신체 측정 기술 적용 가능성

HGU – Mechanical Control Engineering

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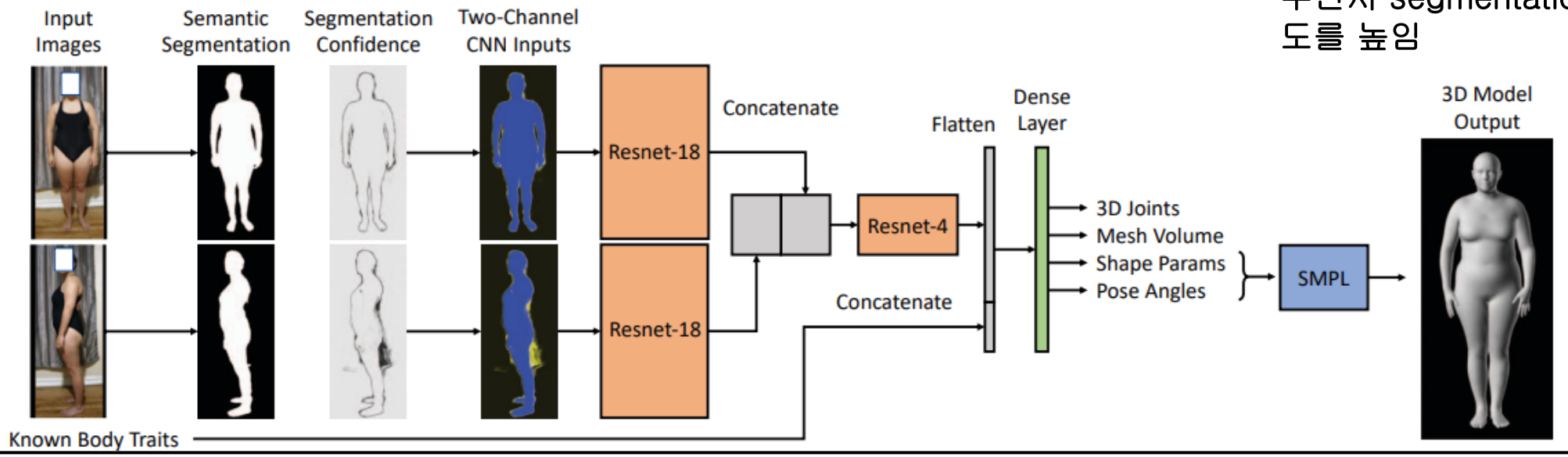
목차

2D 이미지를 사용한 신체측정 기술 논문

1. Towards Accurate 3D Human Body Reconstruction from Silhouettes (2019)

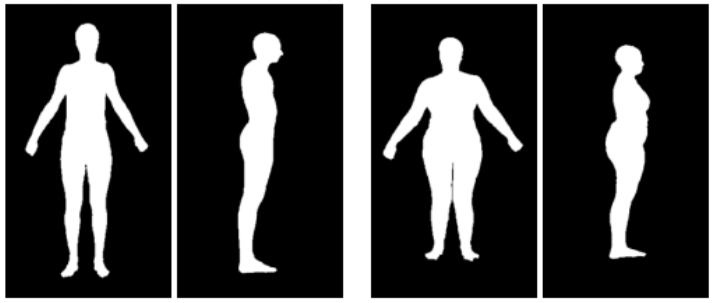
BfSNet이라는 모델을 만들어 3차원 신체의 정확성을 높임

픽셀 단위별 segmentation condfidence map을 입력을 주면서 segmentation 정확도를 높임



Input: Binary Silhouette Images, Segmentation Confidence Maps, Known Body Traits, Gender Information
Output: 3D joint locations, mesh volume, shape parameters, and pose angles

Synthetic silhouettes in prior work [5, 10, 14, 15, 43]

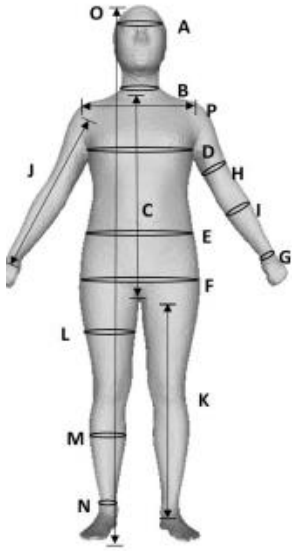


Synthetic silhouettes proposed in this work

Segmentation and
Silhouette Pre-Processing

Measurements	SMPL model [29] **BfSNet** (Our system)	Dibra '16 [14] Our implem.
A. Head circumference	5.1 ± 6.4	3.0 ± 3.8
B. Neck circumference	3.0 ± 3.9	3.0 ± 3.9
C. Shoulder to crotch	**1.5** ± 2.2	2.9 ± 3.8
D. Chest circumference	4.7 ± 7.7	7.2 ± 9.2
E. Waist circumference	**4.8** ± 7.5	8.1 ± 10.2
F. Pelvis circumference	**3.0** ± 5.1	6.0 ± 7.7
G. Wrist circumference	2.5 ± 3.3	2.0 ± 2.7
H. Bicep circumference	2.7 ± 3.8	3.3 ± 4.2
I. Forearm circumference	1.9 ± 2.5	2.3 ± 2.9
J. Arm length	**1.7** ± 2.4	2.7 ± 3.5
K. Inside leg length	**1.5** ± 2.7	2.8 ± 3.5
L. Thigh circumference	**2.4** ± 4.0	4.9 ± 6.2
M. Calf circumference	**2.3** ± 3.6	3.3 ± 4.3
N. Ankle circumference	2.1 ± 2.8	2.0 ± 2.6
O. Overall height	**2.3** ± 4.6	4.0 ± 5.0
P. Shoulder breadth	**1.9** ± 2.5	2.9 ± 3.6
Mean measurement error	**2.72** mm	3.78 mm

Measurements	BfSNet
A. Head circumference	14.2 ± 18.6
B. Neck circumference	11.4 ± 18.7
C. Shoulder to crotch	11.0 ± 13.8
D. Chest circumference	16.2 ± 20.6
E. Waist circumference	25.0 ± 32.1
F. Pelvis circumference	15.2 ± 19.6
G. Wrist circumference	5.5 ± 7.0
H. Bicep circumference	10.4 ± 13.5
I. Forearm circumference	7.9 ± 10.1
J. Arm length	6.0 ± 7.7
K. Inside leg length	8.0 ± 10.1
L. Thigh circumference	11.1 ± 14.2
M. Calf circumference	10.4 ± 13.3
N. Ankle circumference	6.3 ± 8.1
O. Overall height	7.9 ± 10.5
P. Shoulder breadth	8.4 ± 10.7
Mean measurement error	10.9 mm



BfSNet
non-real situation Mean measurement error: 2.72 [mm]
Real situation MME: 10.9[mm]

2D → 3D data
신체 치수가 output이 아님
신체 측정은 SMPL 라이브러리를 사용하여 측정하거나 MeshLab 같이 mesh를 보여주는 것을 수동으로 측정한것으로 예상

*SMPL : Skinned Multi-Person Linear model (shape, pose, joint location)

2. Learning Anthropometry from Rendered Humans (2021)

3D 인체 재구성 단계를 생략하고 심층 신경망을 사용하여 2D 이미지에서 직접 인체 측정값을 추정

학습 데이터셋

Rendered RGB:

XXXX-dataset (신체 스캔데이터, TC2 system으로 스캔됨)

→ XXXX-fits(구멍이나 누락된 스캔 데이터 매꿈)

→ SURREAL (Synthetic hUmans foR REAL tasks) 로 3D를 2D 이미지로 바꿈 // 전면과 옆면 view)

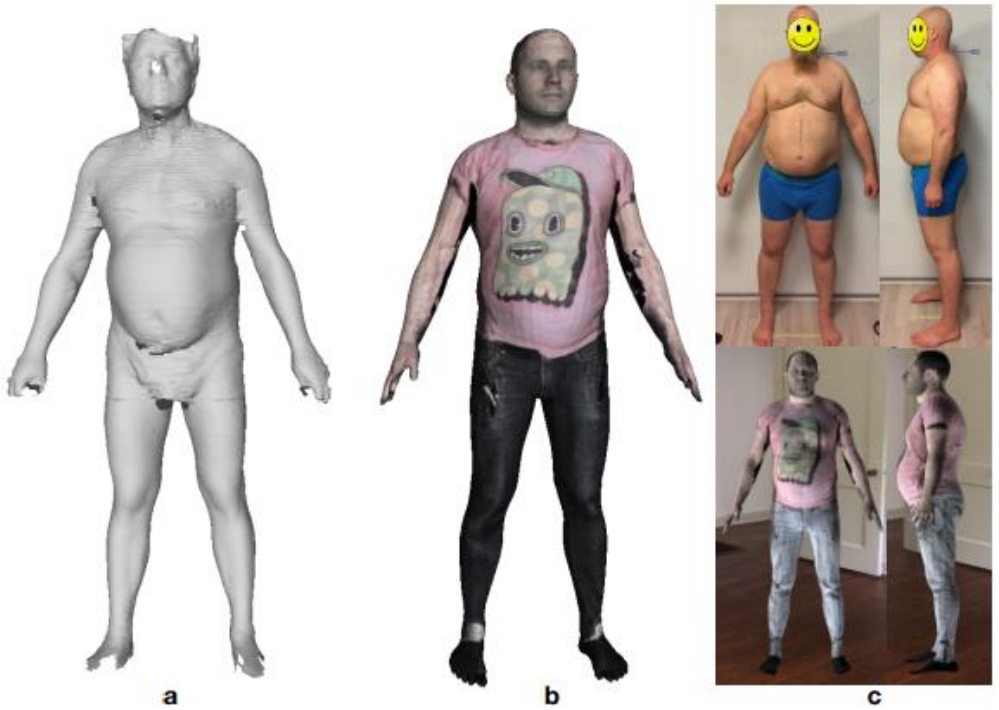
REAL RGB:

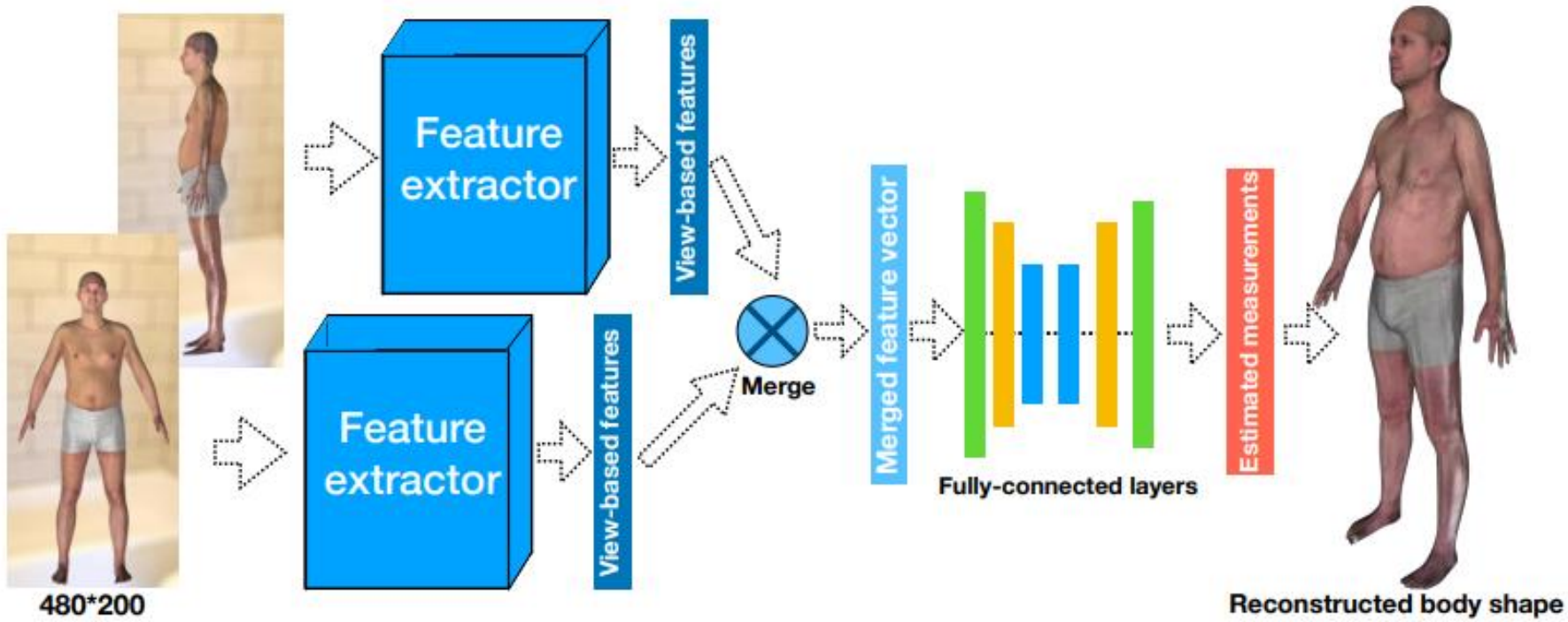
200개 real data set (iphone 5s)

Location of the camera:

height - 1.6[m]

distance – 2.4[m]





입력:

이미지:
RGB 이미지-정면 및 측면에서 촬영된 RGB 이미지

보정 정보:
•피사체의 높이
•가상 카메라 보정 매개변수 (이미지를 480 × 200 해상도로 크기 조정하고 중심을 맞추기 위해 사용)

출력:

신체 치수 16개

Measurements & Datasets	XXX-fits		CAESAR-fits	
	RGB	Silh.	RGB	Silh.
a. Head Circumference	24.9	22.8	11.6	10.4
b. Neck Circumference	14.5	14.4	12.3	10.6
c. Shoulder-crotch Len.	14.8	12.4	13.9	12.9
d. Chest Circumference	34.4	22.2	26.1	15.3
e. Waist Circumference	36.7	32.9	28.7	15.0
f. Pelvis Circumference	23.9	23.8	22.6	17.0
g. Wrist Circumference	7.9	7.4	6.9	6.3
h. Bicep Circumference	13.5	10.6	13.0	9.9
i. Forearm Circumference	9.3	7.7	7.8	6.2
j. Arm length	7.5	5.4	9.5	6.4
k. Inside Leg length	12.9	8.5	11.2	7.1
l. Thigh Circumference	19.6	18.9.	18.2	12.8
m. Calf Circumference	11.2	11.7	11.7	10.6
n. Ankle Circumference	7.5	7.1	7.8	7.2
o. Overall height	29.8	21.9	20.1	12.4
p. Shoulder breadth	8.6	6.9	7.6	6.0

RGB vs silhouette

Measurements	Ours	HKS	HMR	SMPLify
a. Head Circumference	11.6	**10.8**	16.3	28.1
b. Neck Circumference	**12.3**	13.1	27.2	24.4
c. Shoulder-crotch Len.	13.9	**13.4**	28.6	57.8
d. Chest Circumference	**26.1**	28.3	68.3	74.5
e. Waist Circumference	**28.7**	38.6	85.3	72.8
f. Pelvis Circumference	**22.6**	26.0	62.8	99.1
g. Wrist Circumference	6.9	**6.5**	14.3	11.9
h. Bicep Circumference	**13.0**	13.4	35.6	28.4
i. Forearm Circumference	**7.8**	8.0	16.7	25.9
j. Arm length	9.5	**6.9**	45.3	150.2
k. Inside Leg length	11.2	**8.7**	37.2	219.1
l. Thigh Circumference	**18.2**	18.5	39.3	51.3
m. Calf Circumference	**11.7**	11.8	21.4	28.4
n. Ankle Circumference	**7.8**	7.9	13.6	28.8
o. Overall height	20.1.	**11.8**	96.5	398.5
p. Shoulder breadth	**7.6**	7.7	21.8	51.9

CAESAR-fits data

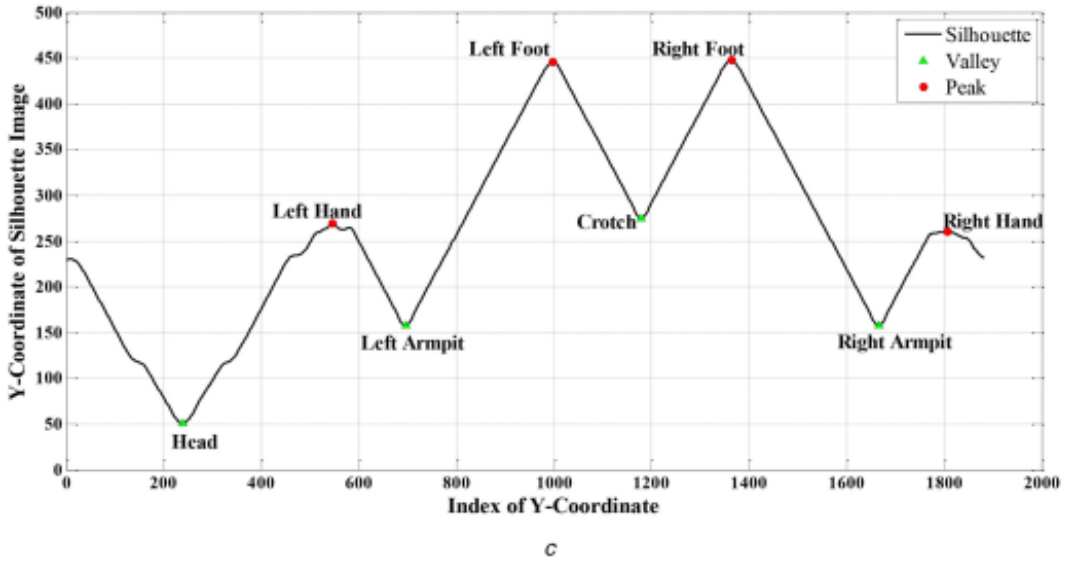
Measurements	Ours	HKS	HMR	SMPLify
a. Head Circumference	24.9	**24.3**	25.2	33.0
b. Neck Circumference	**14.5**	15.8	25.3	22.4
c. Shoulder-crotch Len.	14.8	**13.2**	25.7	63.4
d. Chest Circumference	**34.4**	40.8	92.7	67.3
e. Waist Circumference	**36.7**	50.3	88.7	74.8
f. Pelvis Circumference	**23.9**	28.4	56.2	89.3
g. Wrist Circumference	7.9.	**7.3**	11.0	9.9
h. Bicep Circumference	**13.5**	15.1	37.7	26.4
i. Forearm Circumference	**9.3**	9.7	16.1	20.6
j. Arm length	7.5	**5.9**	24.5	138.0
k. Inside Leg length	12.9	**10.0**	36.3	229.6
l. Thigh Circumference	**19.6**	21.6	36.4	44.8
m. Calf Circumference	**11.2**	12.7	19.7	22.5
n. Ankle Circumference	**7.5**	**7.5**	10.7	23.2
o. Overall height	29.8.	**23.2**	92.9	419.5
p. Shoulder breadth	8.6	**7.9**	19.9	68.4

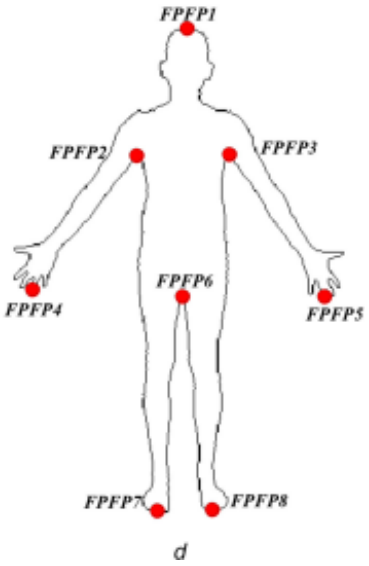
XXX-fits data

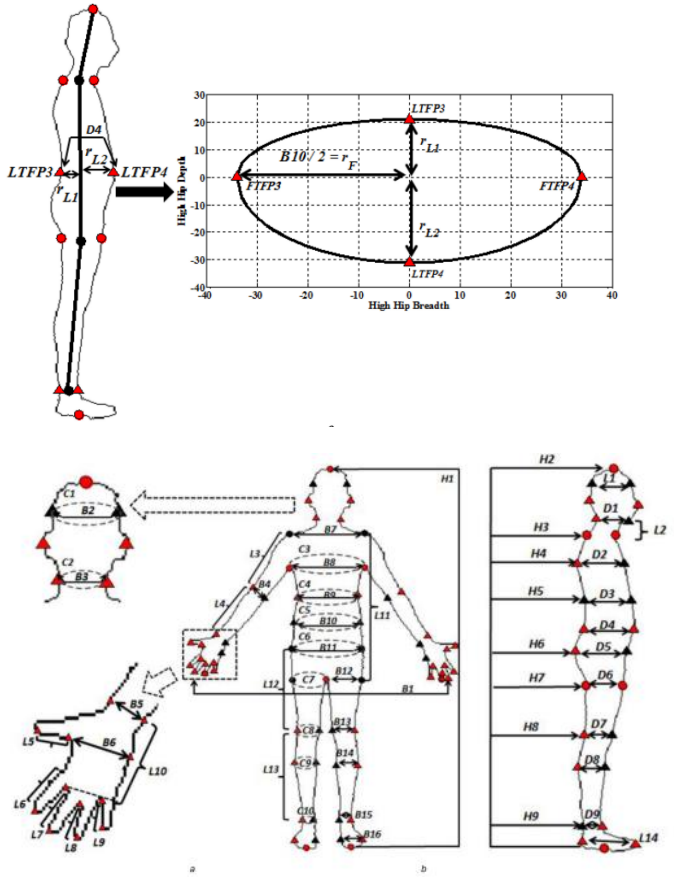
Max Error: 36.7[mm]

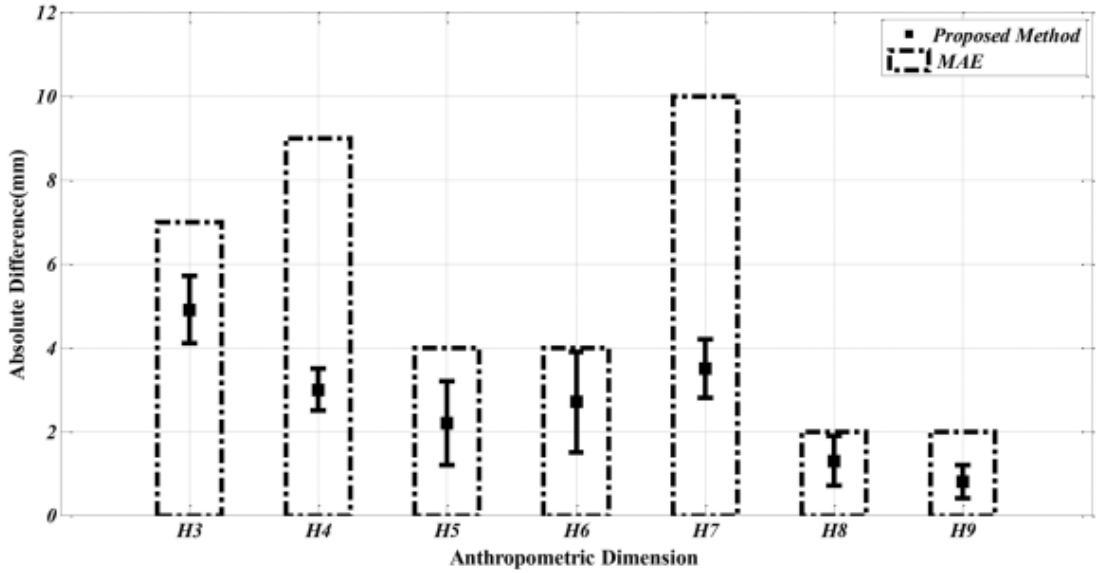
3. Automatic measurement of anthropometric dimensions using frontal and lateral silhouettes (2016)
- key point extraction algorithm with measurement

dataset from 80 subjects including 28 females and 52 males, aged from 20 to 45 years are used for testing the proposed algorithm.

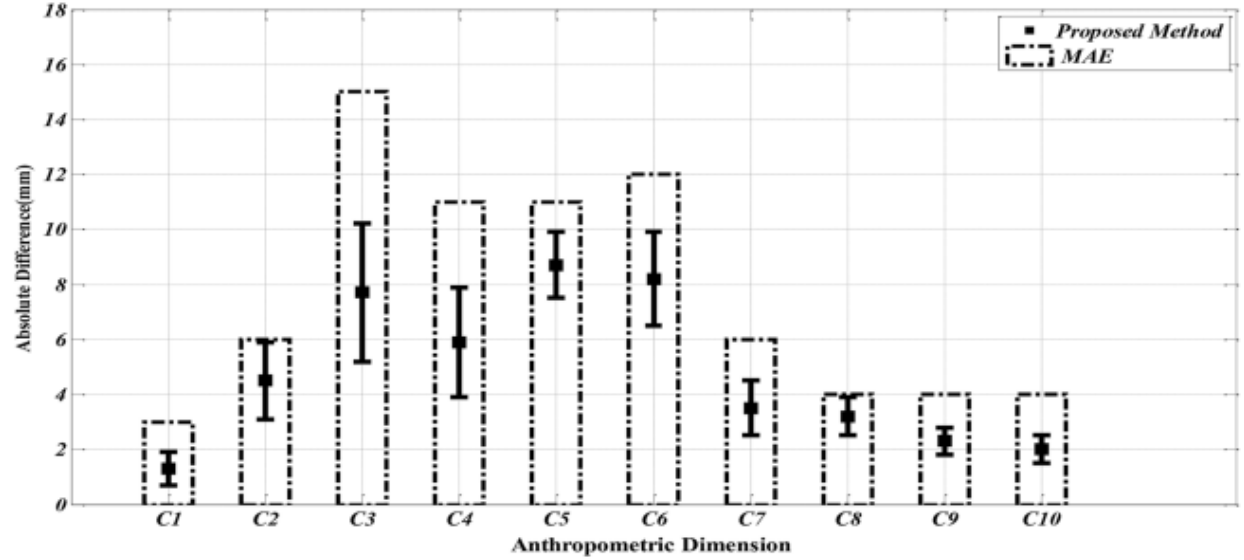




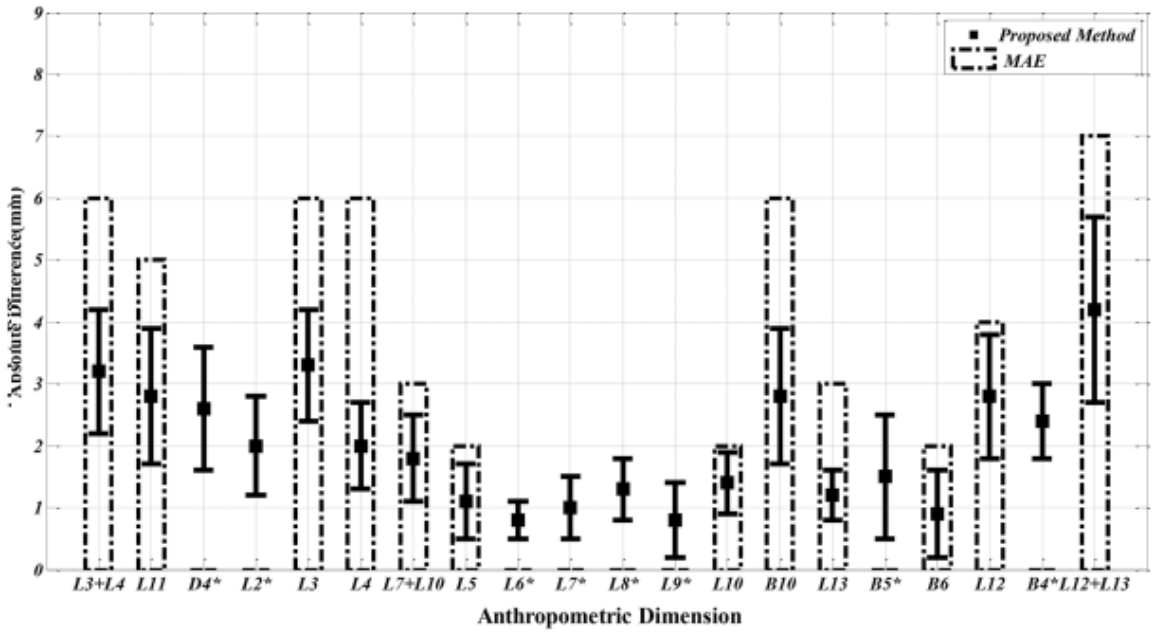



Proposed Method
MAE
Absolute Difference(mm)
H3
H4
H5
H6
H7
H8
H9
Anthropometric Dimension

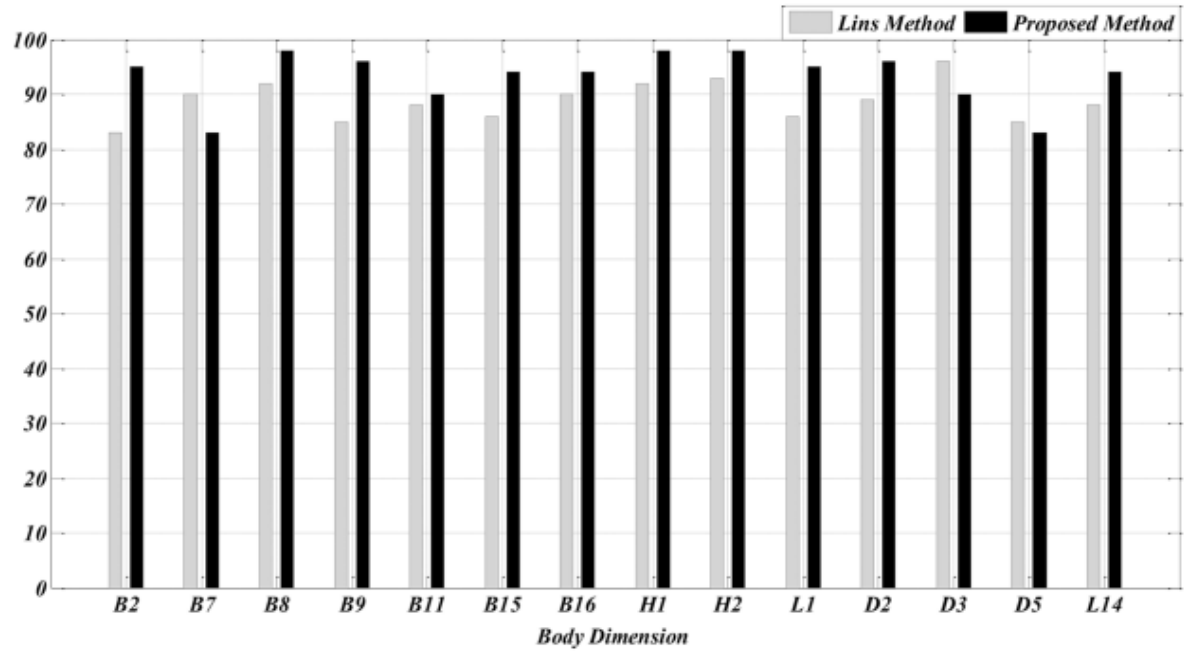
a


Proposed Method
MAE
Absolute Difference(mm)
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Anthropometric Dimension

b


Proposed Method
MAE
L3+L4
L11
D4*
L2*
L3
L4
L7+L10
L5
L6*
L7*
L8*
L9*
L10
B10
L13
B5*
B6
L12
B4*
L12+L13
Anthropometric Dimension

c


Lins Method
Proposed Method
B2
B7
B8
B9
B11
B15
B16
H1
H2
L1
D2
D3
D5
L14
Body Dimension

d

4. Automatic Estimation of Anthropometric Human Body Measurements (2021)

2D 그리고 3D cloud point data를 입력으로 하는 신체 측정 AI 모델

입력 데이터:
1. binary 2D
2. Gray scale 2D
3. 3D point cloud

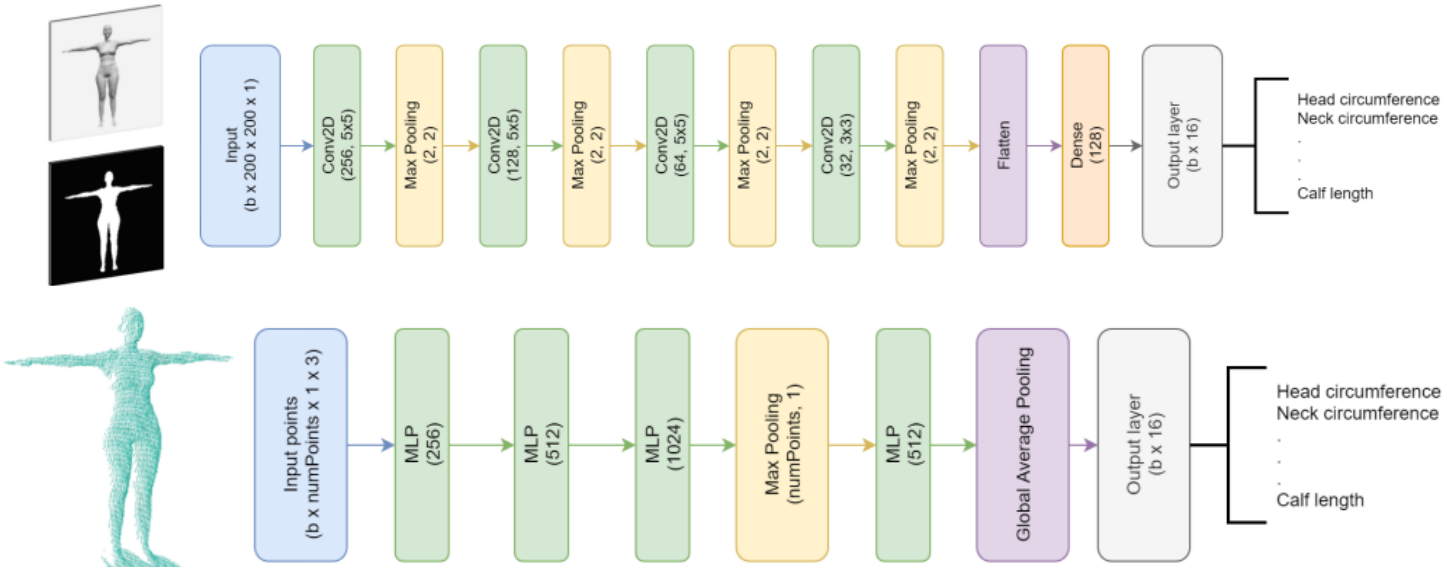
→

출력:
16개의 신체 측정값

두가지 모델 정의:

2D data: Convolutional Body Dimensions Estimation (Conv-BoDiEs)

3D data: f Point Cloud Body Dimensions Estimation (PC-BoDiEs)



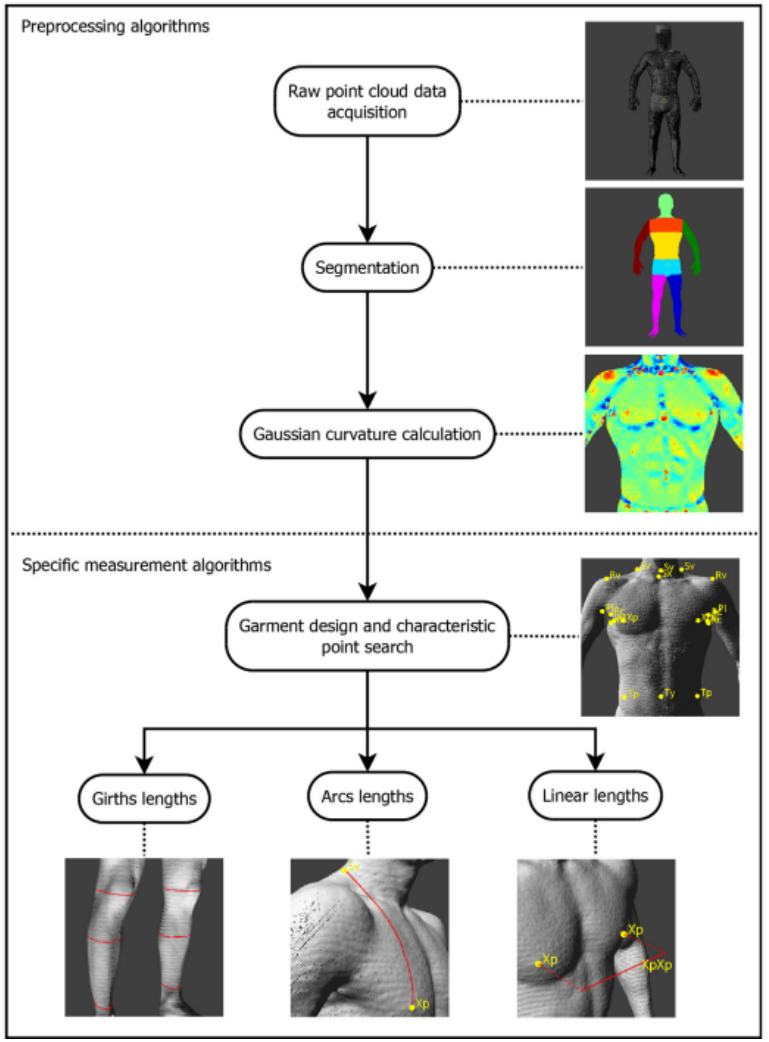
Body measurement	MAE (mm)			AP@20 (%)			AP@10 (%)		
	Conv-BoDiEs G	Conv-BoDiEs B	PC-BoDiEs	Conv-BoDiEs G	Conv-BoDiEs B	PC-BoDiEs	Conv-BoDiEs G	Conv-BoDiEs B	PC-BoDiEs
Head circumference	8.38	16.22	8.06	94.09	67.56	94.87	66.12	37.70	68.44
Neck circumference	8.82	17.39	9.07	93.08	64.54	91.76	63.81	35.57	62.46
Shoulder-to-shoulder	7.54	12.41	8.21	96.37	80.36	94.57	71.28	48.06	67.43
Arm span	5.32	7.45	6.95	99.63	96.82	97.75	86.77	71.88	75.57
Shoulder-to-wrist	3.90	6.00	5.18	99.97	99.14	99.66	95.81	81.67	87.63
Torso length	6.51	10.13	7.85	98.46	88.48	95.68	78.10	56.99	69.23
Bicep circumference	4.60	6.66	5.79	99.87	98.37	99.40	91.46	77.05	83.16
Wrist circumference	2.23	3.28	2.48	100.00	99.99	100.00	99.80	98.11	99.79
Chest circumference	2.57	5.24	3.29	100.00	99.71	100.00	99.57	87.22	98.31
Waist circumference	1.65	3.11	2.29	100.00	100.00	100.00	99.98	98.96	99.96
Pelvis circumference	3.51	4.92	5.11	99.89	99.57	99.66	97.09	89.52	88.17
Leg length	2.65	3.69	3.48	100.00	100.00	100.00	99.63	96.97	97.77
Inner leg length	4.16	5.80	2.76	99.67	98.51	99.99	94.10	83.89	98.92
Thigh circumference	2.46	3.31	2.80	99.99	99.97	99.99	99.75	97.98	99.41
Knee circumference	2.76	5.47	3.45	99.98	99.47	99.98	99.33	85.38	97.67
Calf length	7.27	10.56	7.90	96.08	87.39	95.20	73.23	53.68	69.11
Mean	**4.64**	7.60	4.95	**100.00**	99.99	**100.00**	99.84	88.70	**99.86**

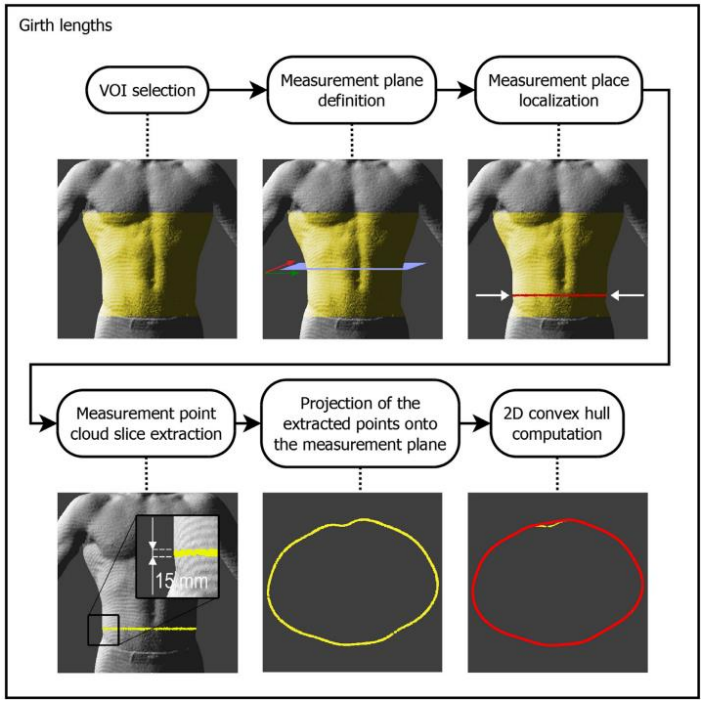
3D 데이터를 이용한 신체측정 기술 논문

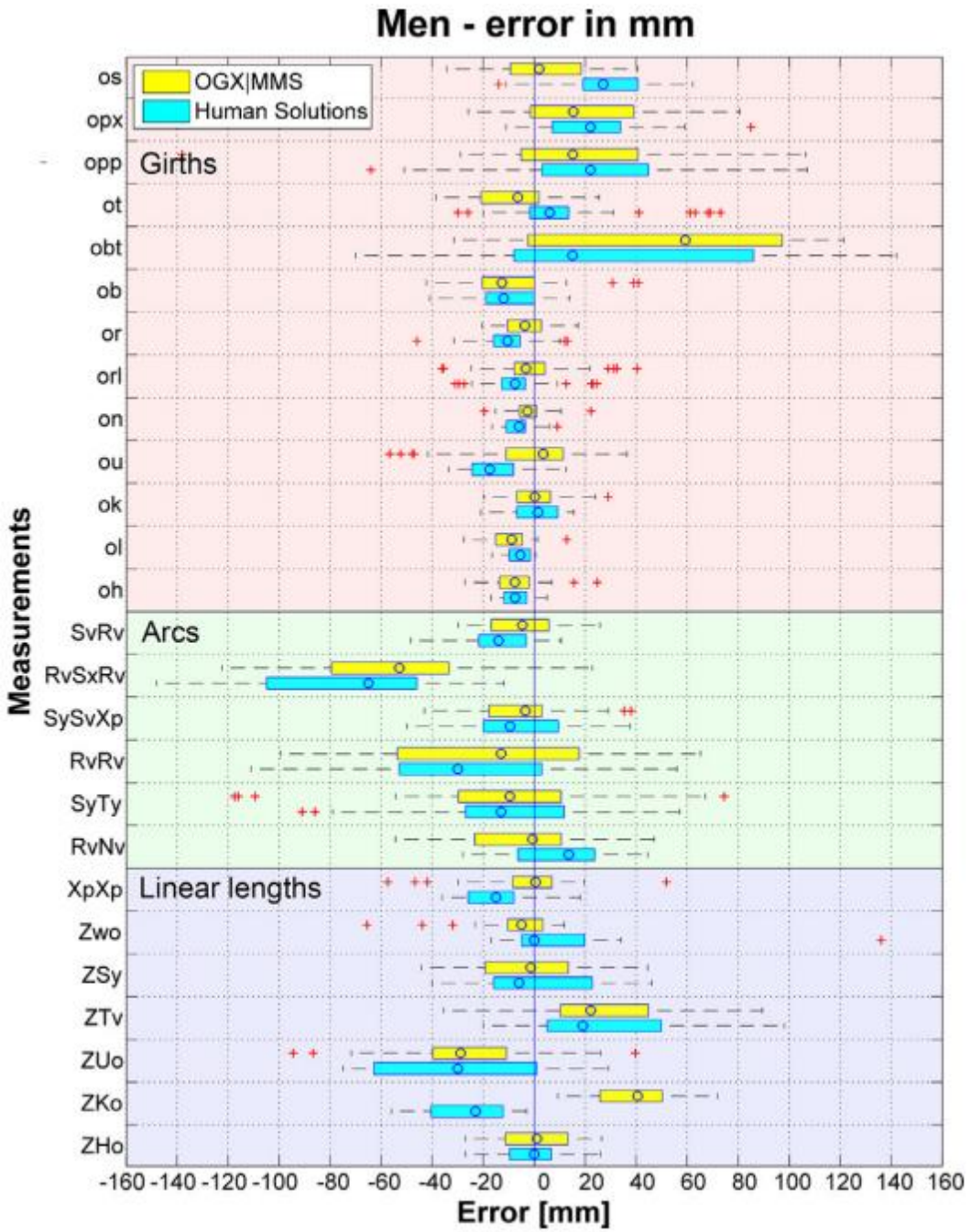
1. 3D anthropometric algorithms for the estimation of measurements required for specialized garment design (2016)

   Data: 3D scan data (point cloud)

   두개의 3D scanner로 data를 받고 비교한다.
   1. OGX
   2. HS (Human Solution)







	Manual vs OGX|MMS		Manual vs HS		Manual vs OGX|MMS vs HS		OGX|MMS vs HS	
	c	a	c	a	c	a	c	a
Girths	0.93	0.90	0.93	0.87	0.93	0.89	0.94	0.92
Arcs	0.73	0.67	0.60	0.54	0.69	0.63	0.70	0.69
Linear lengths	0.79	0.71	0.75	0.68	0.77	0.68	0.79	0.71
All	0.84	0.80	0.80	0.74	0.83	0.78	0.85	0.81

Obt - Front-back torso

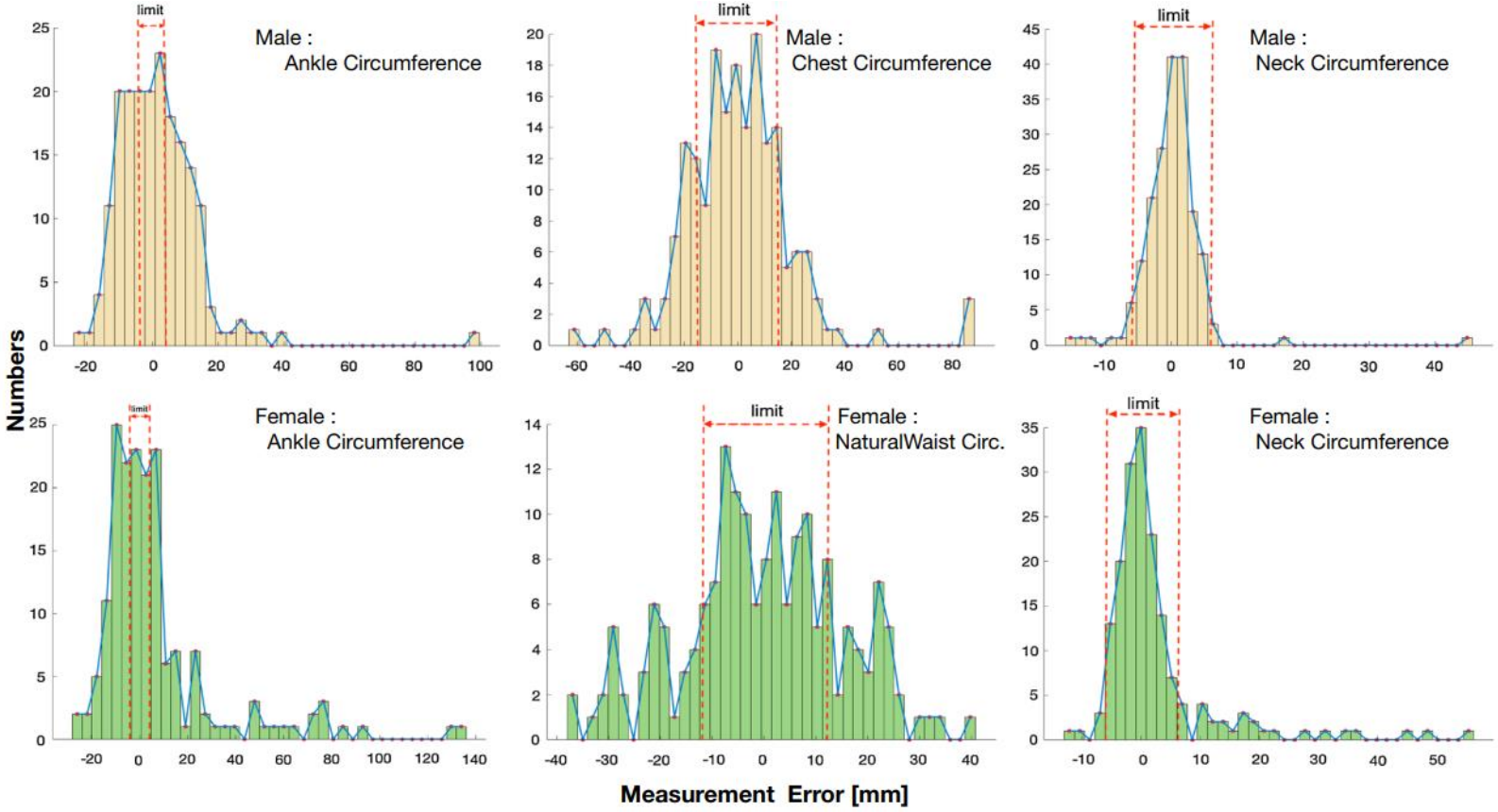
- **둘레 측정값**: 최대 6cm 이내의 error
- **길이 측정값**: 최대 6cm의 에러
- **호 길이 측정값**: 큰 에러

에러의 값이 크다:
1. 오래된 기술
2. 알고리즘 부실

*ICC (Intraclass Correlation Coefficient): 급내 상관계수

2. Anthropometric clothing measurements from 3D body scans (2018)

3D scan triangular mesh → SMPL model fitting (ICP) → Measure using pre-defined landmarks



남성의 경우 28%에서 93%, 여성의 경우 24%에서 82%의 성공률을 제공

Measure	Best single ($C = 1$)		Best single + SVR		L-BFGS-B + SVR			Multiple paths + SVR			Limit [9]
	MAE (mm)	%	MAE (mm)	%	C	MAE (mm)	%	C	MAE (mm)	%	(mm)
Male											
Ankle circ.	36.4	0	8.4	**37.6**	6	12.3	27.5	6	**7.7**	28.6	4
Bicep circ.	7.8	45.8	6.5	**57.8**	8	19.4	16.2	8	**6.1**	57.6	6
Calf circ.	6.9	41.2	4.0	70.3	6	17.7	16.8	6	**3.0**	**82.2**	5
Chest circ.	15.6	60.0	15.5	61.6	5	43.3	22.9	5	**14.3**	**63.7**	15
Elbow circ.	4.0	56.5	3.7	62.8	8	11.4	16.2	8	**2.6**	**77.9**	4
Hip circ.	9.2	71.7	9.3	**75.4**	4	32.6	22.9	4	**8.8**	73.3	12
Knee circ.	8.5	28.3	6.0	44.0	6	15.5	12.9	6	**5.1**	**46.6**	4
NaturalWaist circ.	15.8	49.0	13.2	57.3	4	50.0	15.6	4	**12.8**	**57.6**	12
NeckBase circ.	35.1	4.2	10.2	61.0	3	15.7	43.6	3	**8.0**	**72.6**	11
Neck circ.	3.0	92.1	3.0	91.1	4	16.3	22.4	4	**2.5**	**93.7**	6
Thigh circ.	10.6	31.4	10.5	32.5	8	27.9	16.8	8	**7.9**	**48.7**	6
TrouserWaist circ.	25.5	–	12.0	–	3	36.4	–	3	**9.1**	–	–
Wrist circ.	7.2	43.2	5.2	57.8	6	6.6	49.2	6	**4.5**	**67.2**	5
Shoulder_to_shoulder	13.7	–	13.8	–	4	18.0	–	4	**12.0**	–	–
Shoulder_to_wrist	40.3	–	14.7	–	6	27.3	–	6	**12.7**	–	–
Avg.	16.0	43.6	9.1	59.1		23.4	23.6		**7.8**	**64.1**	
Female											
Ankle circ.	18.8	14.4	14.3	23.0	6	17.7	14.7	6	**13.4**	**24.7**	4
Bicep circ.	19.7	8.5	7.9	48.3	8	15.9	25.4	8	**4.9**	**73.9**	6
Calf circ.	7.3	37.4	3.8	70.7	6	18.0	19.8	6	**3.0**	**82.8**	5
Bust circ.	17.3	44.0	15.2	60.6	3	42.1	19.2	3	**12.0**	**71.4**	15
Elbow circ.	4.5	57.4	4.5	59.7	6	11.7	22.0	6	**3.4**	**70.5**	4
Hip circ.	18.7	26.3	8.9	70.9	4	37.0	21.5	4	**8.9**	**71.4**	12
Knee circ.	9.9	21.1	6.9	39.4	6	17.3	22.0	6	**5.9**	**41.1**	4
NaturalWaist circ.	13.7	55.7	12.8	56.3	5	41.0	16.4	5	**12.0**	**59.7**	12
NeckBase circ.	58.8	0.6	10.6	**63.6**	3	13.0	54.2	3	**10.2**	62.5	11
Neck circ.	6.3	67.1	5.5	74.0	5	13.4	32.2	5	**4.8**	**81.5**	6
Thigh circ.	10.1	35.8	9.7	39.2	8	29.9	13.6	8	**7.9**	**46.3**	6
TrouserWaist circ.	15.6	–	15.4	–	3	38.0	–	3	**14.8**	–	–
Wrist circ.	6.0	49.1	5.0	59.4	8	6.9	40.7	8	**4.4**	**65.7**	5
UnderBust circ.	14.2	69.5	14.3	69.5	2	34.3	27.1	2	**13.4**	**71.8**	16
Shoulder_to_shoulder	26.5	–	13.8	–	4	17.9	–	4	**12.7**	–	–
Shoulder_to_wrist	22.4	–	16.8	–	4	25.5	–	4	**13.7**	–	–
Bust_to_bust	12.2	46.0	11.6	54.6	9	15.7	39.6	9	**10.4**	**57.5**	10
NeckSide_to_wrist	26.4	–	16.8	–	4	25.8	–	4	**16.0**	–	–
NeckSide_to_bust	13.9	30.9	13.4	35.4	6	17.7	24.9	6	**13.0**	**36.6**	8
Avg.	17.0	37.6	10.9	55.0		23.1	26.2		**9.7**	**61.2**	

결론

방법		정확도
AI 모델	RGB에서 바로	MAE = 4.62[mm]
	3차원 데이터에서	MAE= 4.95[mm]
	2D to 3D 이후	MME = 10.9[mm]
알고리즘	2D 알고리즘	AD = 10[mm]
	3D 알고리즘	Error = 60[mm]
	3D SMPL fitting	MAE = 7.8[mm] MAE (female) = 9.7[mm]

- 2D AI의 architecture를 따라서 만들고 실험을 통해서 실제 정확도 파악 필요.
- 3D 알고리즘도 구현하여 정확도를 비교한다.

- 2D AI 모델이 제일 좋은 정확도를 보인다.

  데이터가 SMPL의 rendering

  3D 알고리즘이 너무 과거의 것이다.