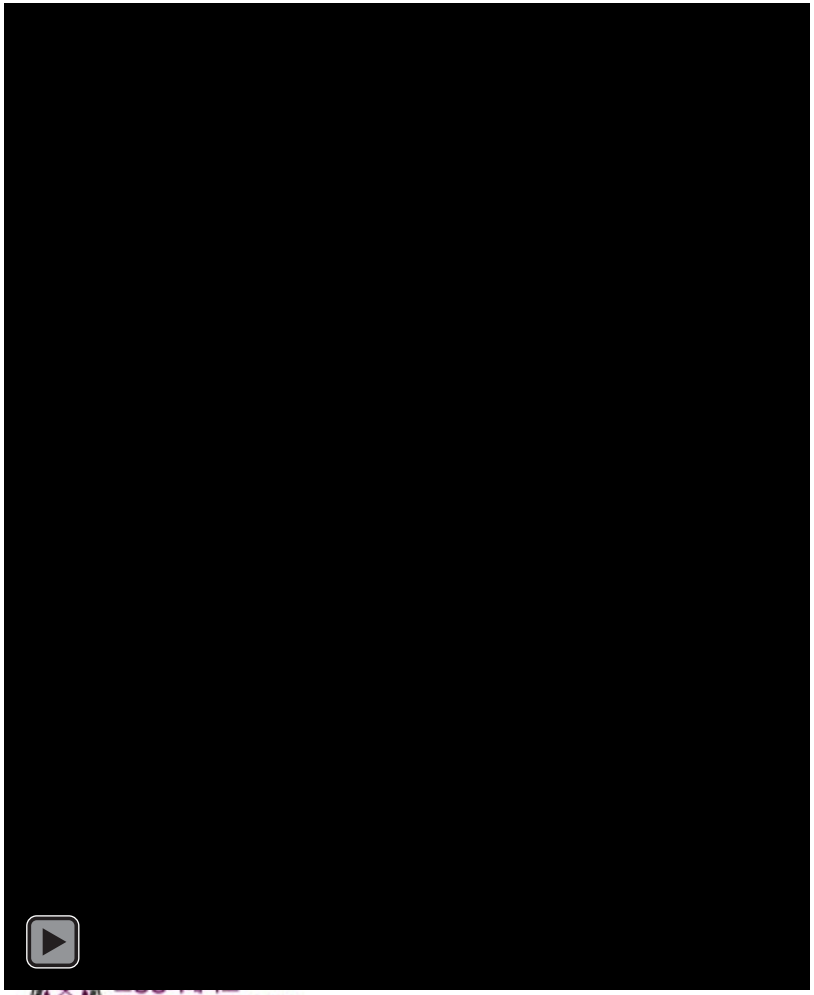


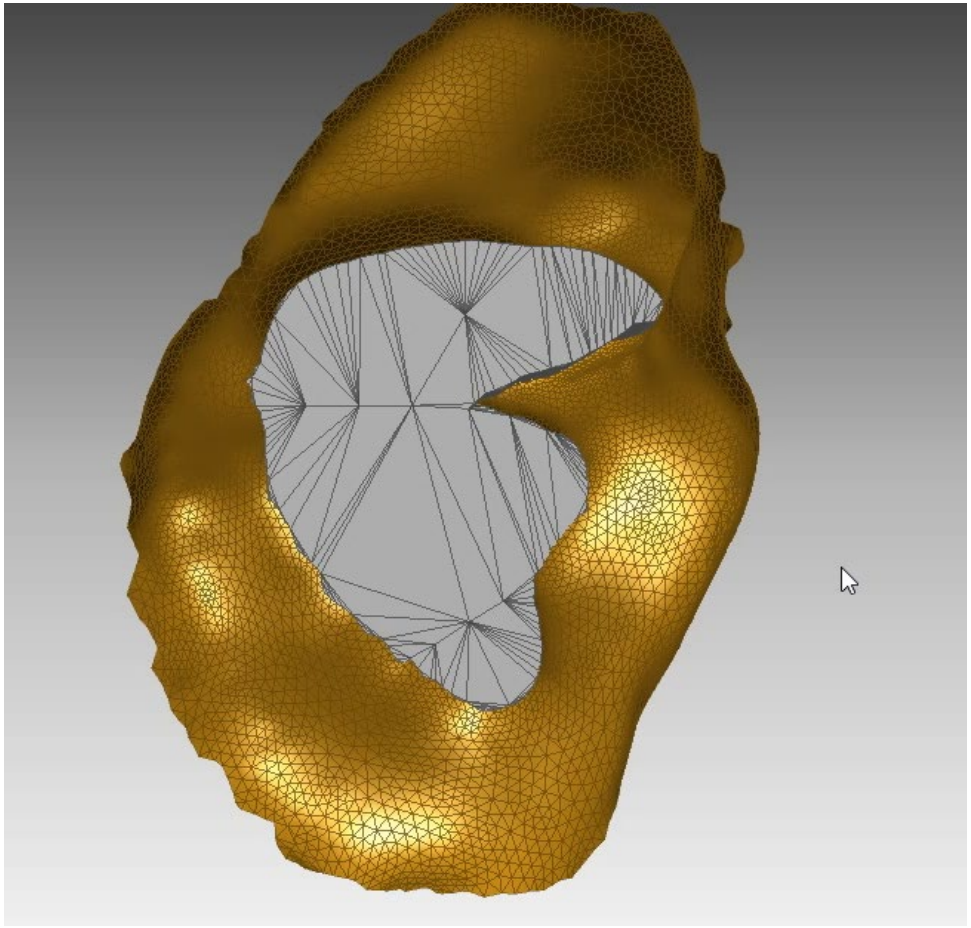
Examples of 2D concha profile extraction



Analysis of Contour and Volume of Concha

- Extraction of the contour and volume of ear concha for earphone shape and size design





Representative Concha Shape & Volume Analysis Module: Developed

CurvatureVolumeAnalysisModule

Representative Earbud Shape and Volume Analysis Module

1. Sizing Category Options

Coverage range (%ile) = 5 ~ 95 (Accommodation rate = 90 %)

# of Sizing category: ○1 ○2 ◉3

Overlap area (%): 10

Representative point

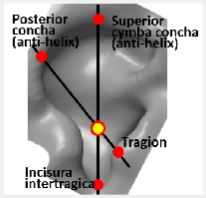
Size increment (%): 10

Thickness of plate (mm): 5

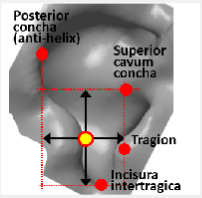
	Small	Medium	Large
Min	○	○	○
Average	◉	◉	◉
Max	○	○	○

2. Shape Snalysis Standard

Center of concha

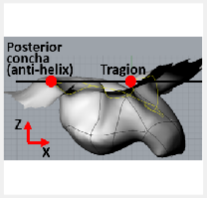


◉ Alternative 1

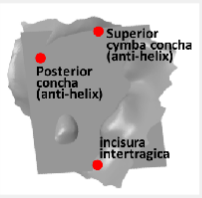


○ Alternative 2

Reference plane



◉ Alternative 1

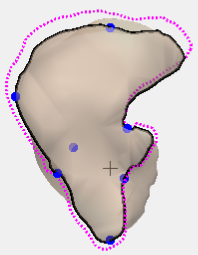


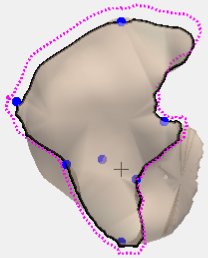
○ Alternative 2

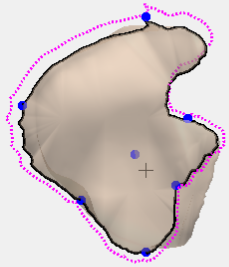
Show Results

3. Earbud Shape Analysis

Small (23.5%ile, ID: POSTECH_220) Medium (50%ile, ID: LOG_352) Large (76.5%ile, ID: LOG_106)







2D 3D

Export Curves Open Folder

4. Volume Analysis

	Small	Medium	Large
cymba concha	1551	1645	1598
cavum concha	782	1367	1946
tail	401	784	634
sub-total	2734	3796	4177
plate	1493	1638	2075
total	4228	5434	6252

Export Volume

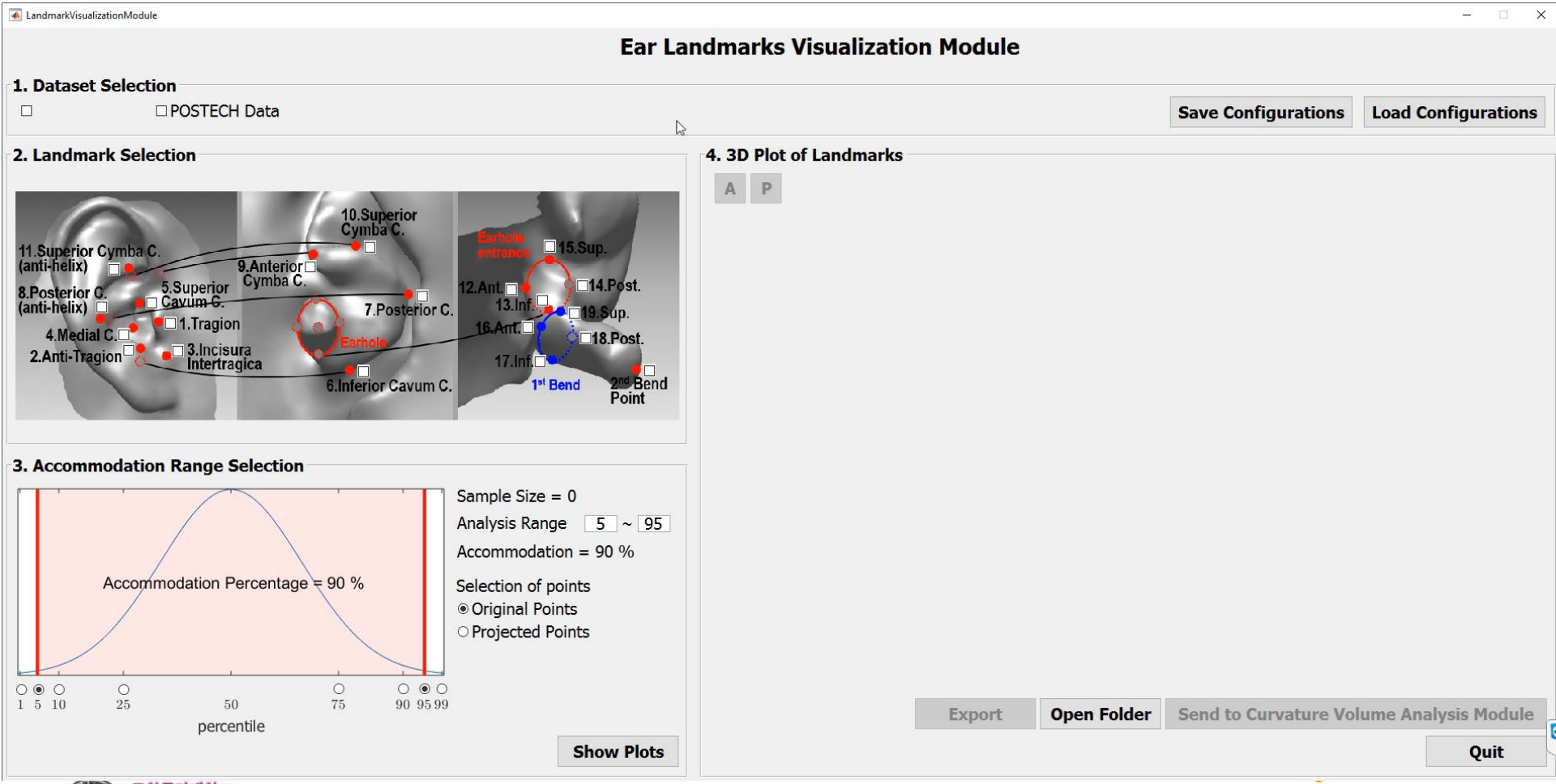
Open Folder

Close

∗ The system was developed using Matlab.

Development of Representative Ear Analysis System

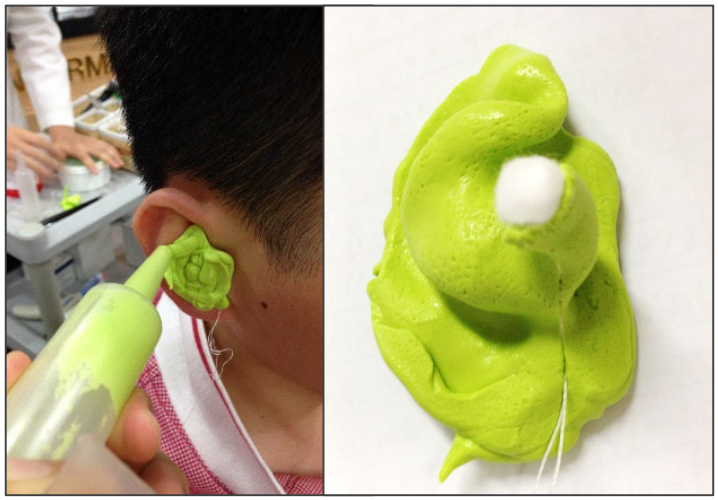
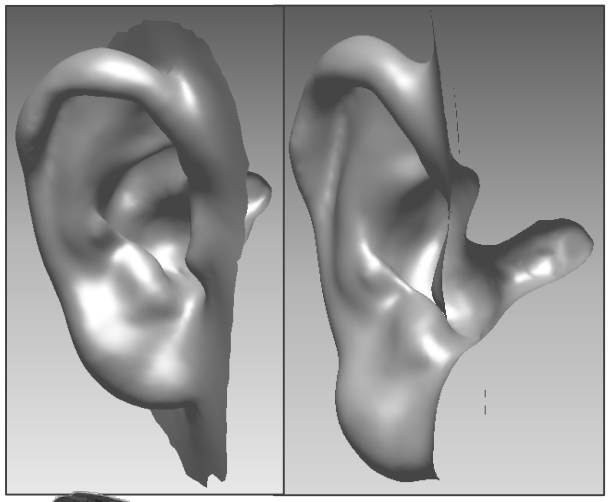
- Developed an ear analysis system which can search representative ears based on selections of landmarks, accommodation percentage, etc.



* The system was developed using Matlab.

Discussion (1/2)

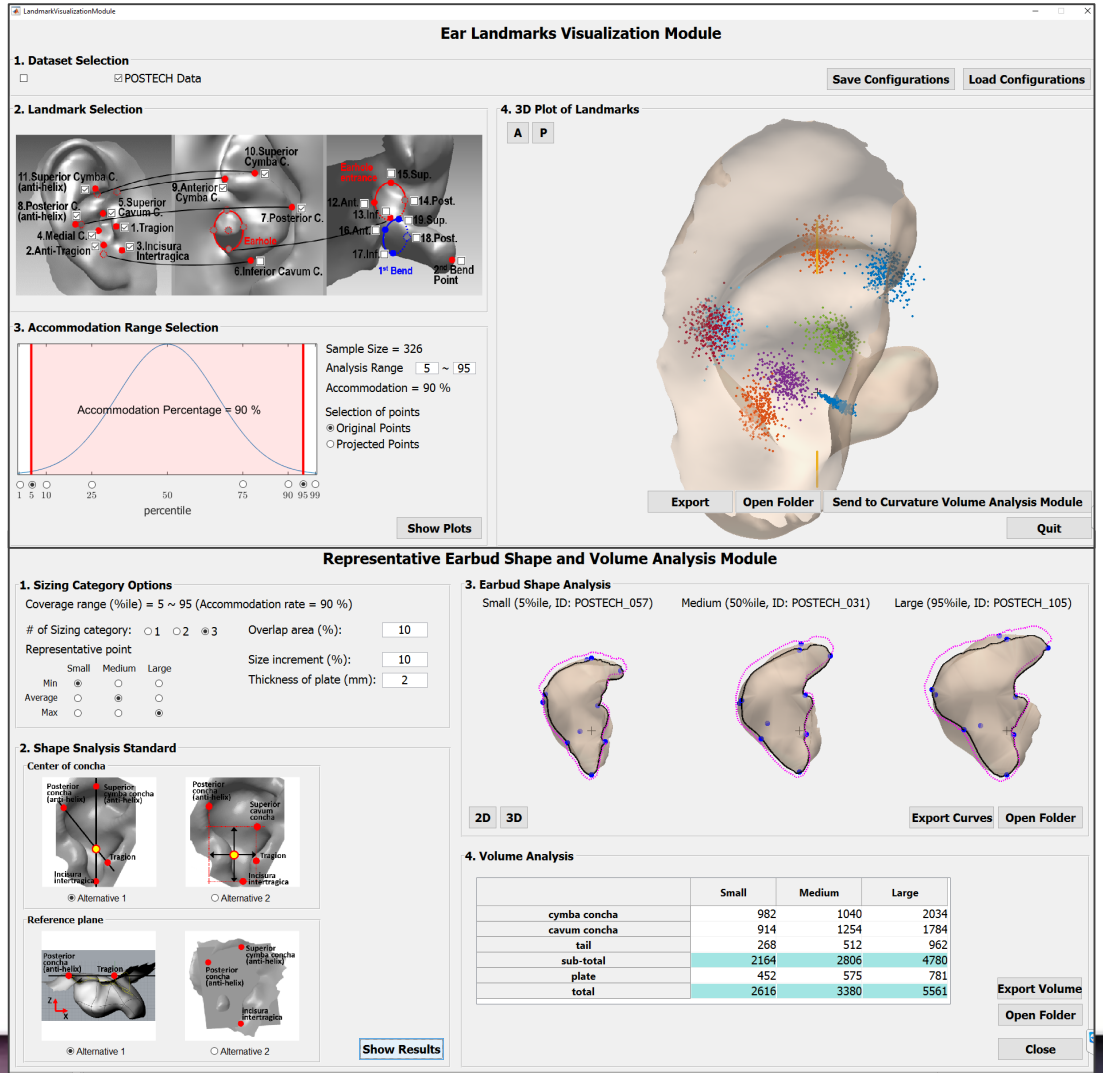
- Collected 3D ear scans (pinna and earhole) through a process of scanning, casting, editing, and merging
- ⇒ Applicable to design of ear wearable products (earphones, hearing-aids, headsets, glasses, goggles, and ear protector)




Discussion (2/2)

- Utilized ear scans to develop a computerized system to support designers for analysis of the shape and size variation of the ear



Q & A

경청해 주셔서 감사합니다. ☺

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