Potential Application of Temporal 3D Body Scanning Techniques to Ergonomic Product Design

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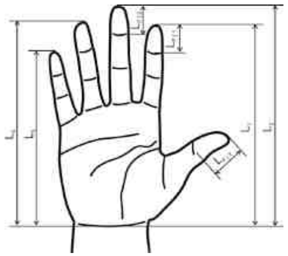
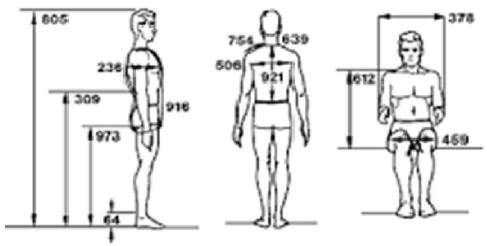
Agenda

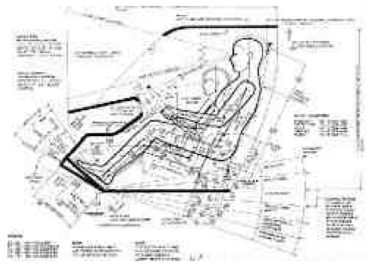
- Introduction
  - Background
  - Objectives
- Static 3D & Temporal 3D Scanning Techniques
- Case Studies
- Discussion

Background

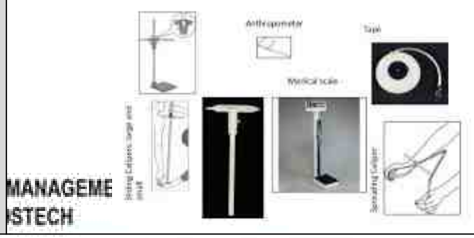
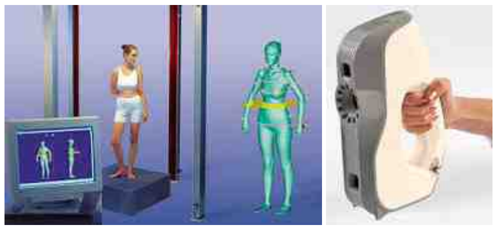
- Ergonomic product design depends on anthropometry, the study of the measurement of the human body.





- Development of anthropometric measurement techniques

Timeline	1900s to 1990s	1990s to 2010s	2010s to present/future
Measurement tools	Grid, anthropometer, calipers, scale, measuring tape	3D body scanners	Temporal 3D body scanners
Measurement dimensions	• 1D: height, length, breadth, depth, curvature, circumference	• 1D • 2D: surface area, shape • 3D: volume	• 1D, 2D, 3D • 4D: dynamic anthropometry
Limitations or strengths	Simple but time demanding	Realistic shape & size, but not available for dynamic anthropometry	Fast, accurate, dynamic, motion, still not well known
			

Objectives

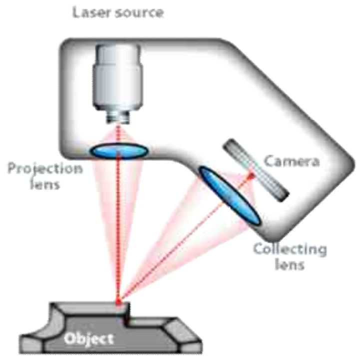
- To introduce static 3D & temporal 3D body scanning techniques
- To address the potential application of temporal 3D body scanning techniques to ergonomic product design

Static 3D Scanning Techniques

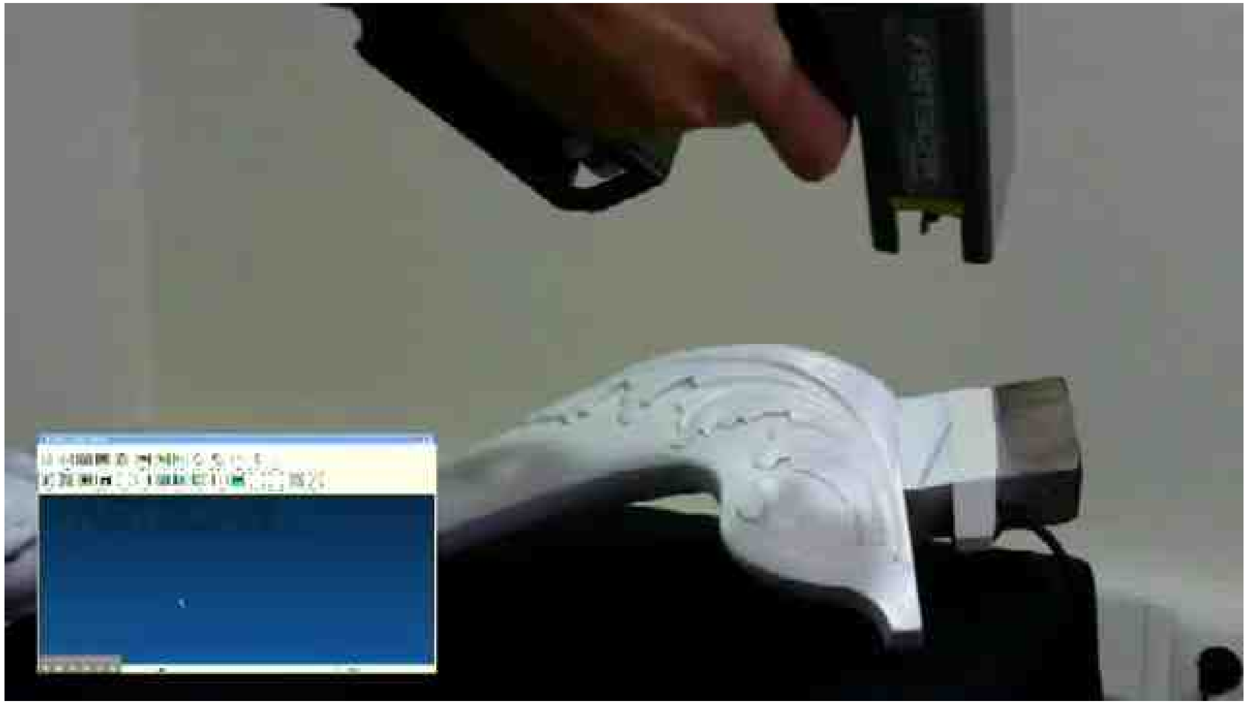
Classification	Laser scanning	Structured light scanning	Stereo photogrammetry scanning
Techniques	Application of a laser beam (spot or stripe) across the target surface	Projection of organized patterns of white light, such as grids, dots, or stripes to the target surface	Software approach that creates a stereo pair from 2 pictures taken from the same object • Passive: using natural pattern or landmarks • Active: using natural pattern or landmarks with a projected unstructured light pattern
Limitations or strengths	• Accurate • Time demanding, therefore difficult to use on living, breathing people, especially children	• Color texture well recorded • Hard to scan symmetric body surfaces at the same time due to light pattern interference	• Passive: requiring high resolution single-lens reflex cameras to capture enough surface detail, and careful control of lighting conditions • Active: flexible to lighting conditions; able to easily capture darker skins, fast, high data quality
Existing models	• Head & Face Color 3D Scanner (Cyberware Inc., USA) • FastSCAN (Polhemus, USA)	• TC2-19R body scanner ([TC]^2, USA) • Artec Eva (Artec 3D, Luxembourg)	• Active: 3dMD static solutions (3dMD, USA)
	 	 	 

Laser-Based 3D Scanning Technique

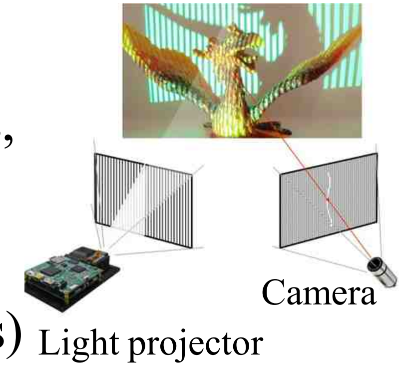
- Laser-based technique
  - Project a laser beam (spot or stripe) across the target surface; detect the surface location by trigonometry
  - Limitation: not efficient for scanning living people



Laser: FastSCAN (Polhemus, USA)



Structured Light-Based 3D Scanning Technique

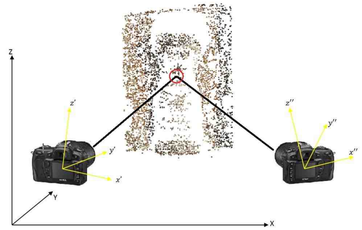


- Structured light-based technique
  - Project organized patterns of white light, such as grids, dots, or stripes to the target surface; capture the distorted light over the object for surface generation
  - Limitation: hard to scan symmetric body surfaces (e.g., ears) at the same time due to light pattern interference

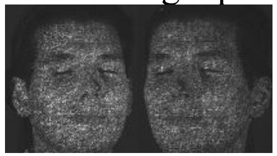
Structured light: Artec Eva (Artec 3D, Luxembourg)

Stereo Photogrammetry-Based 3D Scanning Technique

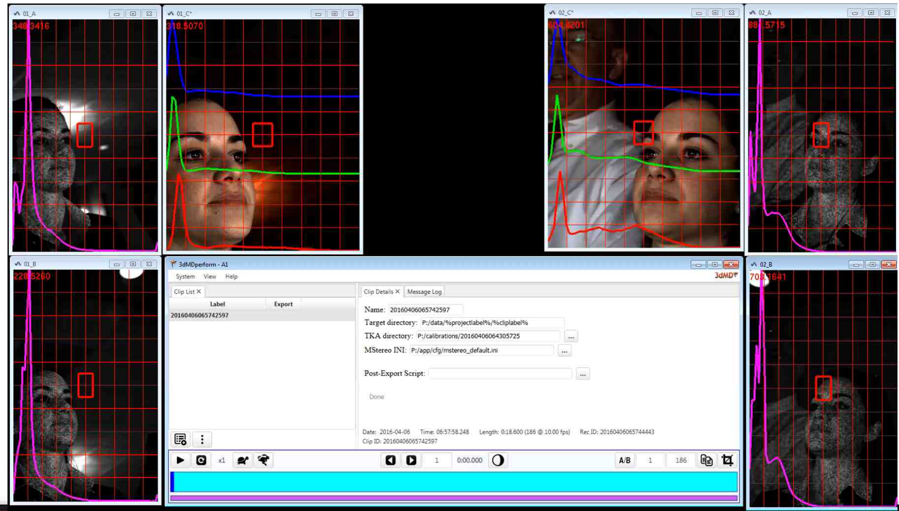
- Stereo photogrammetry-based technique: capture 2 images of the same object with 2 cameras and combine them to a 3D object
  - Passive: use natural patterns or landmarks
    - Require high resolution camera to capture enough detail
    - Sensitive to light condition
  - Active: use combination of natural patterns or landmarks with a projected unstructured light pattern
    - Flexible to lighting conditions; able to easily capture darker skins; fast; high data quality



Unstructured light pattern



Active stereo photogrammetry: 3dMD face (3dMD, USA)



Case Studies: Application of 3D Scanning Techniques to Ergonomic Product Design

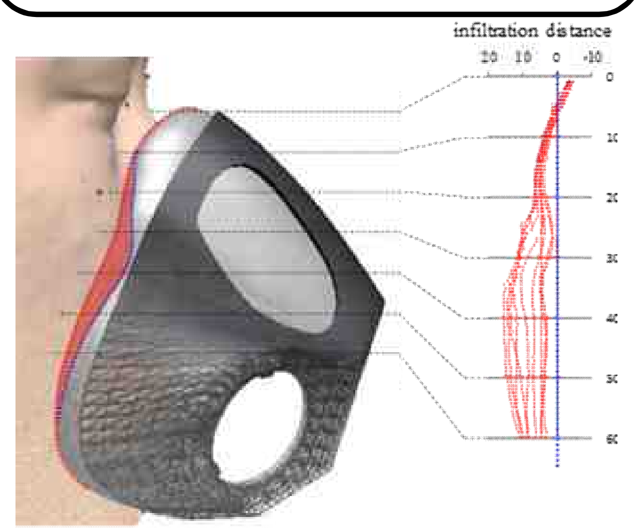
- Provide detailed measurements of complex dimensions (e.g., curvature, area, and volume) of the human body applicable to various product designs

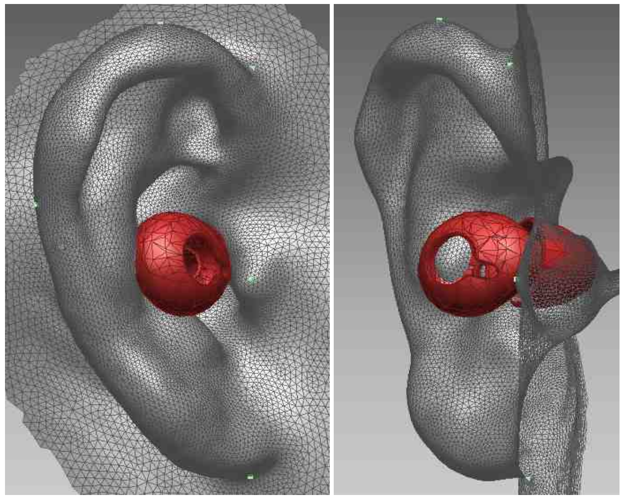
Application of 3D scan images to product design

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 ears of 200 Koreans and 96 Caucasians for design of earphone

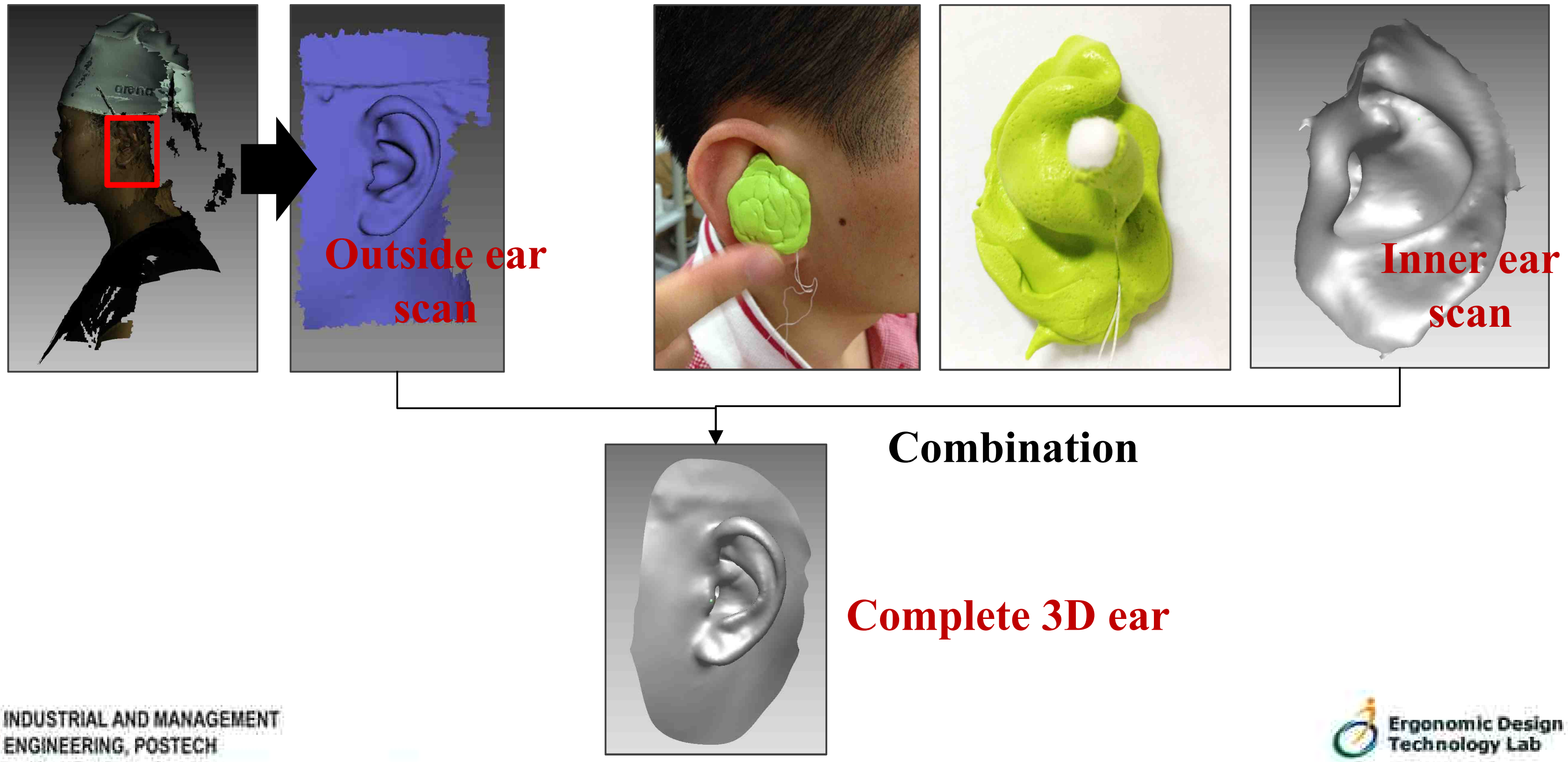




Earphone Design using 3D Scanning Techniques

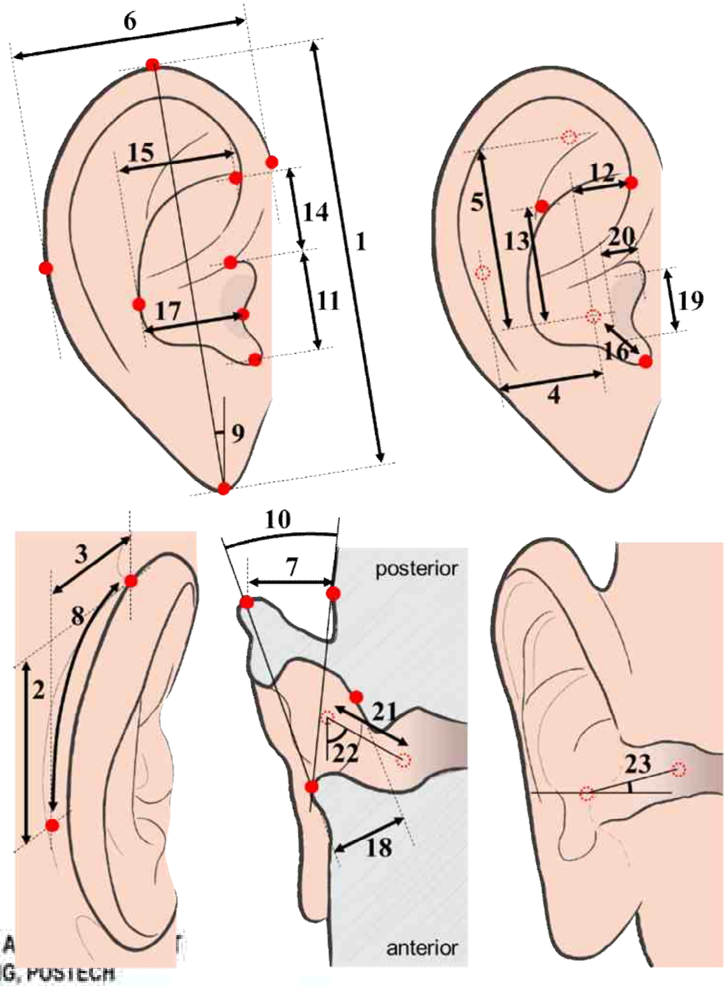
- Scanned the outside of the ear (pinna) using the Artec Eva 3D scanner for 296 participants in 20s to 50s (200 Koreans: 100 males and 100 females; 96 Caucasians: 50 males and 46 females)

- Scanned the casts of their inner ears and combined the outer and inner ears



Measurement of Ear Dimensions & Characteristics

- 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

Generation of Representative Ears

- Determined 5 representative ears (2.5, 25, 50, 75, and 97.5%iles) by considering all the ear dimensions

Smallest
(2.5%ile)

Small
(25%ile)

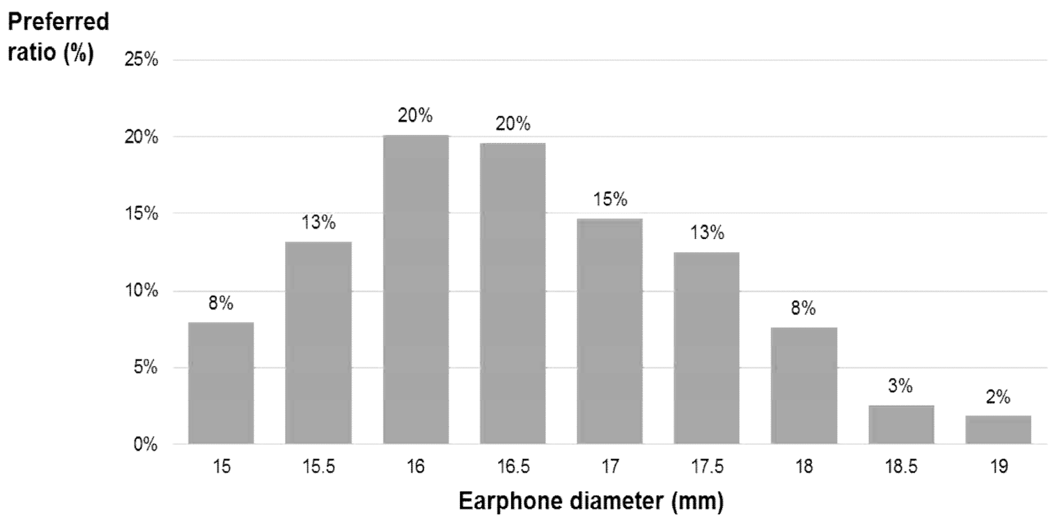
Medium
(50%ile)

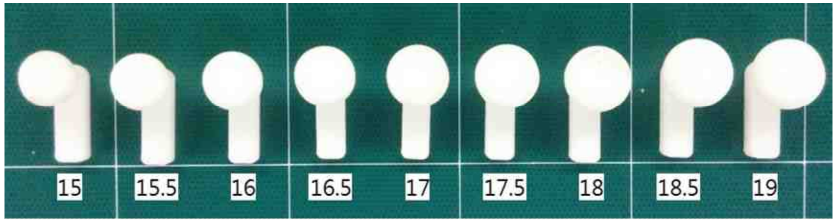
Large
(75%ile)

Largest
(97.5%ile)

Analysis of Preferred Earbud Size

- Fabricated earbud prototypes with different diameters (15 to 19 mm; 0.5 mm interval)
- Asked participants (*n* = 296) to select the most preferred sizes of earbud

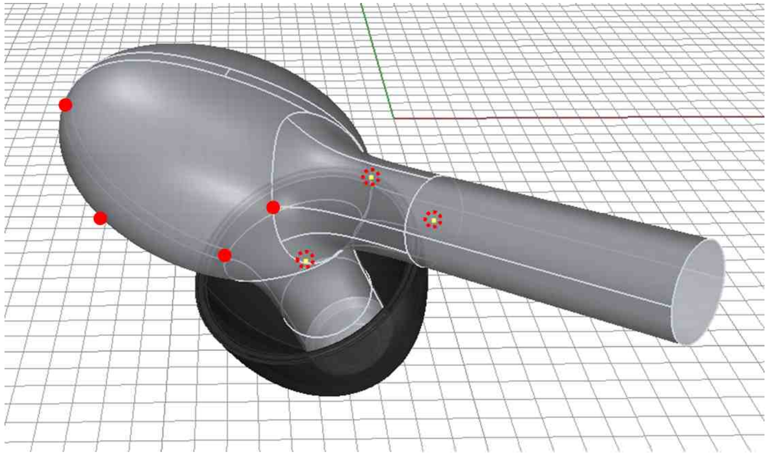


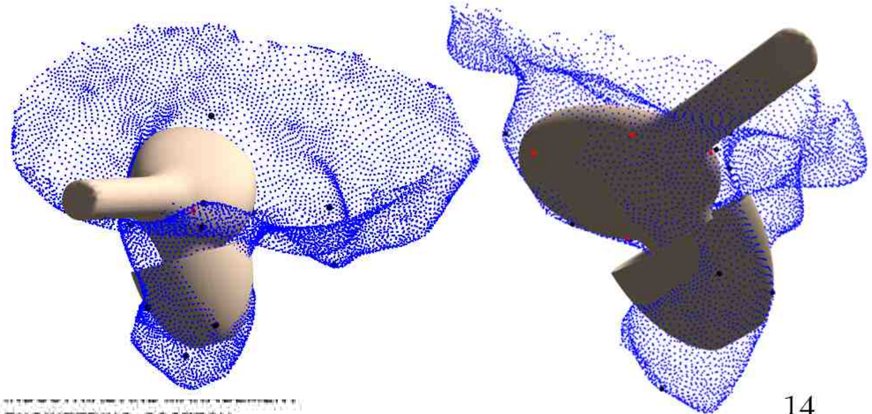


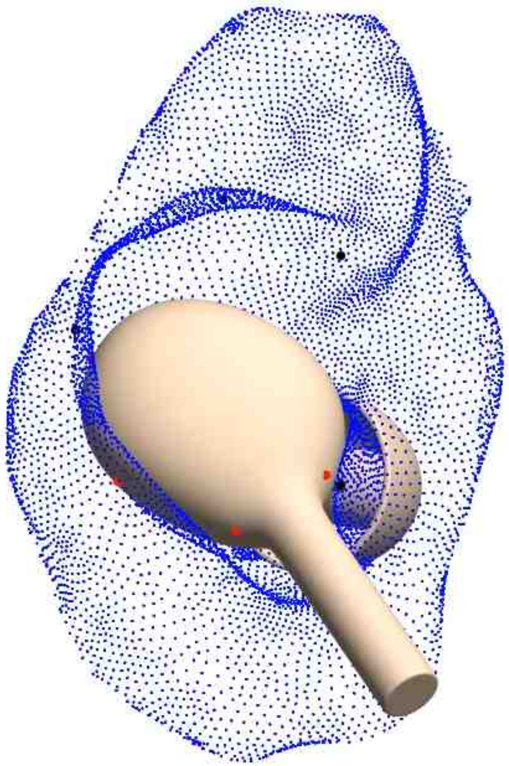
Ethnicity	Gender	Preferred size	Concha width
Korean	M	16.9 ± 0.9	17.2 ± 1.7
	F	16.3 ± 0.8	16.5 ± 1.7
	Composite	16.6 ± 0.9	16.8 ± 1.8
Caucasian	M	16.5 ± 1.1	16.9 ± 1.9
	F	16.5 ± 1.1	16.5 ± 1.6
	Composite	16.5 ± 1.1	16.7 ± 1.8
Range		**16.3 ~ 16.9 mm**	**16.5 ~ 17.2 mm**

Virtual Fit Analysis

- Virtual fit simulation to find the optimal shape and size of earphone
- Placed an earphone based on the relationship between ear landmarks and earphone landmarks identified from the use characteristics analysis of earphone

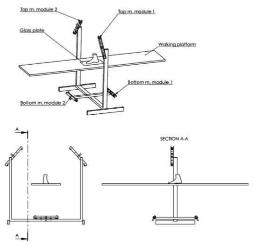
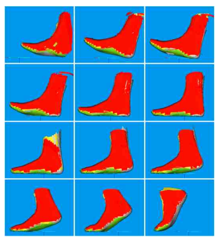






Temporal 3D Scanning Techniques

- Continually capture 3D body surface in motion with certain frame rate (10 fps to 60 fps)
- Challenges
  - Large scan space, complicated movement, many synchronized scanners needed
  - Time for scanning & image processing

Classification	Laser scanning	Structured light scanning	Stereo photogrammetry scanning
Model	MV-03M2M-CS (Point Grey Firefly, Canada)	DynaScan4D (ViALUX, Germany) Shapify Booth (Artec 3D, Luxembourg)	3dMD T & U systems (3dMD, USA)
Limitations or strengths	• Data missing • More effort on post-processing of the data	• Data missing • More effort on post-processing of the data	• High quality data • Fast image processing • Less effort on post-processing
	 	 	 

Demo: Temporal 3D Scanning Techniques

Shapify Booth (Artec 3D, Luxembourg)
Structured light based

3dMD T & U systems (3dMD, USA)
Stereo photogrammetry-based

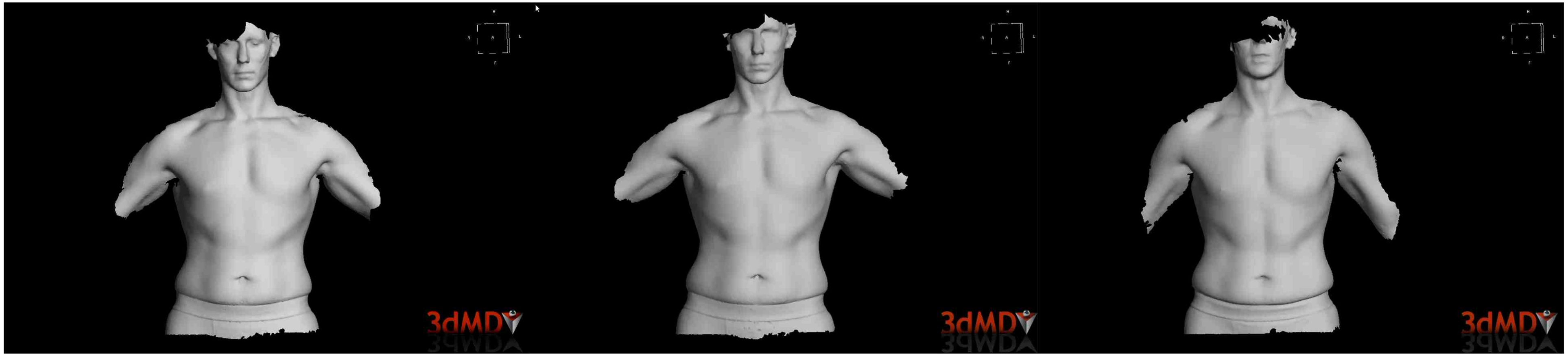
Case Studies: Application of Temporal 3D Scanning Techniques to Ergonomic Product Design

- No academic studies have been conduced for product design using temporal 3D scanning techniques.
- Leading sportswear makers such as Nike and Under Armour have started using the techniques for sportswear design.
- Advantages: able to capture 3D body in motion to analyze dynamic body dimensions during doing certain sports for better sportswear design to improve athletes' performance

Chest Dimension Change During Breathing

- Able to quantify chest dimension change during breathing

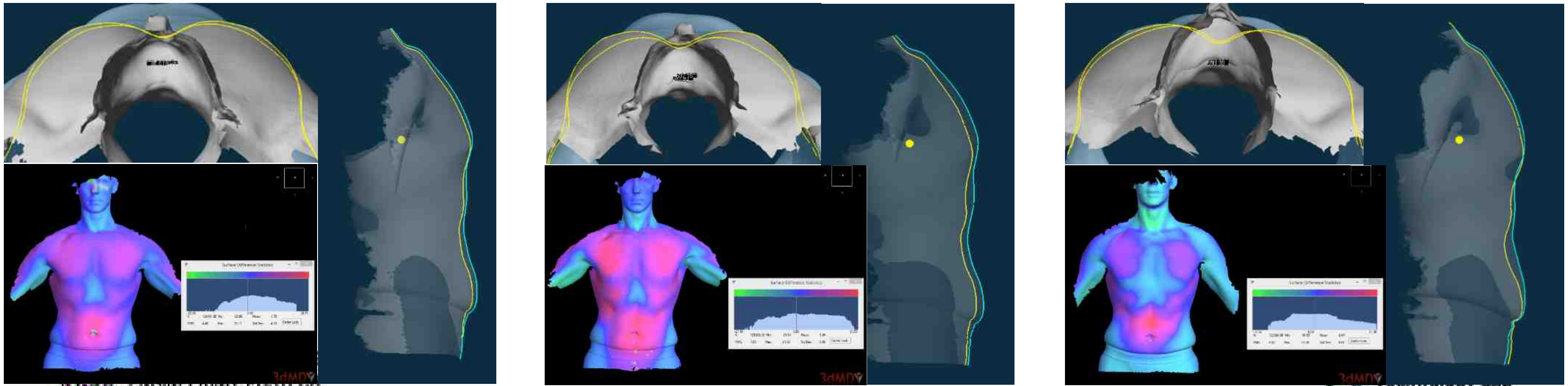
Normal Breathing — Heavy Breathing — Breathing After Exercise



Normal Breathing
Frames 58 & 70

Heavy Breathing
Frames 26 & 37

Breathing Post Exercise
Frames 15 & 20

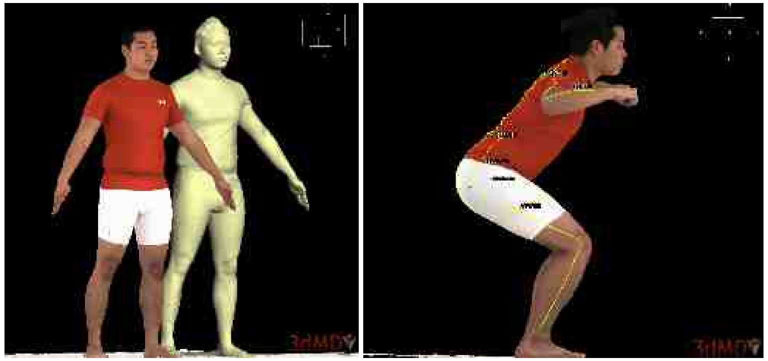


Body Dimension Change Under Different Postures

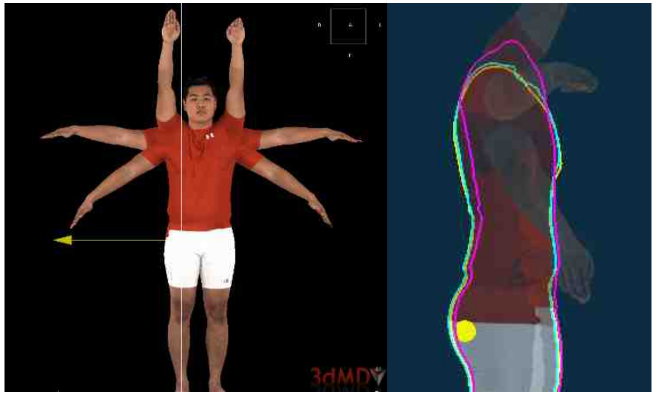
- Able to quantify body dimension change at different postures

Body Dimension Change Under
A-Pose and Squat

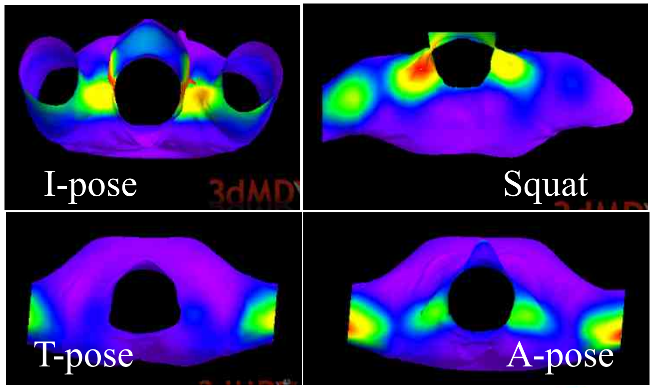
Right Side	A-pose (mm)	Squat (mm)
Thigh Circumference	585.2	693.1
Leg Length	1104.0	1150.5
Seat Circumference	1039.5	1227.8
Back neck to crotch	711.2	892.4
Cross Shoulder	444.7	392.0
Sleeve Length	584.7	600.9



Body Shape Change Under A-Pose,
T-Pose, and I-Pose



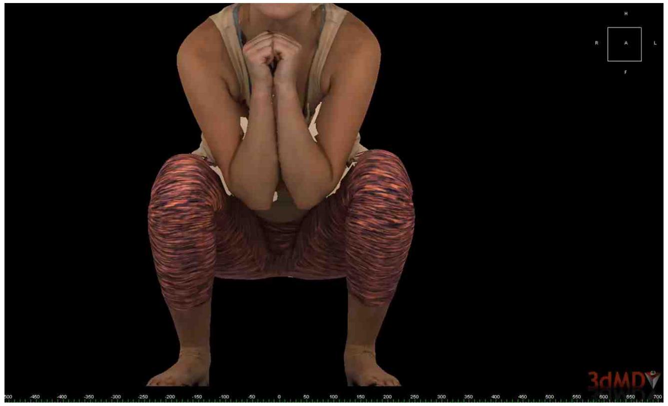
Shoulder Deformation at
Different Poses



Assessment of Extremity of Movement in Cloths with Different Materials

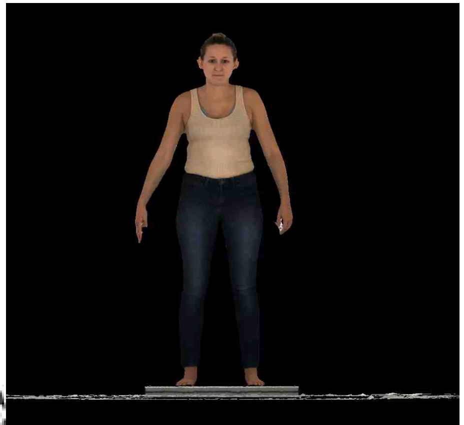
- Able to quantify extremity of movement in clothes with different materials

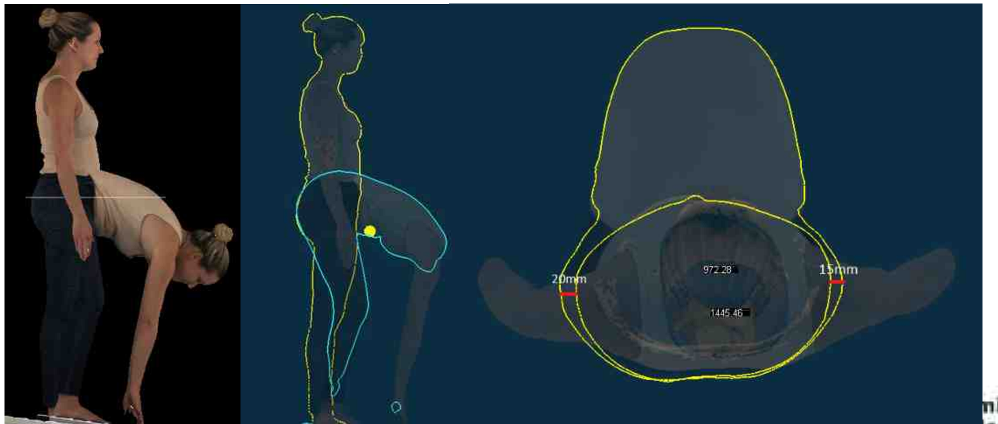
Extremity of squat movement in yoga pants



Extremity of squat movement in jeans

Quantification of body shape change from A-pose to the extreme posture of bending over





Discussion

- Stereo photogrammetry-based scanning technique is superior to the laser-based and structured light-based techniques in terms of scanning time and data quality.

- 3D scanning techniques can be used for effective measurement of human body dimensions applicable to product design, such as mask and earphone.

- Temporal 3D canning techniques can capture human body surface in motion in certain frame rate for analyzing dynamic body dimensions for ergonomic design of products such as sportswear to improve the performance of athletes.

- Temporal 3D scanning techniques have high potential in academic study for dynamic anthropometry, human modeling, and product design.

Q & A

Thank you for your attention!