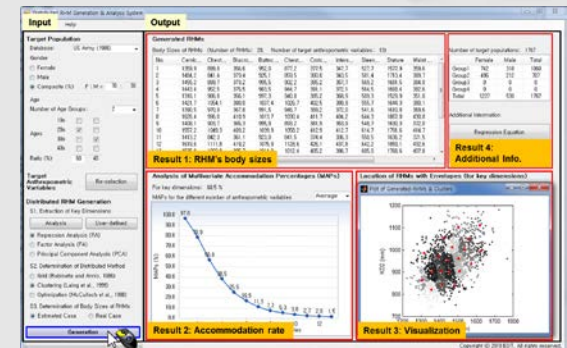


Development of a **Distributed Representative Human Model (DRHM)** Generation and Analysis System for **Multiple-Size Product Design**



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Agenda

- ❑ Introduction
 - Background
 - Objective of the Study
- ❑ Literature Review
- ❑ System Development
- ❑ Application: Flight Suit Sizing System
- ❑ Discussion

Sizing System of Multiple-Size Product

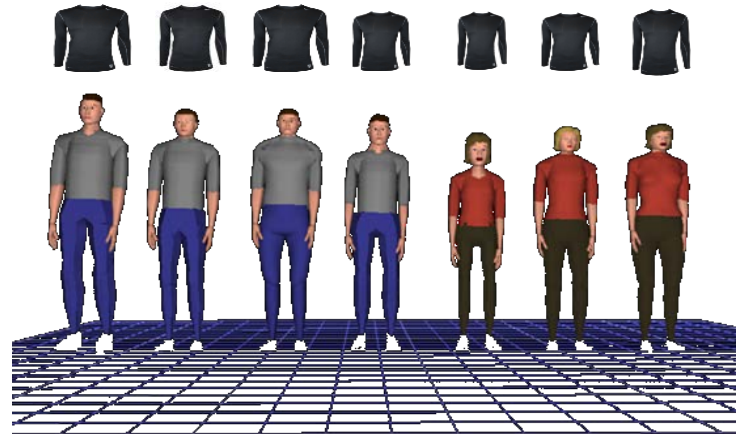
- Multiple-size product: n sizes to fit n groups of people within a designated percentage (e.g., 90%) of the population (Winks, 1997; Ashdown, 2003; Jung et al., 2010)



Clothing



Gloves

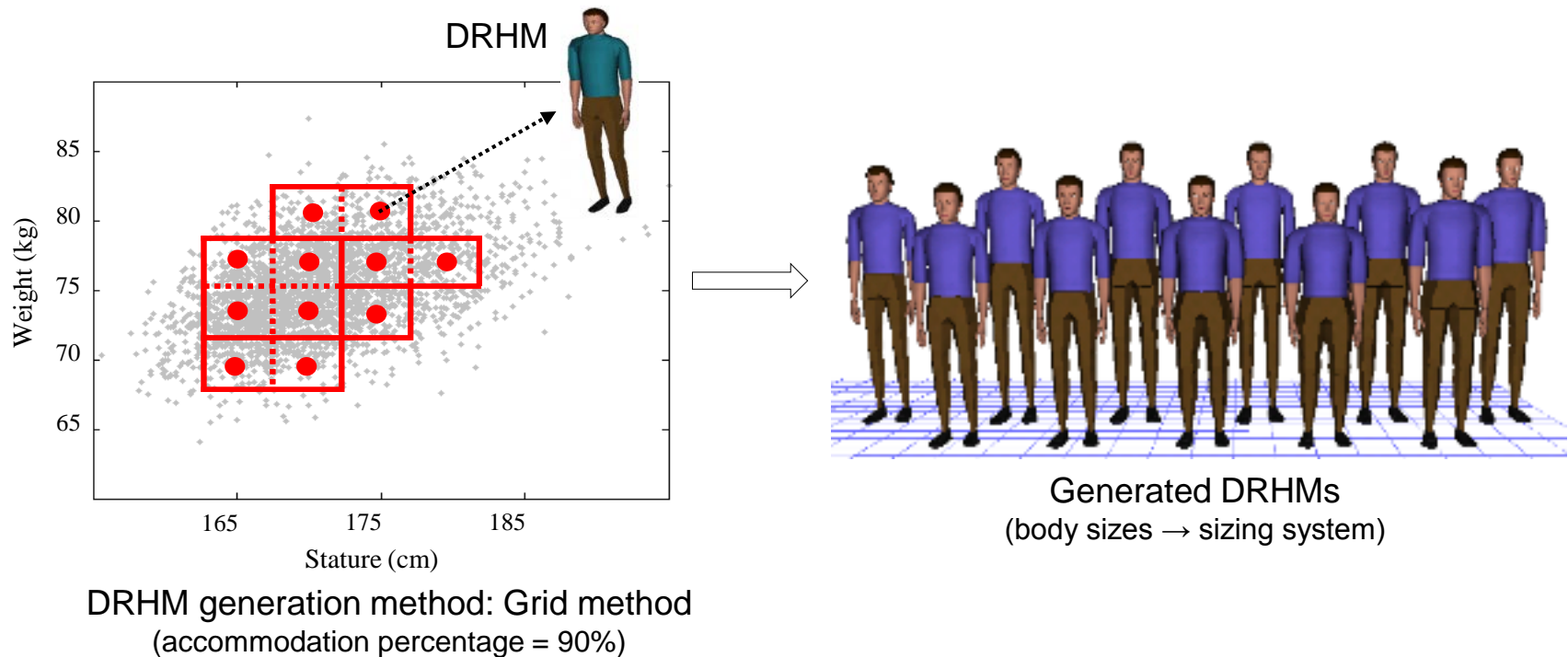


Sizing system of a multiple-size product

⇒ Sizing system of multiple-size product: Need to be properly designed to accommodate the anthropometric characteristics of a target population

Distributed Representative Human Model (DRHM)

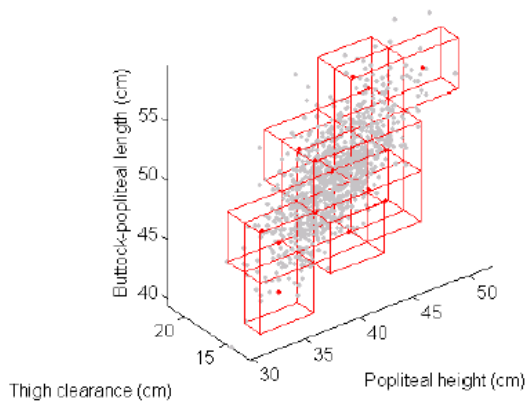
- DRHMs: **Human models chosen over a set of grids** which accommodate a designated percentage (e.g., 90%) of the population in the distribution of anthropometric dimensions
(Robinette and Annis, 1986; Kwon et al., 2009; Jung et al., 2010)



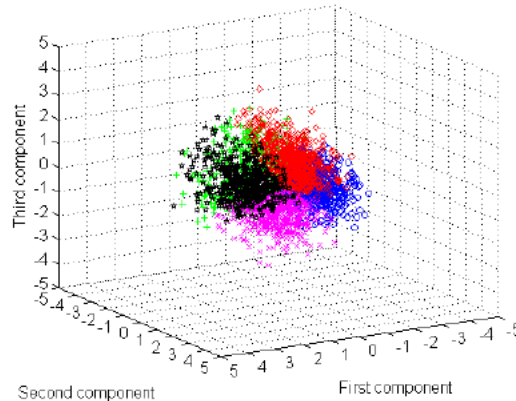
⇒ **Body sizes of DRHMs:** Applied for the **design and evaluation of a sizing system**

DRHM Generation Methods & Limitations

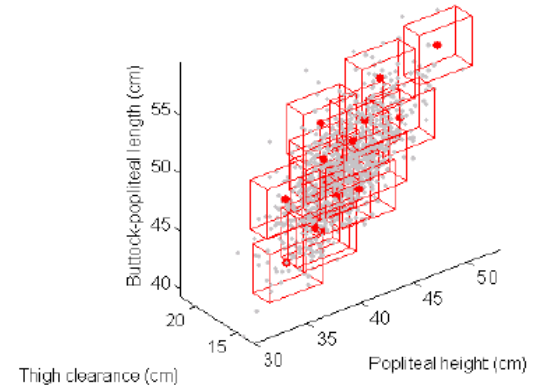
- ❑ DRHM generation method: **Form a set of grids** to accommodate a **designated percentage** (e.g., 90%) of the target population (Jung et al., 2010)



Grid method
(Robinette and Annis, 1986)



Clustering method
(Laing et al., 1999)



Optimization method
(McCulloch et al., 1998)

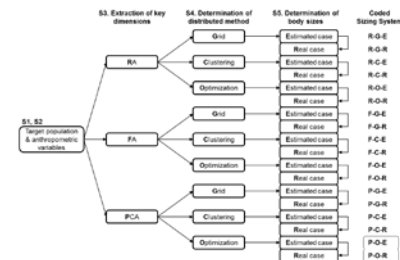
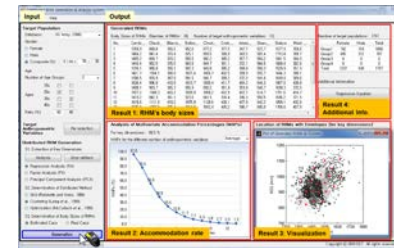
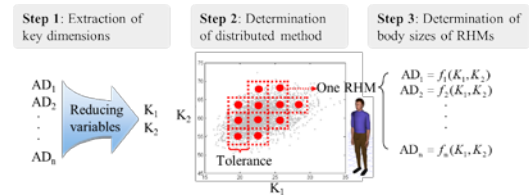
- ❑ Limitations: (1) **unavailability of computerized systems**, (2) **time demand**, (3) **complexity**

⇒ **Not easy to choose an optimal sizing system** out of a variety of sizing system alternatives without computerized systems

Objectives of the Study

Development of a Distributed Representative Human Model (DRHM) Generation and Analysis System for Multiple-Size Product Design

1. Analyze the DRHM generation **process and methods**
2. Develop a **computerized system** for DRHM generation and analysis
3. Examine the **effectiveness** of the DRHM computerized system by applying to **flight suit design**



DRHM Generation: Process & Methods

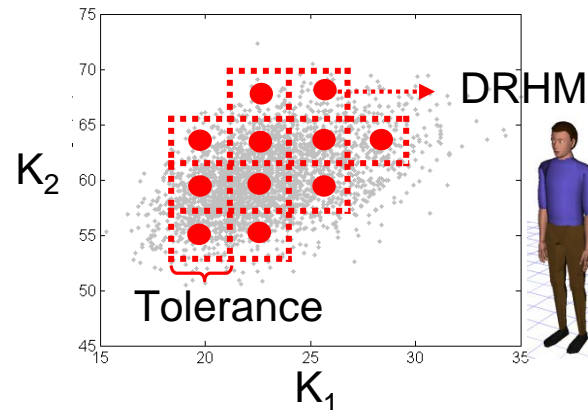
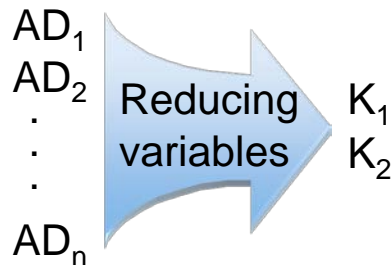
- Jung et al. (2010): established the DRHM generation process and methods based on a comprehensive literature review

S1: Determination of **key dimensions/factors**

S2: Application of **DRHM generation method**

S3: Determination of **body sizes of DRHMs**

Process



$$\begin{cases}
 AD_1 = f_1(K_1, K_2) \\
 AD_2 = f_2(K_1, K_2) \\
 \vdots \\
 AD_n = f_n(K_1, K_2)
 \end{cases}$$

(note) AD = anthropometric dimension, K = key dimension/factor

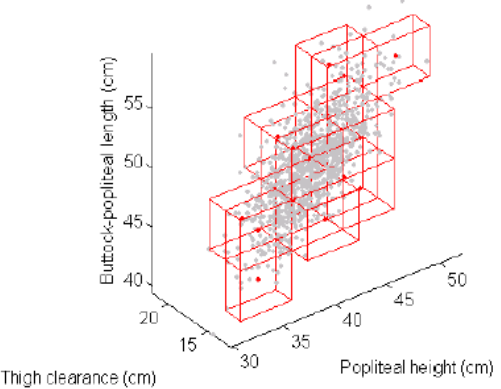
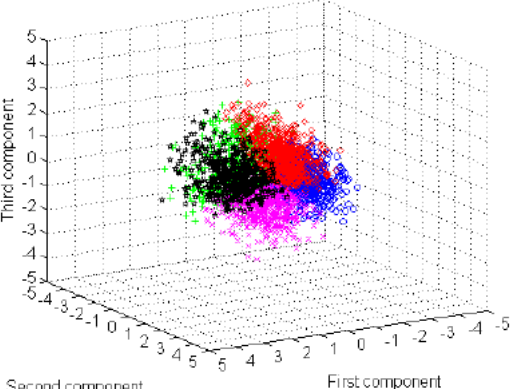
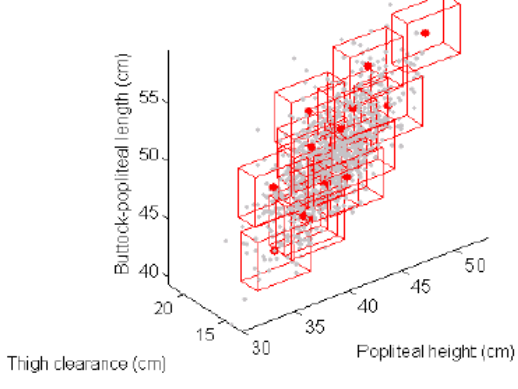
Methods

- Regression analysis (RA)
- Factor analysis (FA)
- Principal component analysis (PCA)

- Grid method
- Clustering method
- Optimization method

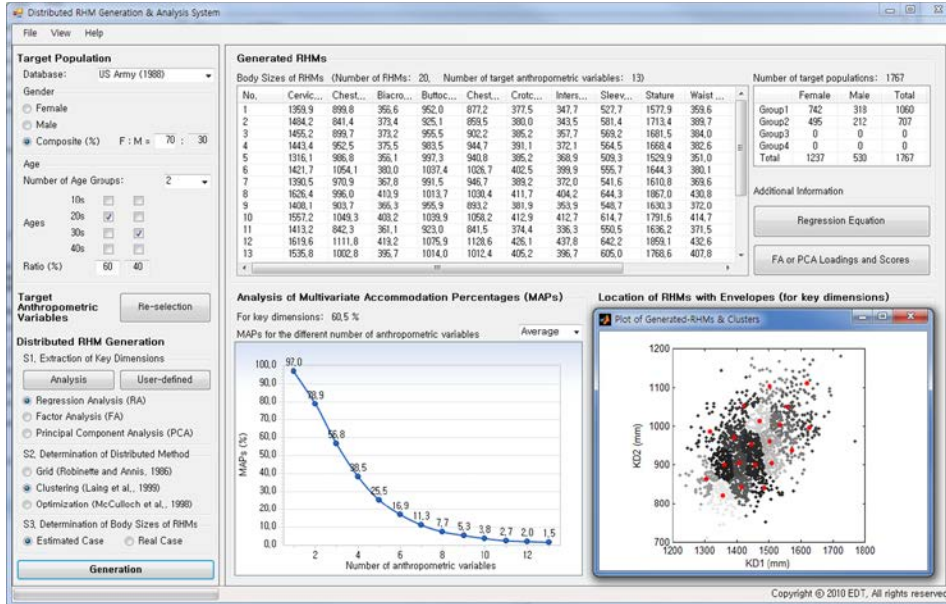
- Estimated case
- Real case

DRHM Generation: **Methods**

Method	Grid	Clustering	Optimization
Illustration			
Studies	<ul style="list-style-type: none"> • Robinette and Annis (1986) • Rosenblad-Wallin (1987) • Moon (2002) • Kwon et al. (2004) • Zheng et al. (2007) 	<ul style="list-style-type: none"> • Laing et al. (1999) 	<ul style="list-style-type: none"> • McCulloch et al. (1998)
Formation method of grids/clusters	<ul style="list-style-type: none"> • Generate grids which accommodate a designate percentage of the target population 	<ul style="list-style-type: none"> • Generate clusters using <i>K</i>-means cluster analysis 	<ul style="list-style-type: none"> • Generate grids applying the Nelder-Mead optimization algorithm
Parameters	<ul style="list-style-type: none"> • Design fitting tolerance • Accommodation percentage 	<ul style="list-style-type: none"> • Number of clusters (<i>K</i>) referring to within- and between-cluster average distances 	<ul style="list-style-type: none"> • Loss score • Accommodation percentage

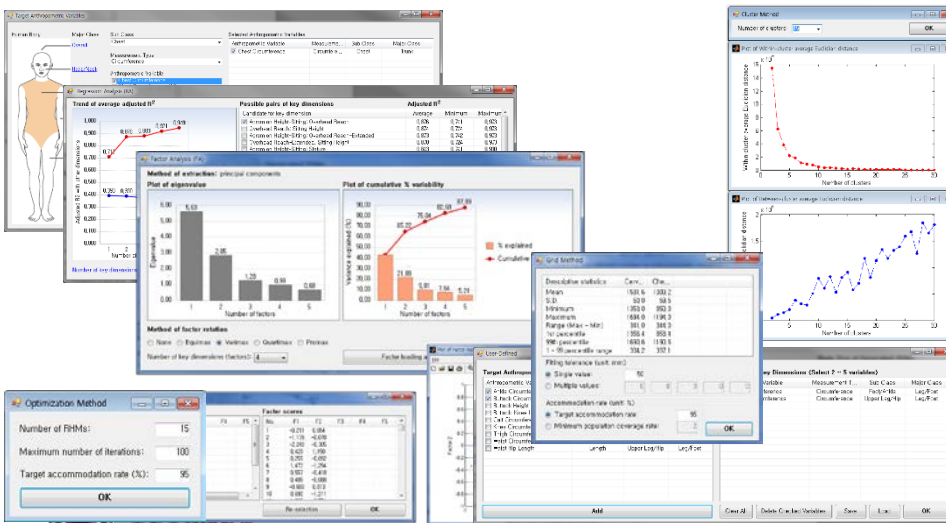
System Development

System Features



F1. Procedural interface of DRHM generation

F2. Sophisticated input and output interfaces in one panel



F3. Interoperation with anthropometric databases

Procedural Interface for DRHM Generation

Input Help

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables Re-selection

Distributed RHM Generation

S1, Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Generated RHMs

Body Sizes of RHMs (Number of RHMs: 20, Number of target anthropometric variables: 7)

No.	Cervic...	Chest...	Blacro...	Buttoc...	Chest...	Crotc...
1	1359.9	899.8	356.6	952.0	877.2	377.5
2	1494.2	841.4	373.4	925.1	859.5	380.0
3						
4						
5						
6						
7						
8						
9	1408.1	903.7	365.3	955.9	893.2	381.9
10	1557.2	1049.3	403.2	1039.9	1058.2	412.9
11						
12						
13						

Analysis of Multivariate Accommodation Percentages (MAPs)

For key dimensions: 60.5 %

MAPs for the

DRHM generation process & methods

Process

S1: Determination of key dimensions/factors

S2: Application of DRHM generation method

S3: Determination of body sizes of DRHMs

AD₁ 1668.4 382.6

AD₂ 509.3 351.0

AD_n 1667.0 430.8

AD = anthropometric dimension, K = key dimension/factor

Regression Equation

$AD_1 = f_1(K_1, K_2)$

$AD_2 = f_2(K_1, K_2)$

$AD_n = f_n(K_1, K_2)$

Methods

- Regression analysis (RA)
- Factor analysis (FA)
- Principal component analysis (PCA)
- Grid method
- Clustering method
- Optimization method
- Estimated case
- Real case

S1. Selection of target population

S2. Selection of anthropometric variable

S3. Determination of key dimensions/factors

S4. Selection of DRHM generation method

S5. Determination of DRHMs' body sizes

User-defined

Analysis-based

Regression analysis (RA)

Factor analysis (FA)

Principal component analysis (PCA)

Grid

Clustering

Optimization

Estimated case

Real case

DRHM generation process

S1. Selection of Target Population

- Select an anthropometric database and form a target population

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables [Re-selection]

Distributed RHM Generation

S1. Extraction of Key Dimensions

[Analysis] [User-defined]

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2. Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3. Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2 (1, 2, 3, 4)

10s

20s

30s

40s

Ratio (%) 60 40

Anthropometric databases		US Army	US Army Pilot	Korean Pilot
Year disseminated		1988	1988	2007
Sample size (n)	Female	2,208	334	-
	Male	1,774	487	1,237
	Total	3,982	821	1,237
Range of age		10s ~ 40s	20s ~ 40s	20s ~ 40s

	70%	30%		
	Female	Male	Total	
Group1	742	318	1060	60%
Group2	495	212	707	40%
Group3	0	0	0	
Group4	0	0	0	
Total	1237	530	1767	

S2. Selection of Anthropometric Variable

- Provide a hierarchical interface for systematic and efficient search of anthropometric variables (You et al., 2004)

Anthropometric databases	US Army	US Army Pilot	Korean Pilot
Number of AVs	132	132	16

e.g., selection of chest circumference

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables [Re-selection]

Distributed RHM Generation

S1, Extraction of Key Dimensions

[Analysis] [User-defined]

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

[Generation]

Target Anthropometric Variables

Human Body

Major Class

Sub Class

Measurement Type

Anthropometric Variable

Selected Anthropometric Variables

Anthropometric Variable	Measureme...	Sub Class	Major Class
<input checked="" type="checkbox"/> Chest Circumference	Circumfer...	Chest	Trunk

Buttons: Add, Clear All, Delete Checked Variables, Save, Load, OK

S3. Selection of Key Dimension: User-Defined

- ❑ Determine key dimensions directly by a user's preliminary knowledge

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables

Re-selection

Distributed RHM Generation

S1, Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

e.g., # anthropometric variables = 9

User-Defined

Target Anthropometric Variables				User-defined Key Dimensions (Select 2 ~ 5 variables)			
Anthropometric Variable	Measurement T...	Sub Class	Major Class	Anthropometric Variable	Measurement T...	Sub Class	Major Class
<input checked="" type="checkbox"/> Ankle Circumference	Circumference	Foot/Ankle	Leg/Foot	<input type="checkbox"/> Ankle Circumference	Circumference	Foot/Ankle	Leg/Foot
<input checked="" type="checkbox"/> Buttock Circumference	Circumference	Upper Leg/Hip	Leg/Foot	<input type="checkbox"/> Buttock Circumference	Circumference	Upper Leg/Hip	Leg/Foot
<input type="checkbox"/> Buttock Height	Length	Combined_L...	Leg/Foot				
<input type="checkbox"/> Buttock-Knee Length	Length	Combined_L...	Leg/Foot				
<input type="checkbox"/> Calf Circumference	Circumference	Lower Leg/K...	Leg/Foot				
<input type="checkbox"/> Knee Circumference	Circumference	Lower Leg/K...	Leg/Foot				
<input type="checkbox"/> Thigh Circumference-Distal	Circumference	Upper Leg/Hip	Leg/Foot				
<input type="checkbox"/> Waist Circumference-Natural	Circumference	Abdomen	Trunk				
<input type="checkbox"/> Waist Hip Length	Length	Upper Leg/Hip	Leg/Foot				

Direct selection

Add Clear All Delete Checked Variables Save Load OK

S3. Selection of Key Dimension: Regression Analysis

- ❑ Determine key dimensions by referring to increase in average **adjusted R^2** by # key dimensions

e.g., # anthropometric variables = 7

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables [Re-selection]

Distributed RHM Generation

S1, Extraction of Key Dimensions

Analysis [User-defined]

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

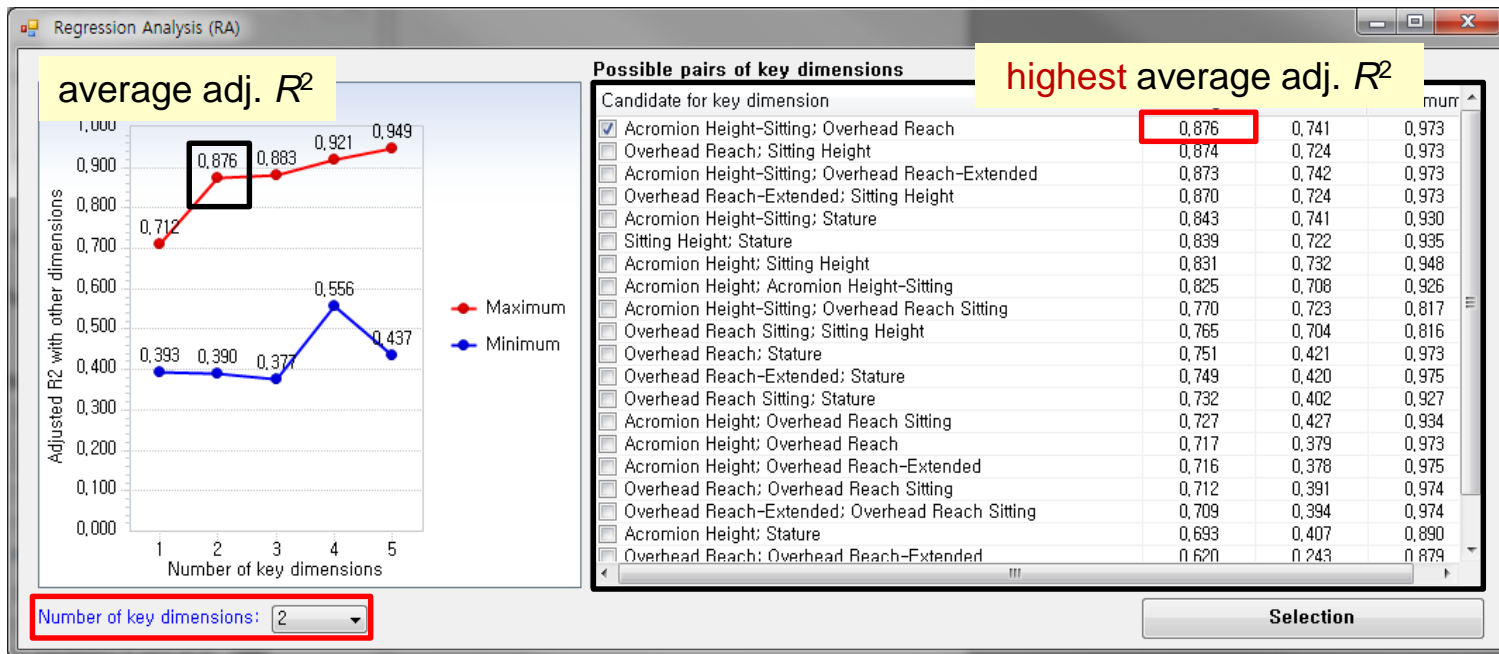
Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation



Select # key dimensions referring to increase in average **adj. R^2**

Provide **adj. R^2** between key dimension candidates and other dimensions in **descending order** for quick search of key dimensions with **high performance**

S3. Selection of Key Factor: Factor Analysis

- Determine key factors by referring to **eigenvalue** and **cumulative percent variability**

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables [Re-selection]

Distributed RHM Generation

S1, Extraction of Key Dimensions

[Analysis] [User-defined]

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

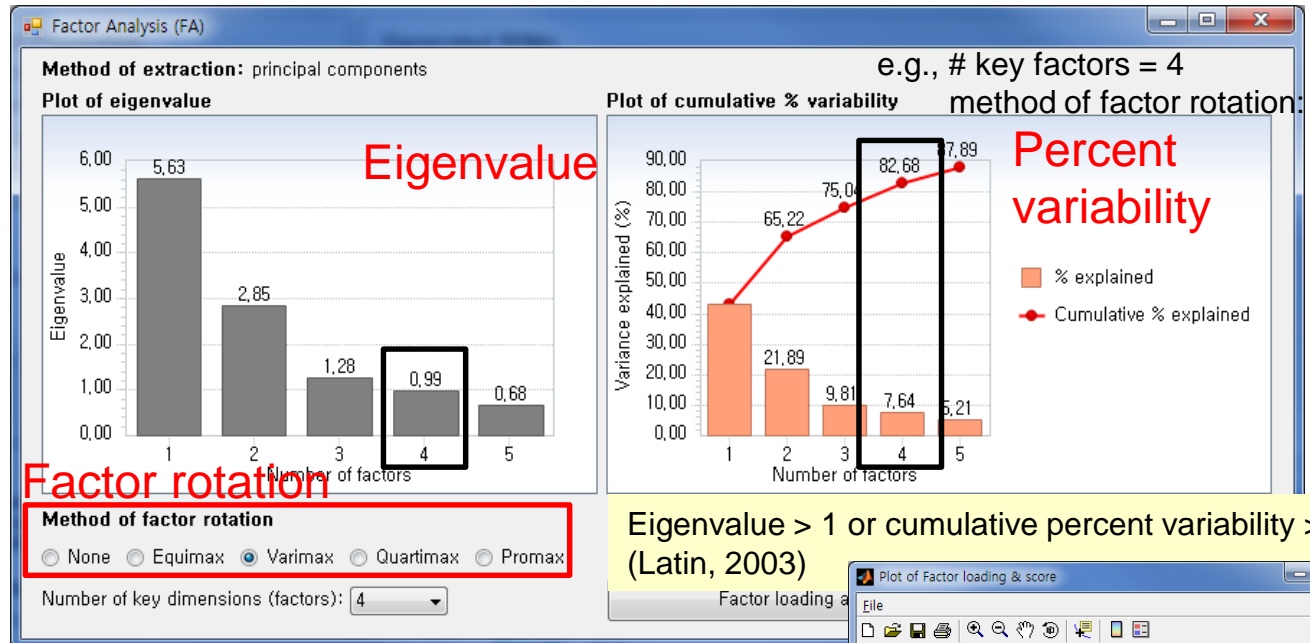
Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

[Generation]



e.g., key dimensions (factors) = 2

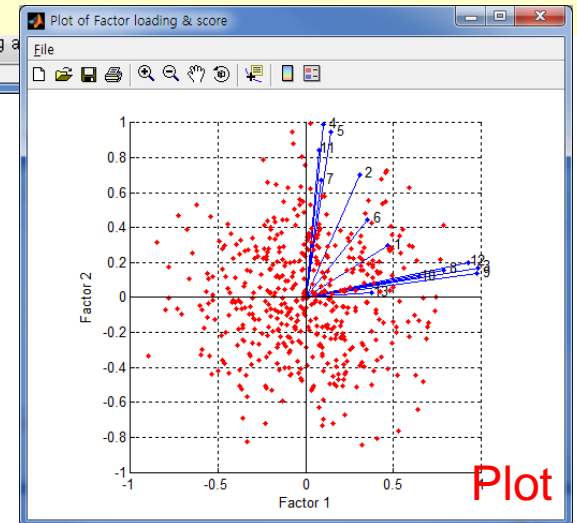
Factor Loadings and Scores

Factor loadings						Factor scores					
No.	F1	F2	F3	F4	F5	No.	F1	F2	F3	F4	F5
1	0.380	0.027				1	-0.211	0.654			
2	0.930	0.202				2	-1.179	-0.078			
3	0.074	0.846				3	-2.240	-0.305			
4	0.647	0.118				4	0.420	1.150			
5	0.970	0.097				5	0.235	0.012			
6	0.788	0.158				6	1.472	-1.294			
7	0.086	0.669				7	0.557	-0.418			
8	0.354	0.444				8	0.485	-0.088			
9	0.145	0.946				9	-0.680	0.813			
10						10	0.692	-1.211			

Factor loadings

Factor scores

[Re-selection] [OK]



S3. Selection of Key Factor: Principal Component Analysis

Refer to **eigenvalue** and **cumulative percent variability**

e.g., # key dimensions = 3

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

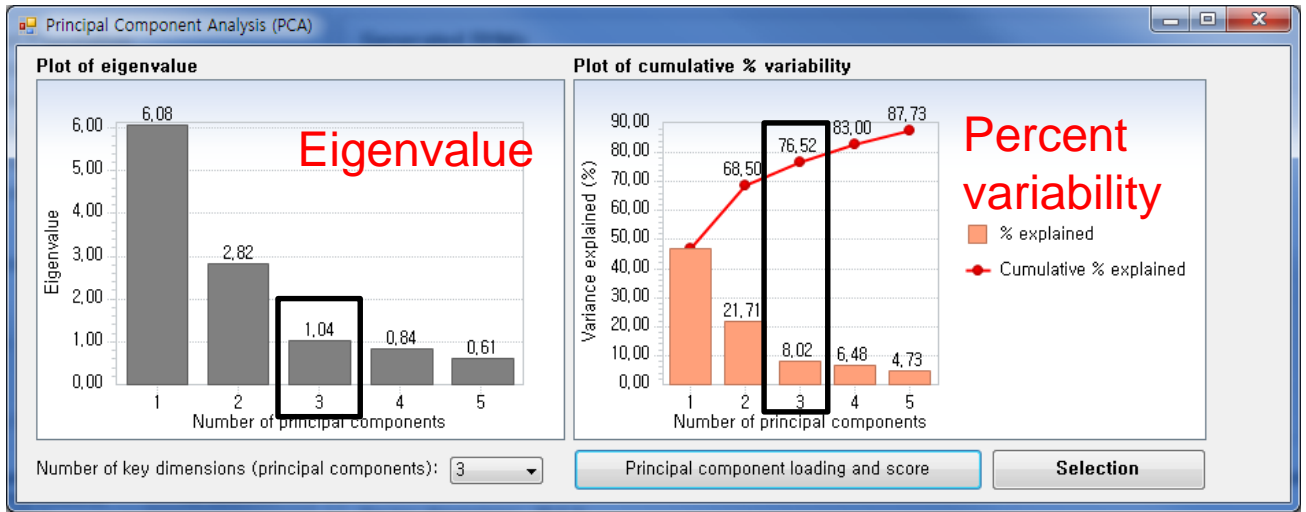
30s

40s

Ratio (%) 60 40

Target Anthropometric Variables

Re-selection



Distributed RHM Generation

S1. Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

Eigenvalue > 1 or cumulative percent variability > 80% (Latin, 2003)

S2. Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3. Determination of Body Sizes of RHMs

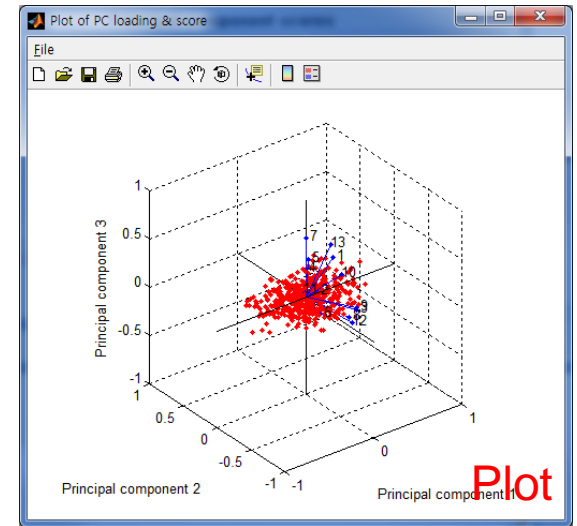
Estimated Case Real Case

Generation

Principal Component Loadings and Scores

Principal component loadings						Principal component scores					
No.	PC1	PC2	PC3	PC4	PC5	No.	PC1	PC2	PC3	PC4	PC5
1	-0.150	-0.182	0.580			1	-0.128	2.053	-1.690		
2	-0.326	-0.267	-0.257			2	1.879	1.601	-0.247		
3	-0.259	0.380	-0.193			3	4.729	2.217	0.682		
4	-0.223	-0.232	0.264			4	-2.510	0.773	0.393		
5	-0.378	-0.102	0.101			5	-0.787	-0.396	0.390		
6	-0.281	-0.280	-0.179			6	-0.923	-2.718	-0.756		
7	-0.227	0.287	0.406			7	0.037	-1.087	0.075		
8	-0.259	0.126	-0.325			8	-0.984	-0.422	0.429		
9	-0.297	0.343	0.128			9	-0.420	1.955	-1.503		
10						10	0.492	-1.720	-0.053		

Re-selection OK



S4. Selection of DRHM Generation Method: Grid

- ❑ Set **fitting tolerance** (size of a grid) and **accommodation percentage**

e.g., # key dimensions = 2

Key dimensions

Descriptive statistics	Cerv...	Che...
Mean	1531,6	1009,2
S.D.	60,0	59,5
Minimum	1353,0	850,0
Maximum	1694,0	1194,0
Range (Max - Min)	341,0	344,0
1st percentile	1356,4	853,4
99th percentile	1690,6	1190,6
1 - 99 percentile range	334,2	337,1

Fitting tolerance (unit: mm)

Single value: 50

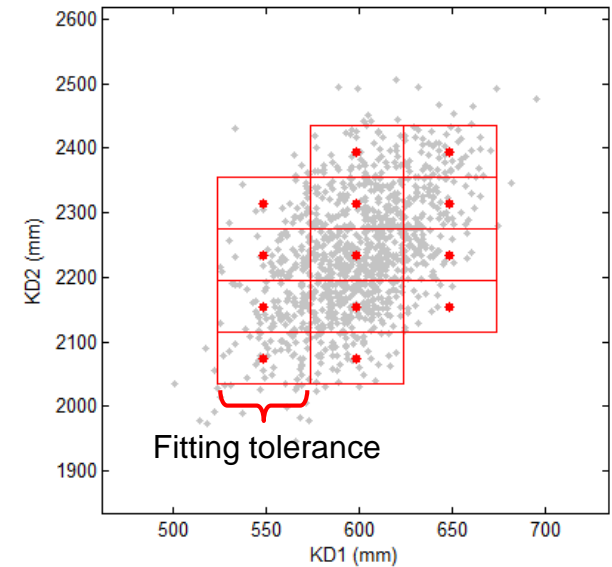
Multiple values: 0 0 0 0 0

Accommodation rate (unit: %)

Target accommodation rate: 95

Minimum population coverage rate: 2

OK



- 1) Target accommodation rate**
: accommodation rate of all grids > 95%
- 2) Minimum presence rate**
: accommodation rate of each grid > 2%

S4. Selection of DRHM Generation Method: Clustering

- Determine the number of DRHMs referring to within- & between-cluster distance plots

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables Re-selection

Distributed RHM Generation

S1. Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2. Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

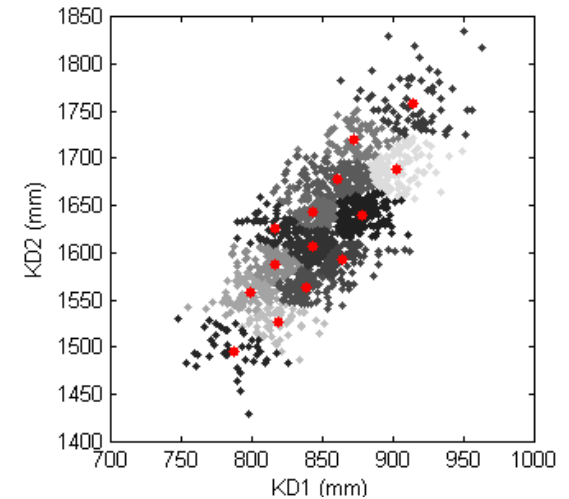
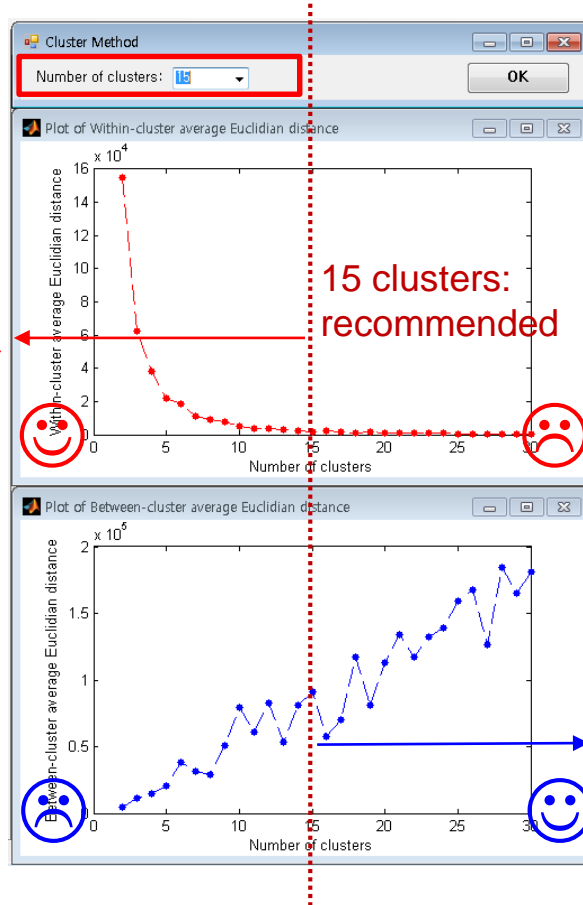
Optimization (McCulloch et al., 1998)

S3. Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Within-cluster homogeneity ↑



Between-clusters heterogeneity ↑

S4. Selection of DRHM Generation Method: Optimization

- Set the number of DRHMs with the target accommodation percentage

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables Re-selection

Distributed RHM Generation

S1. Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2. Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3. Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Optimization Method

Number of RHMs: 15

Maximum number of iterations: 100

Target accommodation rate (%): 95

OK

$$\min \sum_{i=1}^n l(p_i)k_i + l(c_\alpha)(1-k_i)$$

$$k_i = \begin{cases} 1 & \text{if } l(p_i) < l(c_\alpha) \text{ where } l(p_i) \\ 0 & \text{o/w} \end{cases}$$

$$d(\mathbf{x}_i, \mathbf{y}_s) = \sum_{j=1}^k [d(x_{ij}, y_{sj})]^2$$

$$d(x_{ij}, y_{sj}) = \begin{cases} y_{sj} - x_{ij}, & \text{if } x_{ij} \leq y_{sj} \\ x_{ij} - y_{sj}, & \text{if } x_{ij} > y_{sj} \end{cases}$$

where: n = number of the target population,

$l(p_i)$ = loss score of person i ,

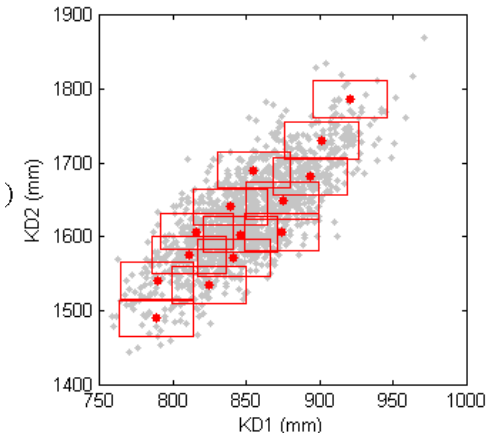
$l(c_\alpha)$ = loss cutoff to determine whether a person is accommodated or not,

$d(\mathbf{x}_i, \mathbf{y}_s)$ = distance between person i and its nearest grid,

k = number of key dimensions,

x_{ij} = body size of key dimension j of person i , and

y_{sj} = centroid of the nearest grid s in key dimension j .



$$l(p(x_k)) \leq l(c_\alpha) \leq l(p(x_m)).$$

S5. Determination of Body Sizes of DRHMs

- Select a body sized determination method

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

Ages

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables

Distributed RHM Generation

S1, Extraction of Key Dimensions

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

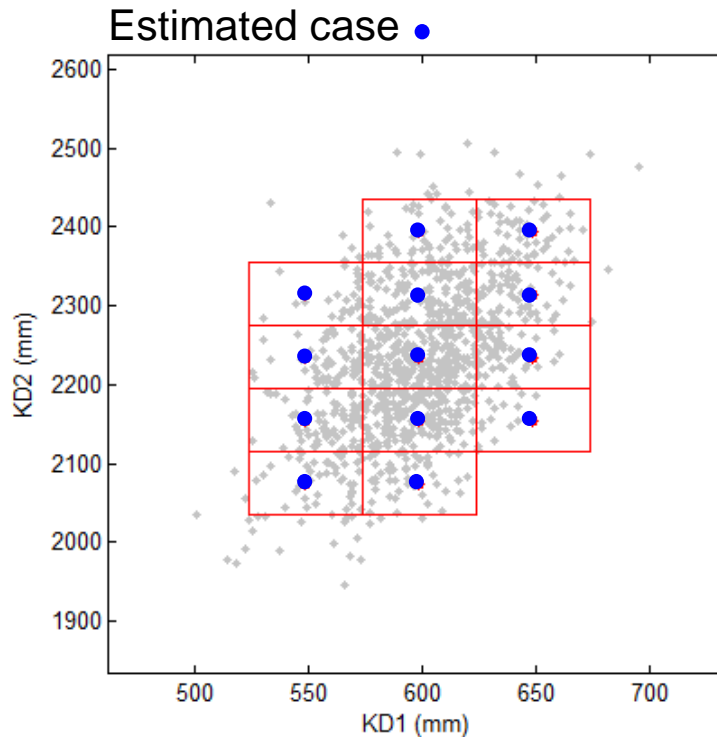
Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

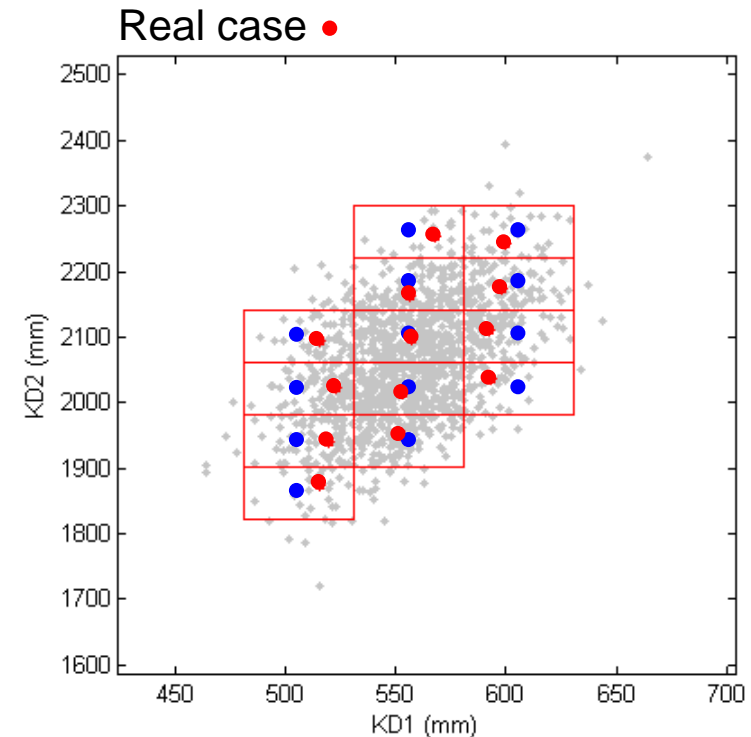
Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case



Centroid: Finding an object i located geometric center in a grid



Medoid: Finding an object i whose average distance is the closest in a grid

Specialized DRHM Analysis

Distributed RHM Generation & Analysis System

Input

Help

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Target Anthropometric Variables

Re-selection

Distributed RHM Generation

S1. Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2. Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3. Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Output

Generated RHMs

Body Sizes of RHMs (Number of RHMs: 20, Number of target anthropometric variables: 13)

No.	Cervic...	Chest...	Biacro...	Buttoc...	Chest...	Crotc...	Inters...	Sleev...	Stature	Waist ...
1	1359,9	899,8	356,6	952,0	877,2	377,5	347,7	527,7	1577,9	359,6
2	1484,2	841,4	373,4	925,1	859,5	380,0	343,5	581,4	1713,4	389,7
3	1455,2	899,7	373,2	955,5	902,2	385,2	357,7	569,2	1681,5	384,0
4	1443,4	952,5						564,5	1668,4	382,6
5	1316,1	986,8						509,3	1529,9	351,0
6	1421,7	1054,1						555,7	1644,3	380,1
7	1390,5	970,9	367,8	991,5	946,7	389,2	372,0	541,6	1610,8	369,6
8	1626,4	996,0	410,9	1013,7	1030,4	411,7	404,2	644,3	1867,0	430,8
9	1408,1	903,7	365,3	955,9	893,2	381,9	353,9	548,7	1630,3	372,0
10	1557,2	1049,3	403,2	1039,9	1058,2	412,9	412,7	614,7	1791,6	414,7
11	1413,2	842,3	361,1	923,0	841,5	374,4	336,3	550,5	1636,2	371,5
12	1619,6	1111,8	419,2	1075,9	1128,6	426,1	437,8	642,2	1859,1	432,6
13	1535,8	1002,8	395,7	1014,0	1012,4	405,2	396,7	605,0	1768,6	407,8

R1: DRHMs' body sizes

Number of target populations: 1767

	Female	Male	Total
Group1	742	318	1060
Group2	495	212	707
Group3	0	0	0

R4: Additional Info.

Additional Information

Regression Equation

FA or PCA Loadings and Scores

Analysis of Multivariate Accommodation Percentages (MAPs)

For key dimensions: 60,5 %

MAPs for the different number of anthropometric variables

Average

Number of anthropometric variables	MAPs (%)
2	97,0
3	78,9
4	48,3
5	25,5
6	16,9
7	11,3
8	7,7
9	5,3
10	3,8
11	2,7
12	2,0
13	1,5

R2: Multivariate accommodation percentage (MAP)

Location of RHMs with Envelopes (for key dimensions)

Plot of Generated-RHMs & Clusters

R3: DRHM Plot

R1. Body Sizes of DRHMs

- Provide **generated DRHMs' body sizes** by anthropometric variable

e.g., # DRHMs = 20, # anthropometric variables = 13

Generated RHMs

Body Sizes of RHMs (Number of RHMs: 20, Number of target anthropometric variables: 13)

No.	Cervic...	Chest...	Biacro...	Buttoc...	Chest...	Crotc...	Inters...	Sleev...	Stature	Waist ...
1	1359,9	899,8	356,6	952,0	877,2	377,5	347,7	527,7	1577,9	359,6
2	1484,2	841,4	373,4	925,1	859,5	380,0	343,5	581,4	1713,4	389,7
3	1455,2	899,7	373,2	955,5	902,2	385,2	357,7	569,2	1681,5	384,0
4	1443,4	952,5	375,5	983,5	944,7	391,1	372,1	564,5	1668,4	382,6
5	1316,1	986,8	356,1	997,3	940,8	385,2	368,9	509,3	1529,9	351,0
6	1421,7	1054,1	380,0	1037,4	1026,7	402,5	399,9	555,7	1644,3	380,1
7	1390,5	970,9	367,8	991,5	946,7	389,2	372,0	541,6	1610,8	369,6
8	1626,4	996,0	410,9	1013,7	1030,4	411,7	404,2	644,3	1867,0	430,8
9	1408,1	903,7	365,3	955,9	893,2	381,9	353,9	548,7	1630,3	372,0
10	1557,2	1049,3	403,2	1039,9	1058,2	412,9	412,7	614,7	1791,6	414,7
11	1413,2	842,3	361,1	923,0	841,5	374,4	336,3	550,5	1636,2	371,5
12	1619,6	1111,8	419,2	1075,9	1128,6	426,1	437,8	642,2	1859,1	432,6
13	1535,8	1002,8	395,7	1014,0	1012,4	405,2	396,7	605,0	1768,6	407,8

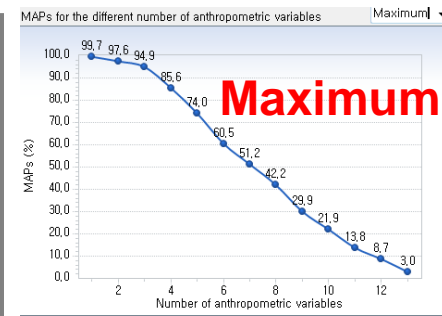
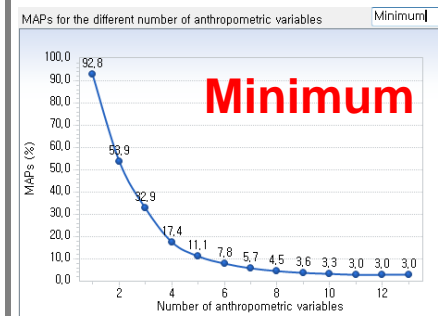
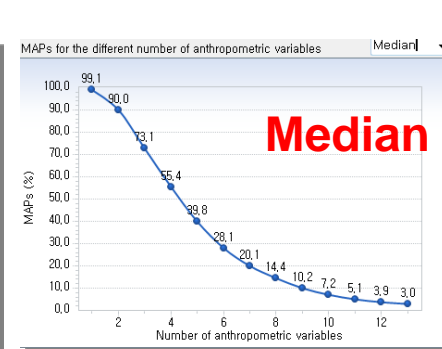
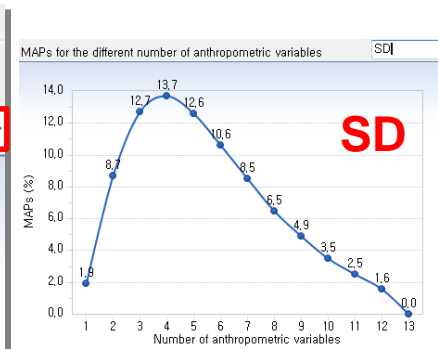
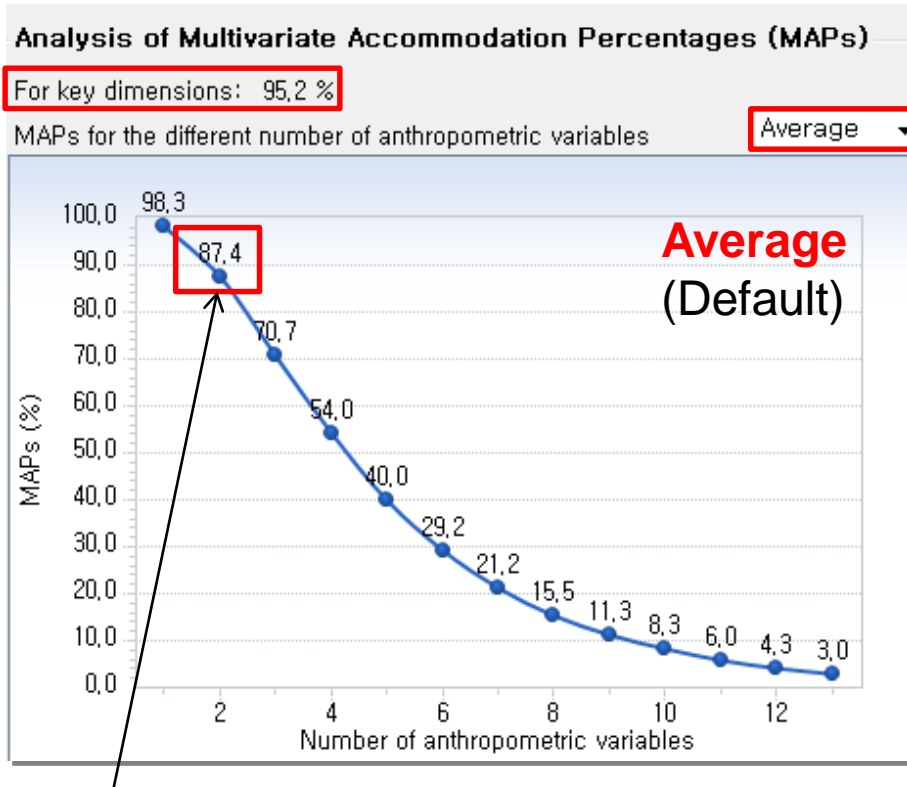
Generated DRHMs

DRHMs' body size
by anthropometric
variable

R2. Multivariate Accommodation Percentage

- Provide multivariate accommodation percentages (average, SD, median, minimum, and maximum) by the number of anthropometric variables

e.g., # anthropometric variables = 13

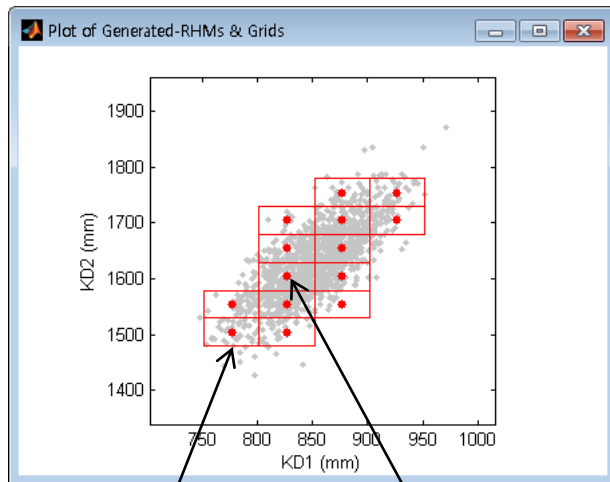


Average of accommodation percentages of 78 cases (${}_{13}C_2$)

R3. DRHM Plot

- Provide plot of DRHMs on the grid in the distribution of key dimensions/factors by the DRHM generation method

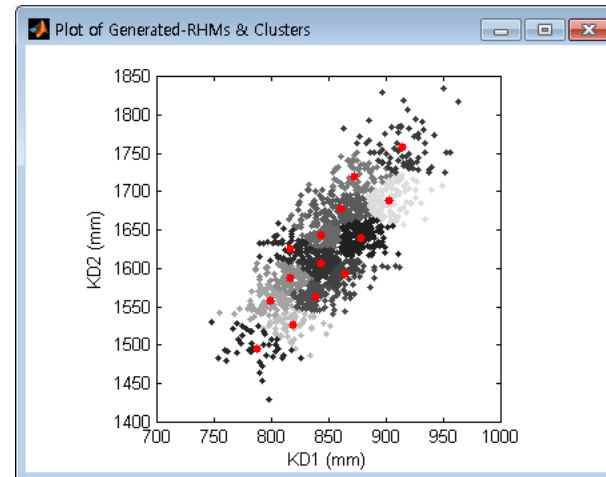
Grid method



Generated grid

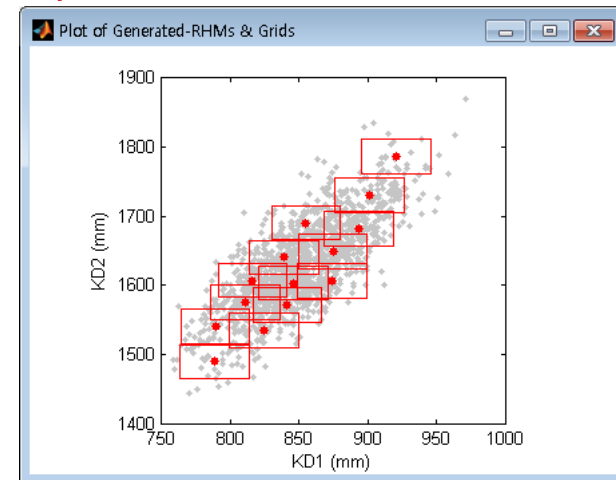
DRHM

Clustering method



Automatic color coding for different clusters

Optimization method



R4. Additional Information

- Provide population information, regression equations for RA, and factor/principal component loadings and scores for FA/PCA

Number of target populations: 1767

	Female	Male	Total
Group1	742	318	1060
Group2	495	212	707
Group3	0	0	0
Group4	0	0	0
Total	1237	530	1767

Additional Information

Regression Equation

FA or PCA Loadings and Scores

Regression Equations

Regression equations using key dimensions

Anthropometric Variable	β_0	β_1	β_2	β_3	β_4	β_5	Adjusted R ²
Overhead Reach	10.848	-0.889	1.723				0.912
Overhead Reach Sitting	48.499	0.038	0.765				0.765
Overhead Reach-Extended	30.468	-0.877	1.761				0.907

e.g., Overhead Reach = 10.848 – 0.889 × Sitting Height + 1.723 × Stature
 ⇒ Overhead reach estimation equation by key dimensions

Independent variables (Key dimensions)

Variable	Key dimension
X1	Sitting Height
X2	Stature

Factor Loadings and Scores

Factor loadings						Factor scores of generated RHMs					
No.	F1	F2	F3	F4	F5	No.	F1	F2	F3	F4	F5
1	0.820	0.527				1	-2.093	-1.329			
2	0.306	0.950				2	0.709	-2.208			
3	0.827	0.431				3	0.254	-2.182			
4	0.954	0.277				4	1.966	1.171			
5	0.959	0.262				5	1.957	-1.357			
						6	-1.744	-0.535			
						7	1.664	0.478			
						8	1.866	-0.490			
						9	-1.779	0.522			
						10	-0.875	-1.298			

Design Application

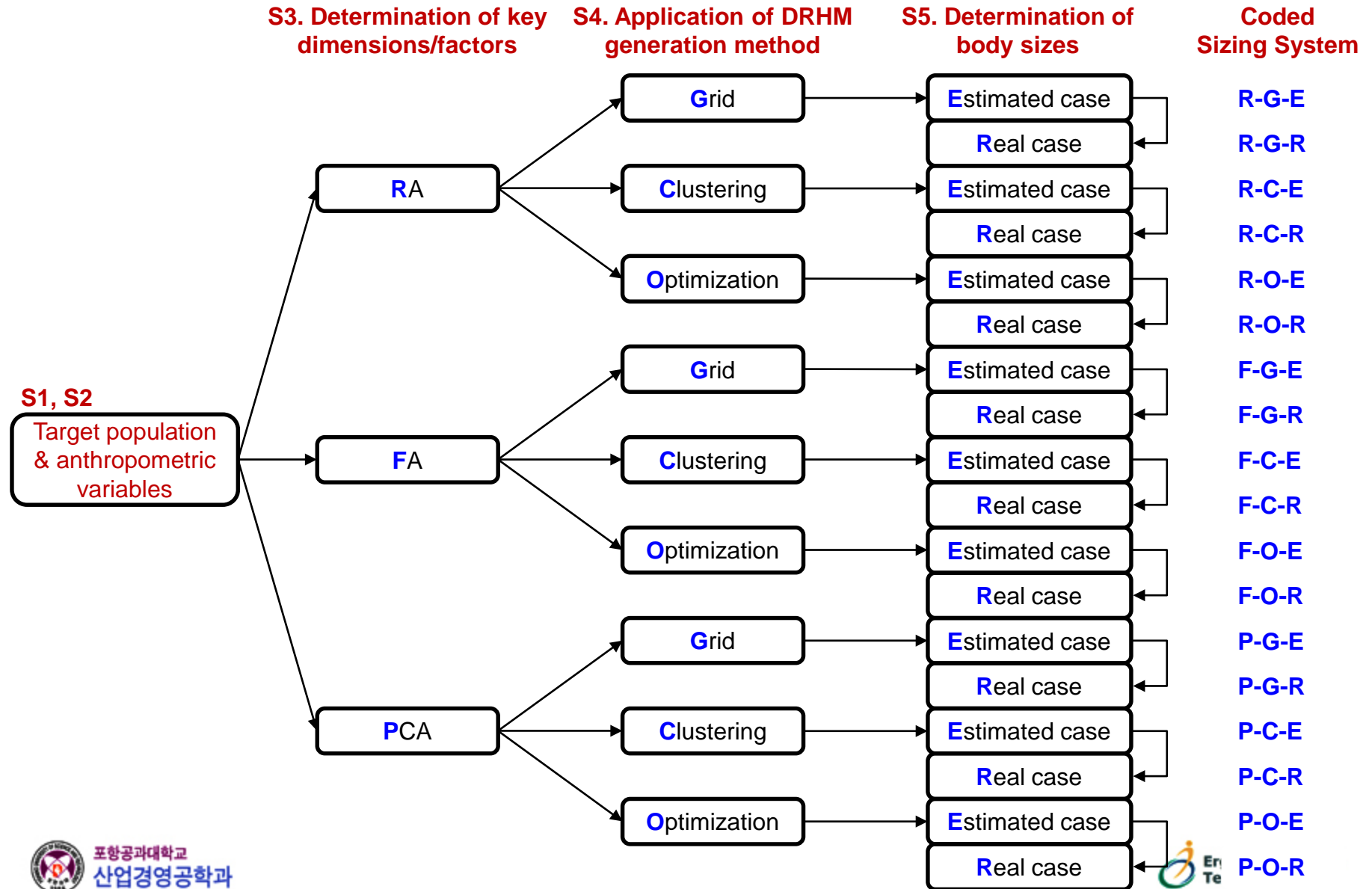
Design Application Context

- ❑ Establish an **optimal men's sizing system for flight suit design**
- ❑ Target population & anthropometric variables
 - ✓ **US Army male pilots** ($n = 485$; Gordon et al., 1998)
 - ✓ **13 anthropometric variables** for flight suit design (Jeon et al., 2009)



Major class	Sub class	Measurement type	Anthropometric variable (AV)	Code	Descriptive statistics (unit: mm)		
					Mean	SD	Range
Trunk	Chest	Width	Biacromial breadth	AV1	400.6	17.5	105.0
Leg/Foot	Upper Leg/Hip	Circumference	Buttock circumference	AV2	991.5	55.0	351.0
Head/Neck	Neck	Height	Cervical height	AV3	1531.8	60.0	341.0
Trunk	Chest	Circumference	Chest circumference	AV4	1009.2	59.6	344.0
Trunk	Chest	Circumference	Chest circumference – at scye	AV5	1035.8	55.3	309.0
Trunk	Combined	Length	Crotch length	AV6	772.0	47.3	339.0
Trunk	Back	Length	Interscye distance	AV7	408.7	28.2	164.0
Arm/Hand	Combined	Length	Sleeve outseam	AV8	601.4	29.9	154.0
Overall	-	Height	Stature	AV9	1771.0	64.8	362.0
Trunk	Back	Length	Waist back length	AV10	421.6	21.2	130.0
Trunk	Abdomen	Circumference	Waist circumference	AV11	856.4	65.7	375.0
Trunk	Abdomen	Height	Waist height	AV12	1131.4	48.1	274.0
Leg/Foot	Upper Leg/Hip	Length	Waist hip length	AV13	184.0	19.6	118.0

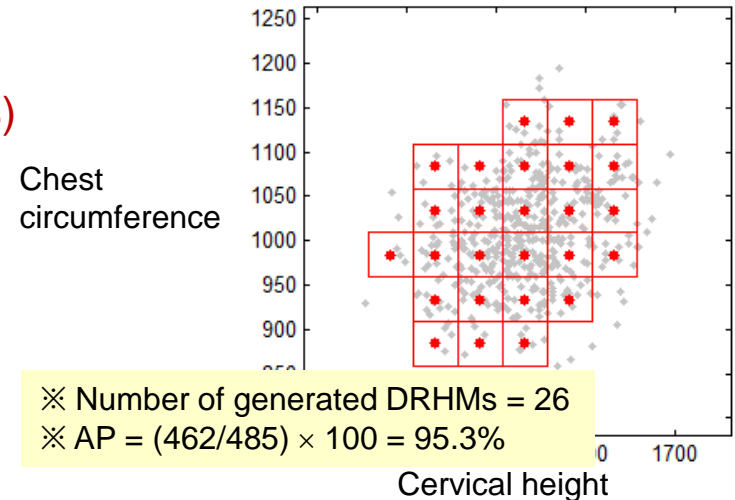
Decision Tree: 18 Sizing System Alternatives



Analysis Method: Measure

- ❑ Number of generated DRHMs
- ❑ Key dimensions: accommodation percentage (AP; %)
- ❑ Non-key dimensions
 - ✓ Cover ratio (%)
 - ✓ Number of outlier DRHMs

e.g., R-G-E



e.g., P-G-E

No.	Anthropometric variable	Original dimensions			Generate DRHM's dimensions			Generated DRHM's dimensions		Outlier dimensions	
		Min	Max	Range	Min	Max	Covered Range	DRHM 16	DRHM 23	DRHM 16	DRHM 23
1	Biacromial breadth	347.0	452.0	105.0	367.2	435.7	68.5	378.0	367.2	×	×
2	Buttock circumference	849.0	1200.0	351.0	879.9	1132.5	252.6	999.1	895.1	×	×
3	Chest circumference – at syce	894.0	1203.0	309.0	937.0	1183.0	246.0	1077.6	954.6	×	×
4	Crotch length	314.0	467.0	153.0	321.8	461.1	139.3	380.1	347.2	×	×
5	Interscye distance	388.0	502.0	164.0	354.5	485.0	130.5	428.7	378.1	×	×
6	Sleeve outseam	530.0	684.0	154.0	528.3	676.1	146.1	528.5	528.3	O	O
7	Stature	1596.0	2056.0	460.0	1586.2	1955.6	359.6	1586.9	1586.2	O	O
8	Waist back length	363.0	493.0	130.0	378.6	464.4	85.8	378.7	378.6	×	×
9	Waist circumference	689.0	1064.0	375.0	709.6	1017.7	308.1	927.1	781.3	×	×
10	Waist height	993.0	1267.0	274.0	999.8	1262.9	263.1	1009.7	999.8	×	×
11	Waist hip length	122.0	240.0	118.0	127.1	229.4	102.3	155.2	157.4	×	×
Total		-	-	2593.0	-	-	2101.9	-	-	2	2

- ※ Cover ratio = $(2101.9/2593.0) \times 100 = 81.0\%$
- ※ Number of outlier DRHMs = 2

e.g., DRHM 16 and 23

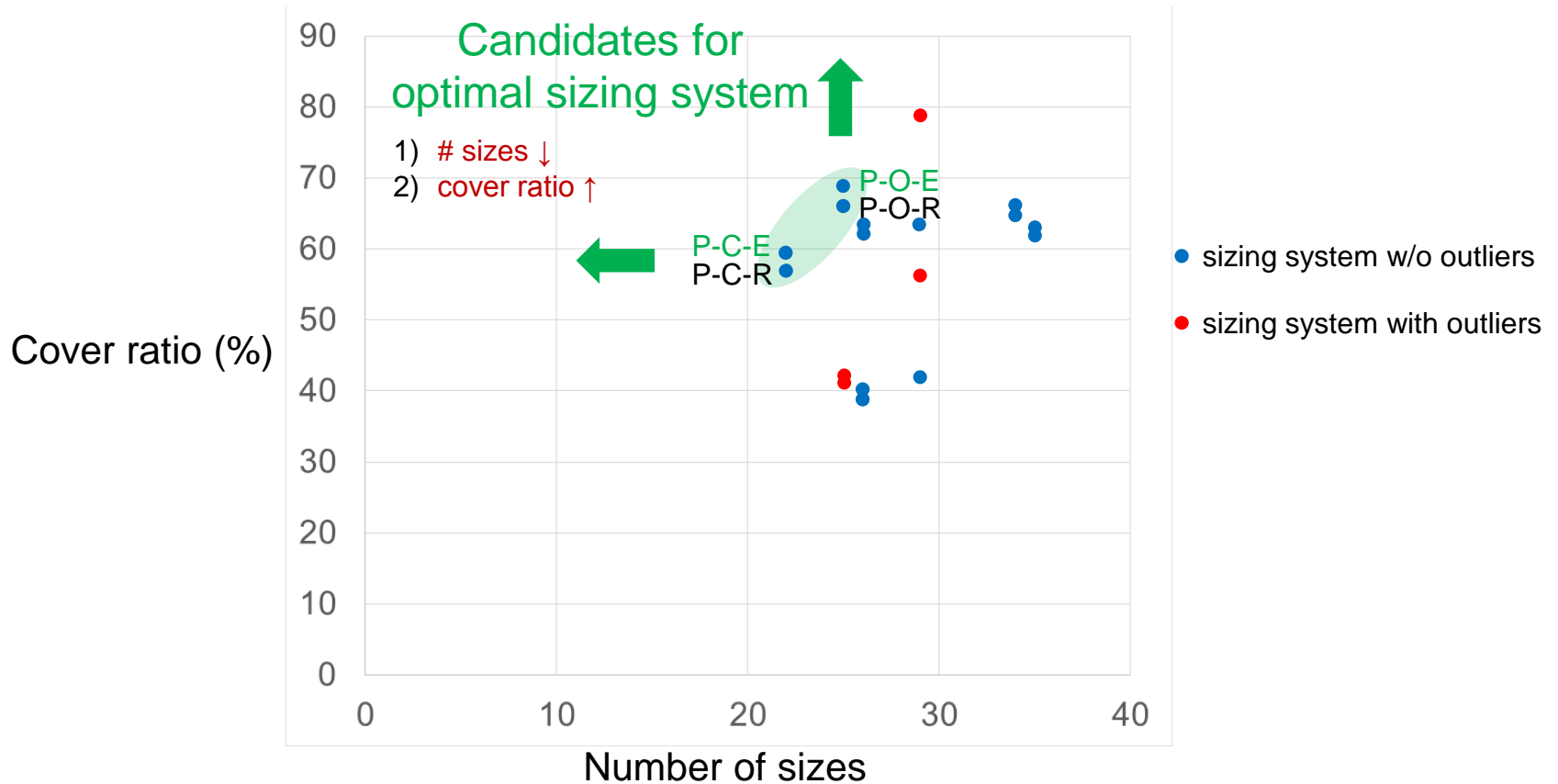
Comparison of Sizing Systems

- Total calculation time of generating 18 sizing systems \approx 2 hrs

No.	Sizing System	Accommodation percentage for key dimensions (%)	Number of generated DRHMs	Non-key dimensions	
				Cover ratio (%)	Number of outlier DRHMs
1	R-G-E	95.3	26	62.2	-
2	R-G-R	83.3	26	63.0	-
3	R-C-E	95.3	34	65.9	-
4	R-C-R	92.4	34	65.0	-
5	R-O-E	95.1	35	61.9	-
6	R-O-R	91.8	35	62.8	-
7	F-G-E	95.1	29	56.2	2
8	F-G-R	91.1	29	41.8	-
9	F-C-E	95.5	25	41.5	1
10	F-C-R	91.1	25	41.6	1
11	F-O-E	96.1	26	38.8	-
12	F-O-R	91.8	26	39.9	-
13	P-G-E	95.3	29	78.7	3
14	P-G-R	91.1	29	63.4	-
15	P-C-E	95.1	22	59.4	-
16	P-C-R	91.5	22	57.3	-
17	P-O-E	95.1	25	68.7	-
18	P-O-R	92.4	25	66.1	-

■ : controlled value

Optimal Sizing System



⇒ Candidates: P-C-E (22 sizes; 59%) vs. P-O-E (25 sizes; 69%)

⇒ Economical sizing system: P-C-E (less than # sizes of P-O-E)

Discussion (1/2)

- Developed a **computerized system** for DRHM generation and analysis by incorporating the **DRHM generation process and methods**

Input

Target Population: US Army (1990)

Gender: Female Male Composite (F : M = 70 : 30)

Number of Age Groups: 2

Target Anthropometric Variables: Re-select

Distributed RHM Generation: Analysis, User-defined

Output

S1. Target population selection

S2. Target anthropometric variable selection

S3. Extraction of key dimensions

S4. Determination of distributed method

S5. Determination of DRHM's body sizes

Analysis: regression analysis, factor analysis, principal component analysis

User-defined

Grid, Clustering, Optimization

Estimated case, Real case

DRHM generation process

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Input

Target Population: US Army (1990)

Gender: Female Male Composite (F : M = 70 : 30)

Number of Age Groups: 2

Target Anthropometric Variables: Re-select

Distributed RHM Generation: Analysis, User-defined

Output

Generated RHMs

No.	Cervic...	Chest...	Butto...	Chest...	Crook...	Inters...	Sleeve...	Stature	Waist...
1	1359.9	699.0	356.6	952.0	672.2	377.5	347.7	1572.9	356.6
2	1444.2	641.4	373.4	925.1	693.5	380.0	343.5	1591.4	380.7
3	1455.2	697.7	373.2	955.5	692.2	385.2	357.7	1603.2	384.0
4	1443.4	552.5	375.5	983.5	644.7	391.1	372.1	1564.5	382.6
5	1316.1	586.8	356.1	997.3	640.8	365.2	368.9	1529.9	351.0
6	1421.7	654.1	380.0	1037.4	626.7	402.5	359.9	1644.3	386.1
7	1390.5	570.9	367.6	991.5	646.7	389.2	372.0	1541.6	368.6
8	1626.4	696.0	410.9	1013.7	1038.4	411.7	404.2	1644.3	430.8
9	1498.1	603.7	385.3	955.9	693.2	381.9	353.9	1548.7	372.0
10	1597.2	1048.9	403.2	1039.9	1098.2	412.9	412.7	1729.6	414.7
11	1413.2	642.3	381.1	921.0	641.5	374.4	336.3	1550.2	371.5
12	1619.6	1111.8	419.2	1075.9	1128.6	426.1	437.8	1642.2	432.6
13	1526.8	699.0	385.2	1014.0	672.4	405.2	396.7	1605.0	407.8

Number of target populations: 1767

Additional Information

Regression Equation

Result 4: Additional Info.

Result 1: DRHM's body sizes

Result 2: Accommodation percentage

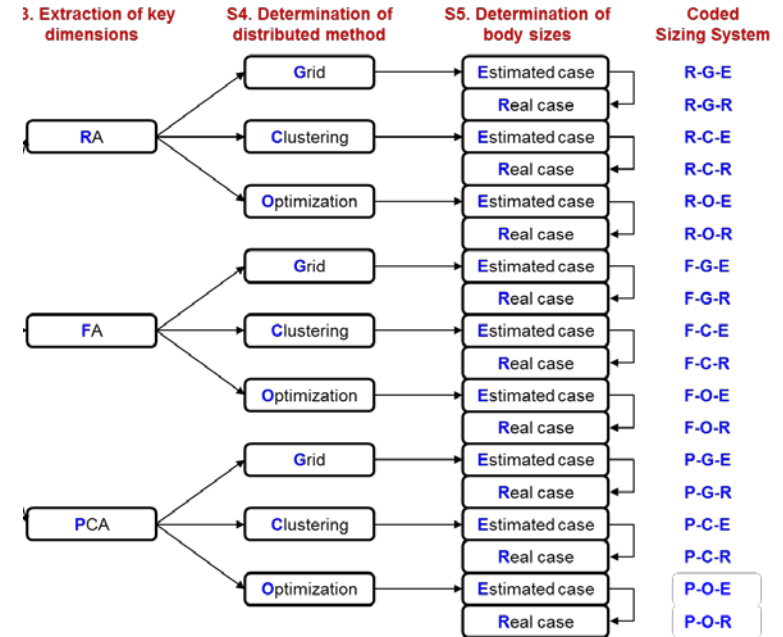
Result 3: DRHM Visualization

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⇒ Can **save time and effort** in establishing a desirable sizing system

Discussion (2/2)

- Developed **sophisticated interfaces** incorporating **complex and various algorithms** for DRHM generation



⇒ Helpful for identifying an **optimal sizing system** out of sizing system alternatives **easily and efficiently**

Q & A

Distributed RHM Generation & Analysis System

File View Help

Target Population

Database: US Army (1988)

Gender

Female

Male

Composite (%) F : M = 70 : 30

Age

Number of Age Groups: 2

10s

20s

30s

40s

Ratio (%) 60 40

Generated RHMs

Body Sizes of RHMs (Number of RHMs: 20, Number of target anthropometric variables: 13)

No.	Cervic...	Chest...	Biacro...	Buttoc...	Chest...	Crotc...	Inters...	Sleev...	Stature	Waist ...
1	1359,9	899,8	356,6	952,0	877,2	377,5	347,7	527,7	1577,9	359,6
2	1484,2	841,4	373,4	925,1	859,5	380,0	343,5	581,4	1713,4	389,7
3	1455,2	899,7	373,2	955,5	902,2	385,2	357,7	569,2	1681,5	384,0
4	1443,4	952,5	375,5	983,5	944,7	391,1	372,1	564,5	1668,4	382,6
5	1316,1	986,8	356,1	997,3	940,8	385,2	368,9	509,3	1529,9	351,0
6	1421,7	1054,1	380,0	1037,4	1026,7	402,5	399,9	555,7	1644,3	380,1
7	1390,5	970,9	367,8	991,5	946,7	389,2	372,0	541,6	1610,8	369,6
8	1626,4	996,0	410,9	1013,7	1030,4	411,7	404,2	644,3	1867,0	430,8
9	1408,1	903,7	365,3	955,9	893,2	381,9	353,9	548,7	1630,3	372,0
10	1557,2	1049,3	403,2	1039,9	1058,2	412,9	412,7	614,7	1791,6	414,7
11	1413,2	842,3	361,1	923,0	841,5	374,4	336,3	550,5	1636,2	371,5
12	1619,6	1111,8	419,2	1075,9	1128,6	426,1	437,8	642,2	1859,1	432,6
13	1302,8	899,7	356,6	952,0	877,2	377,5	347,7	527,7	1577,9	359,6

Number of target populations: 1767

	Female	Male	Total
Group1	742	318	1060
Group2	495	212	707
Group3	0	0	0
Group4	0	0	0
Total	1237	530	1767

Additional Information

Regression Equation

FA or PCA Loadings and Scores

Target Anthropometric Variables

Re-selection

Distributed RHM Generation

S1, Extraction of Key Dimensions

Analysis User-defined

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Analysis of Multivariate Accommodation Percentages (MAPs)

For key dimensions: 60,5 %

MAPs for the different number of anthropometric variables Average

Number of anthropometric variables	MAPs (%)
2	97.0
3	78.9
4	56.8
5	38.5
6	25.5
7	16.9
8	11.3
9	7.7
10	5.3
11	3.8
12	2.7
13	2.0
14	1.5

Location of RHMs with Envelopes (for key dimensions)

Plot of Generated-RHMs & Clusters

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Thank You 😊

APPENDIX

Demonstration: RA – Grid – Estimated Case

Distributed RHM Generation & Analysis System

File View Help

Target Population

Database: US Army (1988) [v]

Gender

Female

Male

Composite (%) F : M = [70] : [30]

Age

Number of Age Groups: [1] [v]

10s

20s

30s

40s

Ratio (%) [100]

Target Anthropometric Variables

Selection

Distributed RHM Generation

S1, Extraction of Key Dimensions

[Analysis] [User-defined]

Regression Analysis (RA)

Factor Analysis (FA)

Principal Component Analysis (PCA)

S2, Determination of Distributed Method

Grid (Robinette and Annis, 1986)

Clustering (Laing et al., 1999)

Optimization (McCulloch et al., 1998)

S3, Determination of Body Sizes of RHMs

Estimated Case Real Case

Generation

Generated RHMs

Body Sizes of RHMs (Number of RHMs: 000, Number of target anthropometric variables: 000)

Number of target populations: 0000

	Female	Male	Total
Group1			
Group2			
Group3			
Group4			
Total			

Additional Information

Regression Equation

FA or PCA Loadings and Scores

Analysis of Multivariate Accommodation Percentages (MAPs)

For key dimensions: 00,0 %

MAPs for the different number of anthropometric variables [Average] [v]

Number of anthropometric variables	MAPs (%)
1	99.0
2	96.0
3	91.0
4	84.0
5	75.0
6	64.0
7	51.0
8	36.0
9	19.0
10	0.0

Location of RHMs with Envelopes (for key dimensions)

Notice: Will be plotted when number of key dimensions is 2 or 3

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Generation Method

S3. Extraction of key dimensions

Accommodation rate = 95%

RA

S4. Determination of distributed method

Grid

Fitting tolerance = 50 mm

Clustering

Optimization

Number of iterations = 1,000

FA

Method of factor rotation: Varimax

Grid

Fitting tolerance = 2.35*

Clustering

Optimization

Number of iterations = 1,000

PCA

Grid

Fitting tolerance = 3.32*

Clustering

Optimization

Number of iterations = 1,000

Random initial solution

Clustering
Optimization

10 trials

Find the minimum number of DRHMs

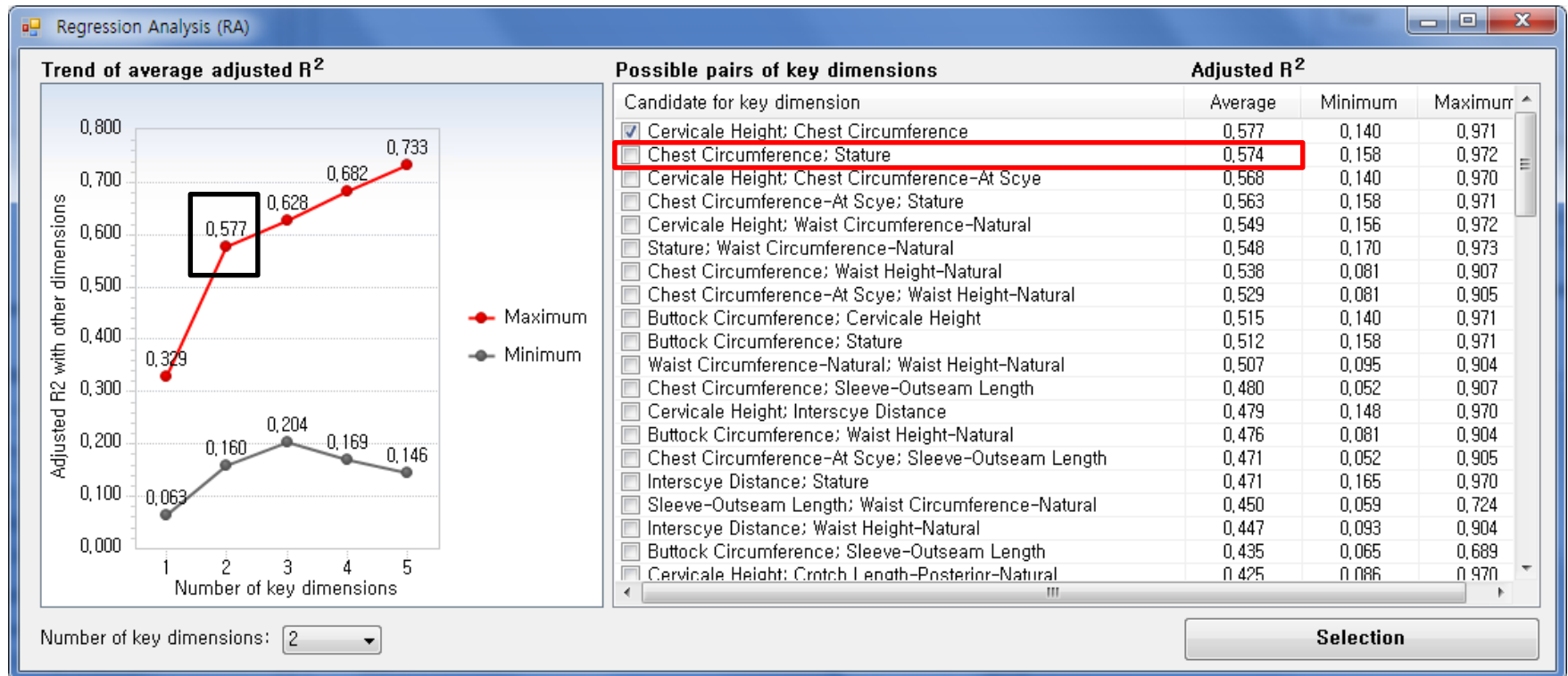
Factor scores

No.	F1	F2	F3	F4
1	0,509	-0,229	0,728	1,184
2	1,115	-0,689	-1,155	-0,834
3	-0,583	1,975	1,278	0,164
4	0,257	-0,331	-1,414	-0,664
5	0,022	1,740	0,463	-0,405
6	-1,661	-0,320	2,617	-0,906
7	0,840	-0,071	-0,827	-1,313
8	0,368	-0,520	-0,663	0,857
9	-0,697	1,719	-0,028	0,908
10	0,527	-0,165	-1,025	2,028

Descriptive statistics	F1	F2	F3	F4
Mean	0,0	0,0	0,0	0,0
S.D.	1,0	1,0	1,0	1,1
Minimum	-2,7	-2,6	-3,5	-3,7
Maximum	2,5	3,2	2,9	3,7
Range (Max - Min)	5,2	5,9	6,4	7,4
1st percentile	-2,7	-2,6	-3,5	-3,6
99th percentile	2,5	3,2	2,8	3,7
1 - 99 percentile range	5,1	5,8	6,3	7,3

Key Dimensions for Flight Suit Design

- Chest circumference and Stature considering both performance (average adjusted R^2 with other dimensions = 0.574; current key dimensions) and usability



Comparison of Sizing Systems: Average of MAPs

No.	Sizing System	Generated number of DRHMs	Number of anthropometric variables												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	R-G-E	29	98.7	90.7	76.8	61.7	48.3	37.5	29.2	23.0	18.4	15.1	12.6	10.7	9.3
2	R-G-R		98.9	91.3	77.6	62.3	48.5	37.2	28.6	22.1	17.4	13.9	11.4	9.5	8.0
3	R-C-E	34	99.1	92.4	80.4	66.7	53.8	42.8	33.9	26.9	21.4	17.3	14.0	11.5	9.5
4	R-C-R		98.9	92.1	80.2	66.7	54.0	43.1	34.2	27.2	21.7	17.5	14.2	11.6	9.5
5	R-O-E	35	98.8	92.3	80.3	66.6	53.7	42.8	34.0	27.0	21.6	17.3	14.0	11.4	9.3
6	R-O-R		98.7	91.9	80.0	66.5	53.8	43.1	34.3	27.3	21.8	17.5	14.0	11.3	9.1
7	F-G-E	29	93.0	78.0	59.9	43.9	31.6	22.8	16.6	12.4	9.5	7.4	5.9	4.7	3.9
8	F-G-R		88.5	71.5	54.7	40.7	29.9	21.9	16.1	11.8	8.8	6.5	4.9	3.6	2.7
9	F-C-E	25	87.3	69.2	52.5	39.1	29.1	21.8	16.7	13.1	10.5	8.6	7.2	6.2	5.4
10	F-C-R		87.1	68.3	51.6	38.4	28.7	21.6	16.5	12.9	10.2	8.3	6.8	5.7	4.7
11	F-O-E	26	87.1	69.8	53.4	40.1	30.0	22.6	17.2	13.3	10.4	8.3	6.7	5.5	4.5
12	F-O-R		86.7	69.5	53.5	40.4	30.3	22.8	17.3	13.1	10.0	7.5	5.7	4.2	3.1
13	P-G-E	29	99.6	92.4	70.5	45.4	27.3	16.5	10.4	6.9	4.9	3.6	2.8	2.3	1.9
14	P-G-R		98.3	91.7	78.3	61.2	45.1	32.4	23.3	17.1	12.8	9.8	7.7	6.1	4.9
15	P-C-E	22	98.2	90.4	76.8	61.2	47.0	35.6	27.1	20.9	16.3	13.0	10.5	8.7	7.2
16	P-C-R		98.4	89.7	75.3	59.4	45.3	34.0	25.6	19.4	14.8	11.4	8.7	6.7	4.9
17	P-O-E	25	98.6	91.5	77.9	61.9	47.2	35.3	26.5	20.1	15.5	12.2	9.7	7.9	6.4
18	P-O-R		99.1	91.6	77.1	60.3	45.3	33.5	24.8	18.7	14.3	11.0	8.6	6.7	5.2

Follow-Up Studies

- Development of (1) a boundary representative human model (BRHM) generation and analysis system for one-size product design and (2) a linkage with the custom-built interface of digital human model simulation systems

Sex		Nominal anthropometric dimension												
Order	Unit	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist	Waist
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
2	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
3	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
4	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
5	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
6	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
7	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
8	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
9	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
10	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
11	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
12	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
13	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
14	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
15	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
16	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
17	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
18	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
19	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
20	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
21	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18
22	733.22	741.78	802.23	862.68	923.13	983.58	1044.03	1104.48	1164.93	1225.38	1285.83	1346.28	1406.73	1467.18

Distributed RHM Body sizes

Boundary RHM Body sizes

Automatic inputting

Statistics | Dependent Measurements

Control Measurements

Measurement Name	Value (mm)
body-height	1710.0
sitting-height	932.0
waist-circumference	865.0

Dependent Measurements

Measurement Name	Value (mm)
head-height	239.0
head-width	167.5
head-depth	185.0
stature	170.1
buttock-knee-length	574.5
knee-height-sitting	505.5
foot-height	82.2
foot-length	254.6
foot-width	100.5
upperarm-circumference	302.5
forearm-circumference	266.0
thigh-circumference	563.0
calf-circumference	405.5

Modify Selected Measurement...

Build Human...

Stature: Units: cm

Gender: Female Male

Abdominal Dep.:

Ankle Hgt:

Acromion Height:

Arm Length:

Biacromial Br.:

Bideltoid Br.:

Buttock-Knee:

Elbow Rest Hgt:

Elbow-Fingertip:

Foot Breadth:

Foot Length:

Hand Breadth:

Hand Length:

Head Breadth:

Head Height:

Head Length:

Hip Breadth:

Interpupul Dist:

Shoulder-Elbow:

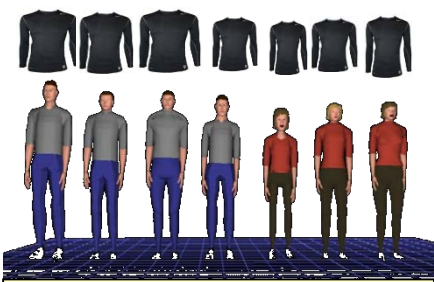
Sitting Acromial:

Sitting Eye:

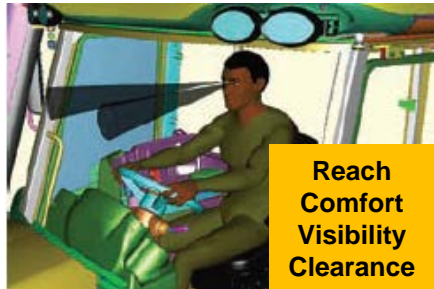
Sit Knee Hgt:

Thigh Clearance:

Thumbtip Reach:



Multiple-size product (e.g., clothing, gloves)



One-size product (e.g., cockpit, seat)

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