포항공과대학교
산업경영공학과

Ergonomic Design Technology Lab

다중치수제품 설계를 위한 산포대표인체모델 생성 및 분석 시스템 개발

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

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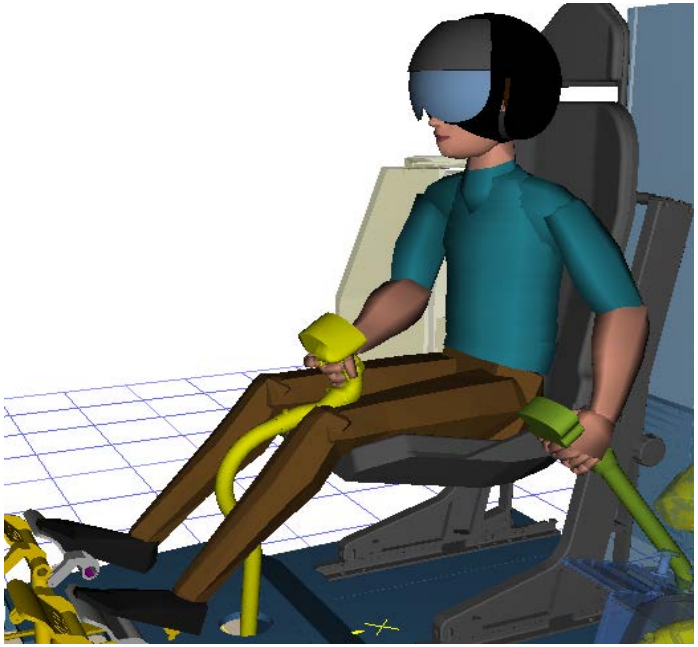
Global Contributor to Eco-Techno-Humanopia

AGENDA

- Background
- Research Objectives
- Literature Review
- System Development
- Discussion

Digital Human Model Simulation System

- Digital human model simulation (DHMS) system: 가상환경상에서 대표인체모델을 생성하여 인간공학적 제품과 작업공간의 설계 및 평가를 위한 효율적인 도구로 사용(Jung et al., 2009)



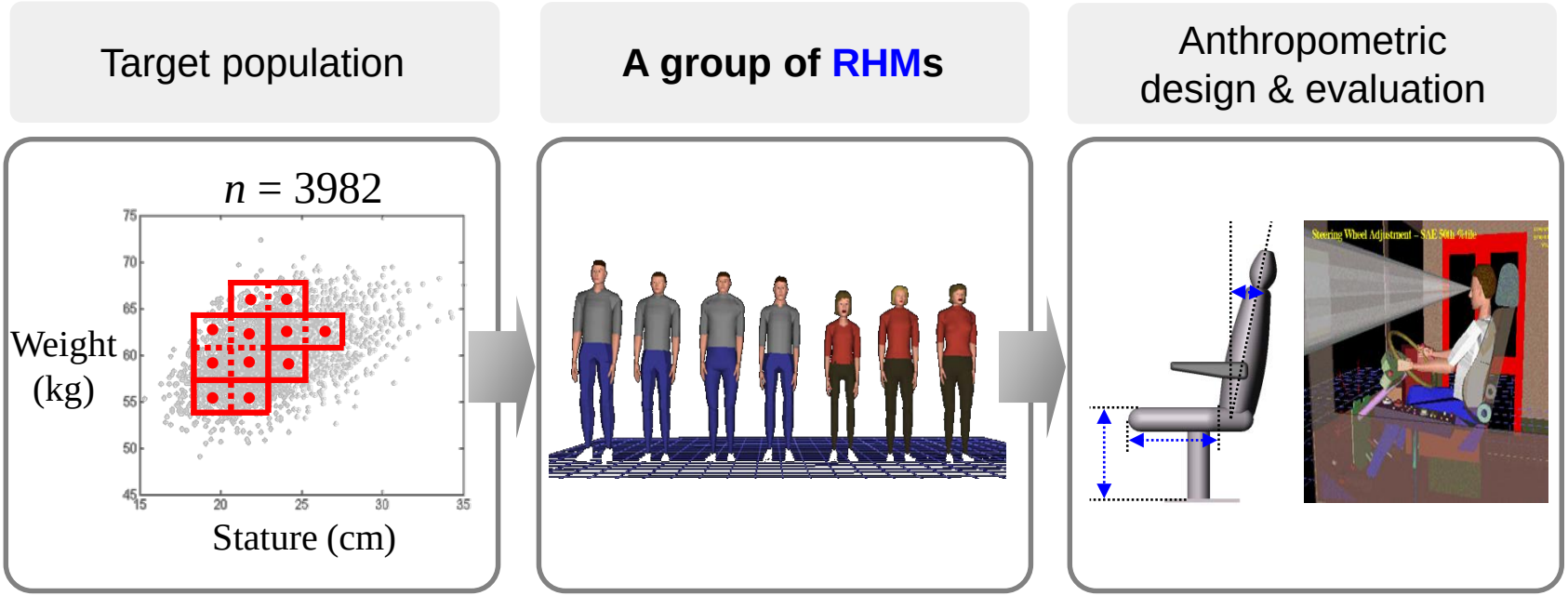
한국형 헬리콥터 조종실 설계
(박장운 외, 2008)

방사성폐기물처리장 주제어실 평가
(이백희 외, 2010)

⇒ **인간공학적 평가 기준(예: reach, visibility) 적용을 위한 human-workstation interaction 평가 및 시각화에 유용하게 활용되고 있음**

Representative Human Model

- 대표인체모델(representative human model; RHM): 제품 설계대상인구(target population)의 인체크기를 통계적으로 적합하게 대표하는 소수의 인체모델(Jung and You, 2005)

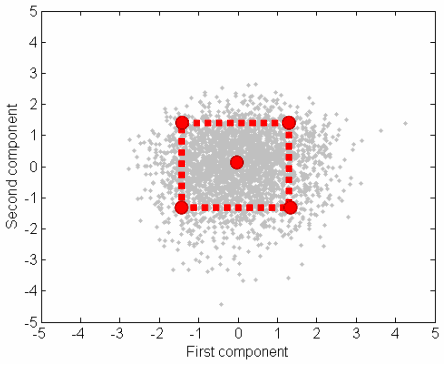
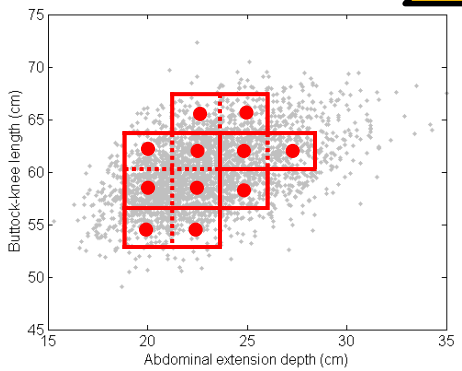


⇒ **소수의 RHM을 활용하는 방법은 효율적인 제품 설계 및 개발을 위한 필수적 기법**

Taxonomy of RHM Generation Method

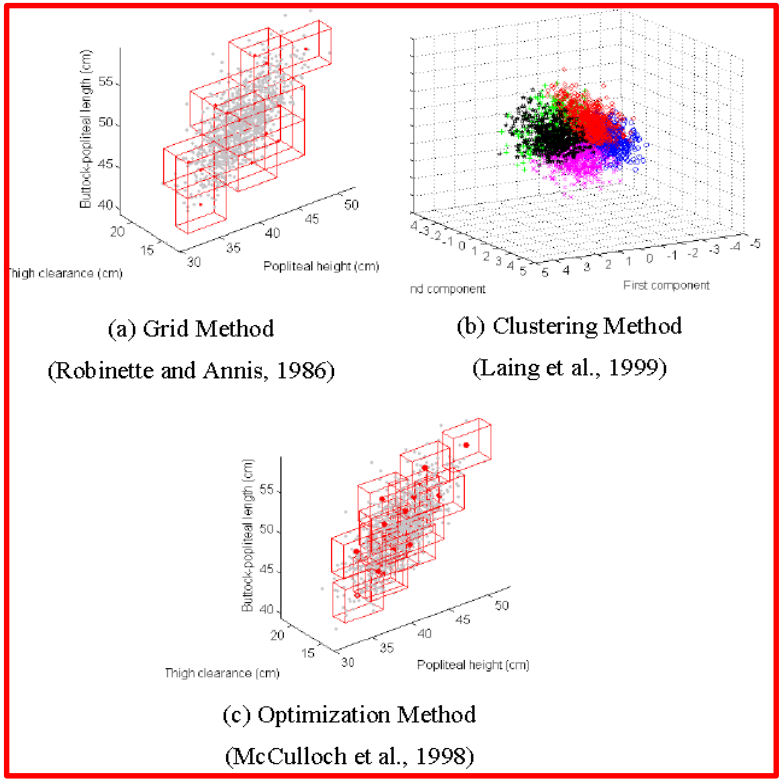
- RHM은 제품 설계 적용 분야에 따라 2가지 방법으로 생성될 수 있음(Jung, 2009)

Focus

	Boundary method	Distributed method
Illustration		
Application	• 단일치수제품(one-size product) 설계 • 예: 비행기 조종석, 자동차 운전석	• 다중치수제품(multiple-size product) 설계 • 예: 의복, 장갑
Methods	• Square method (Bittner, 2000) • Circular method (Meindl et al., 1993) • Rectangular method (Kim and Whang et al., 1997) • Boundary zone method (Jung, 2009)	• Grid method (Robinette and Annis, 1986) • Cluster method (Laing et al., 1999) • Optimization method (McCulloch et al., 1998)

Distributed Representative Human Model

- 산포대표인체모델(distributed RHM)의 생성은 의복과 같은 다중치수제품(multiple-size product) 및 대량맞춤생산(mass customization)을 위한 치수체계(sizing system) 개발에 활용되고 있어 이에 특화된 시스템이 필요함

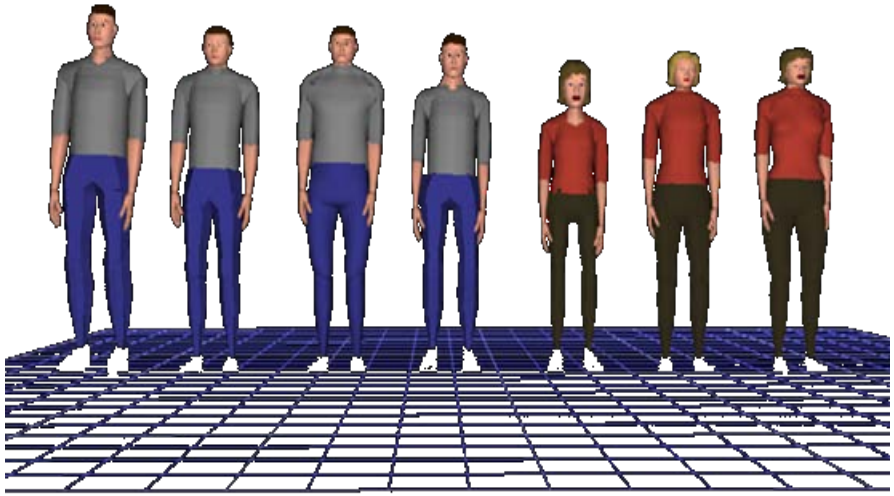


(a) Grid Method
(Robinette and Annis, 1986)

(b) Clustering Method
(Laing et al., 1999)

(c) Optimization Method
(McCulloch et al., 1998)

3가지 DRHM 생성 방법



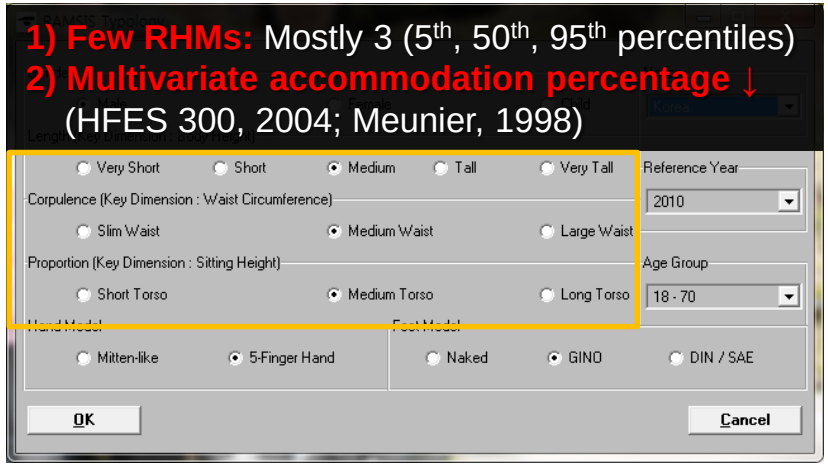
생성된 distributed RHMs

RHM Generation Method in DHMS System

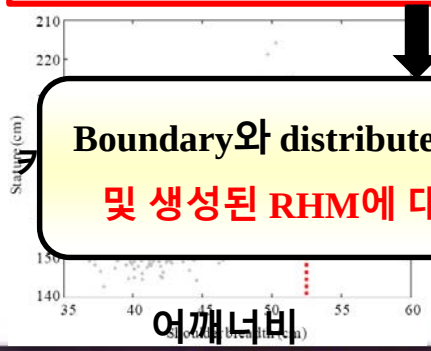
- DHMS system의 RHM 생성은 percentile 방법과 custom-built 방법으로 구분
- **Limitations** (Jung et al., 2009)

  1) Percentile 방법: 설계 대상 인구(target population)에 대한 RHM의 대표성(representativeness) ↓

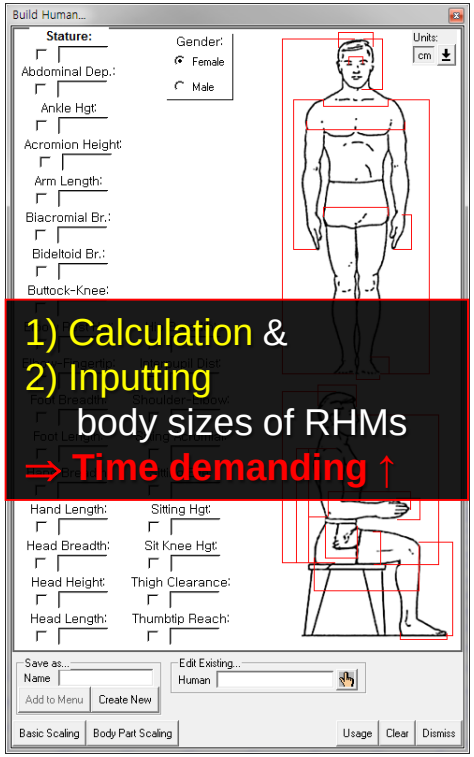
  2) Custom-built 방법: RHM 생성 효율성(generation efficiency) ↓



Percentile method UI (RAMSIS®)

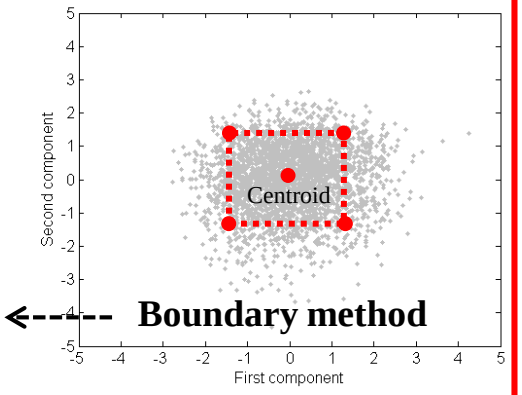


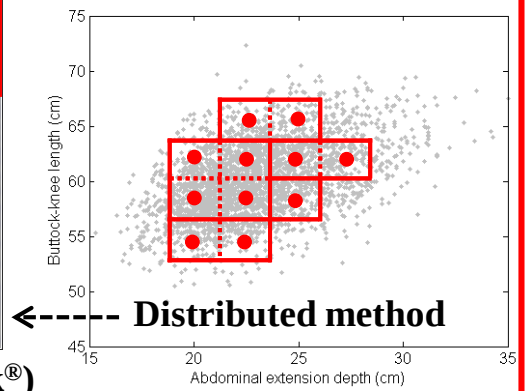
Boundary와 distributed RHM 생성 시스템 및 생성된 RHM에 대한 분석 기능 필요



1) Calculation &
2) Inputting
body sizes of RHMs
⇒ **Time demanding ↑**

Custom-built method UI (Jack®)





Ergonomic Design Technology Lab

Research Objective

다중치수제품 설계를 위한
산포대표인체모델 생성 및 분석 시스템 개발

❑ Distributed RHM 생성 기법 및 DHMS system 특성 파악

- ✓ Distributed RHM 생성 방법(grid, cluster, and optimization method) 및 생성 절차(중요 변수 선정, 대표격자 형성, 대표인체모델 치수 추정) 관련 문헌 조사
- ✓ DHMS system (Jack, RAMSIS, and CATIA Human)의 RHM 생성 인터페이스 파악

❑ Distributed RHM 생성 및 분석에 특화된 시스템 개발

- ✓ 설계 대상 인구 및 설계 대상 인체변수 선정에 용이한 인터페이스 개발
- ✓ Distributed RHM 생성간 적용되는 통계적 기법의 총체적 제공
- ✓ 생성된 Distributed RHM의 분석 기능 구현 및 3차원 시각화

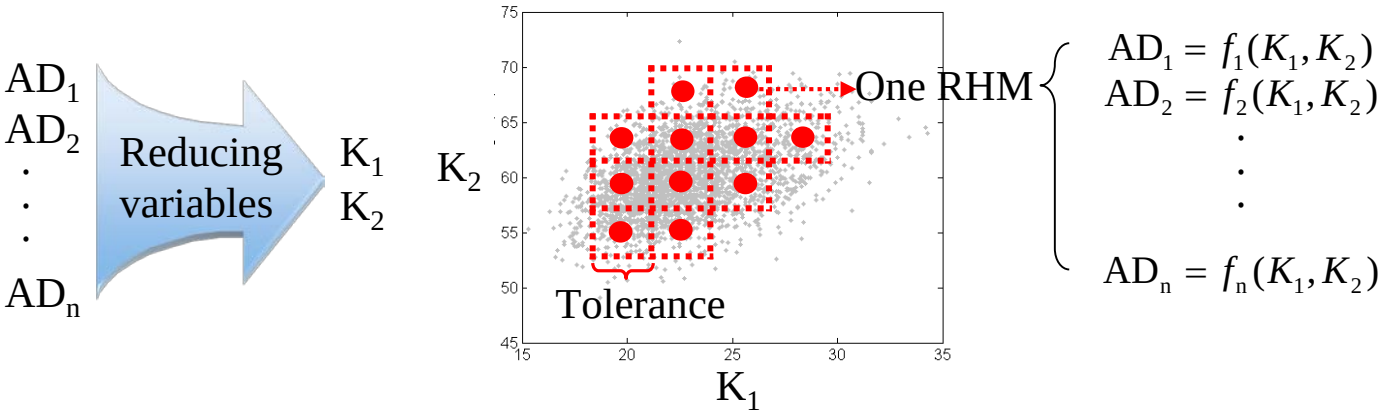
Distributed RHM Generation Process

- Distributed RHM 생성 절차(Jung, 2009)

Step 1: Extraction of key dimensions

Step 2: Determination of distributed method

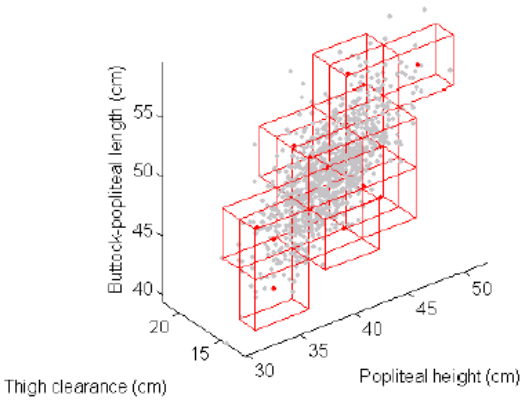
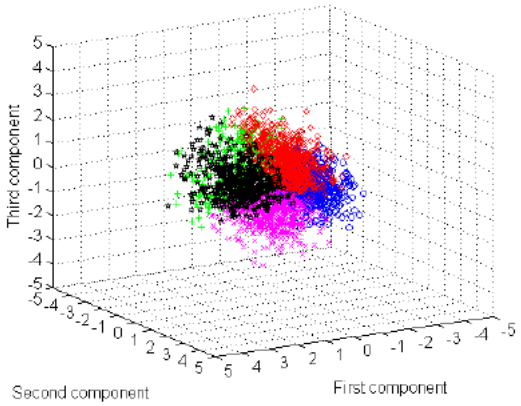
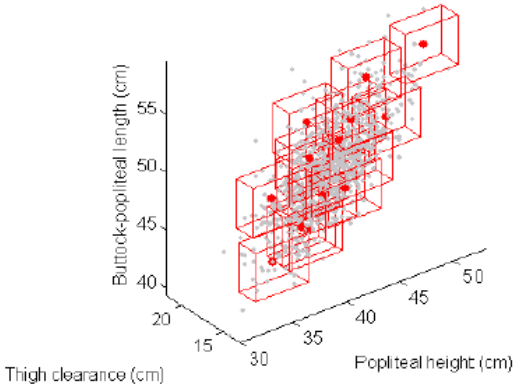
Step 3: Determination of body sizes of RHMs



Factor analysis	Grid method	Estimation	**Used statistical method**
Principal component analysis	Cluster method	Real case	
Regression analysis	Optimization method		

Note: AD = anthropometric dimension, K = key dimension

Distributed Methods

	Grid method	*Cluster* method	*Optimization* method
Illustration			
Study	• Robinette and Annis (1986) • Rosenblad-Wallin (1987) • Moon (2002) • Kwon et al. (2004) • Zheng et al. (2007)	• Laing et al. (1999)	• McCulloch et al. (1998)
Determination of grid	• Determined as the centroids of the grids formed to accommodation rate of the target population by grading system • Size of the grid was determined with a design fitting tolerance value	• Determined as the centroids of the clusters generated by K-means cluster analysis in the space of the factors • Number of clusters was determined by the trend of within-cluster average distances	• Determined as the centroids of the grids formed in the space of the key dimensions by applying the Nelder-Mead optimization algorithm • Optimal location was determined by the loss score

RHM Generation in DHMS System

❑ 대표적으로 사용되는 3가지 DHMS system의 RHM 생성 인터페이스 특징 파악

	Jack	RAMSIS	CATIA Human
Developer	SIMENS, Germany	Human Solutions, Germany	Dassault Systemes, France
Latest release ver.	Ver. 5.1	Ver. 3.8.30	Ver. 5
Database / Nation (Reference year)	US Army (1988)	Germany etc., 17 nations (1984 - 2020)	American, canadian, French, Japanese, Korean (*N.S.)
Gender	Female, Male, (Child)	Female, Male, (Child)	Female, Male
Age groups	**N.F.	Fixed 4 groups (18-70, 18-29, 30-49, 50-70)	N.F.
Number of anthropometric variables (in custom-built RHM)	26	24	N.F.
RHM-generation method	Percentile method Custom-built method	Percentile method Custom-built method	Percentile method

*N.S.: not specified
**N.F.: no function

Limitations

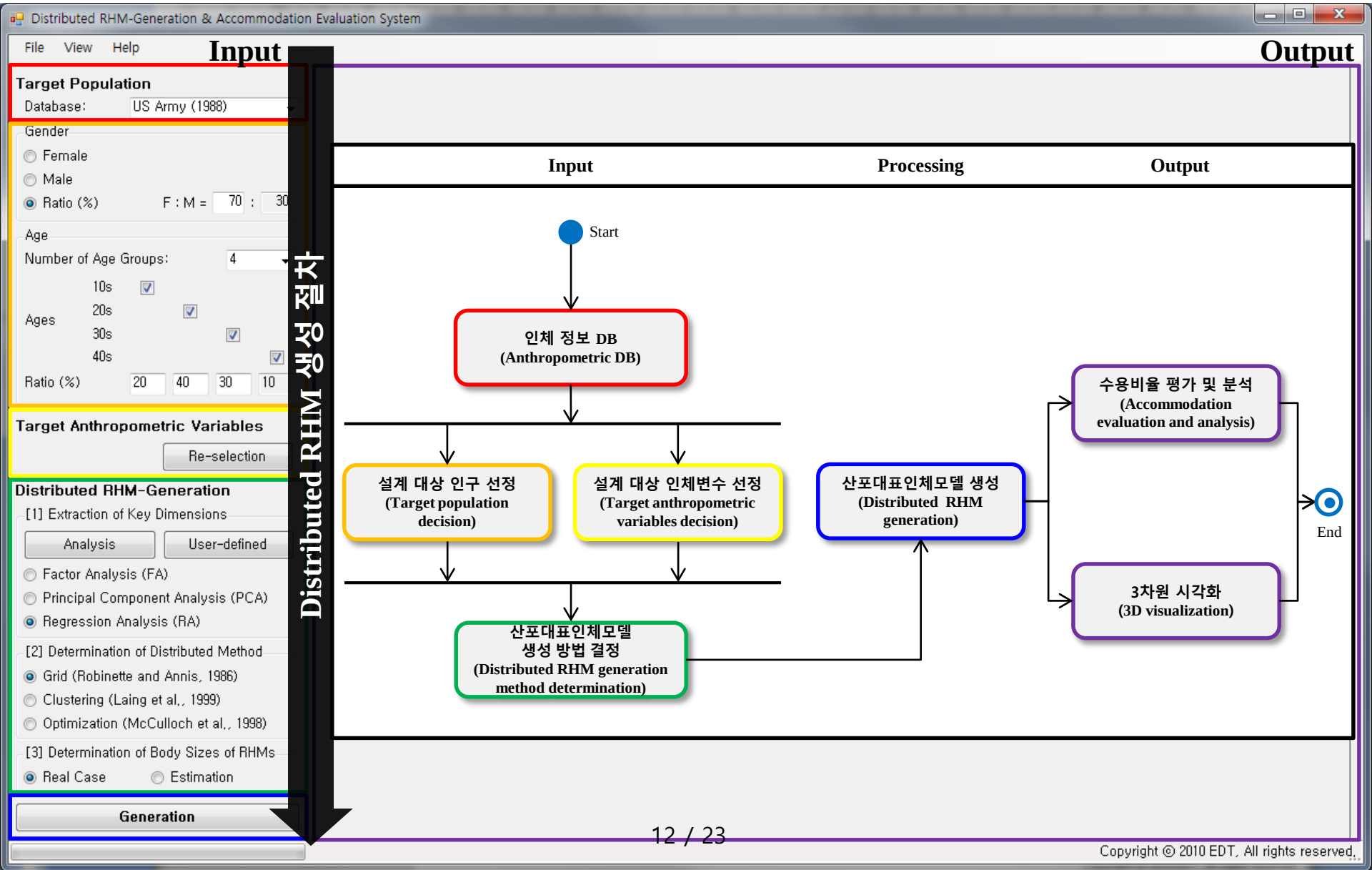
⇒ **Gender:** 혼성 인구가 고려되지 않음

⇒ **Age groups:** 다양한 연령대의 인구가 고려되지 않음

⇒ **Number of anthropometric variables:** 대표적인 소수의 인체변수만 제공

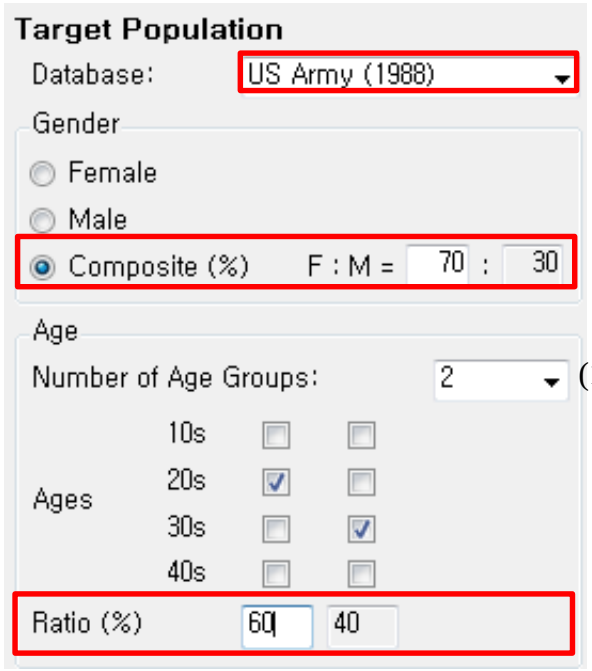
⇒ **RHM generation method:** distributed (or boundary) method와 연동되지 않음

System Overview & Activity Diagram



User Interface: Target Population

- 3가지 인체측정 DB로부터 다양한 성별과 연령집단을 선택 가능하도록 개발됨



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

$$Maximize \quad Z = \sum_i \sum_j x_{ij}$$

Gender와 age group 각각의 비율을 만족하는 최대의 인구 수 추출

< Algorithm for extraction of target population >

$Let \quad x_{ij}$ = # [will be selected] of i(gender) aged j's

y_{ij} = # [in database] of i(gender) aged j's

R_k = # in k_ratio cell

$i = F, M, \; j = 10, 20, 30, 40, \; k = F, M, 10, 20, 30, 40$

$subject \ to$

$$x_{ij} \le y_{ij} \quad \text{for all } i, j$$

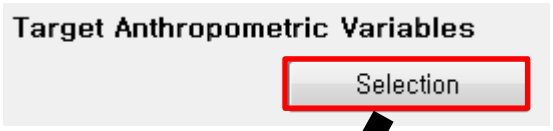
$$R_F : R_M = \sum_j x_{Fj} : \sum_j x_{Mj}$$

$$R_{10} : R_{20} : R_{30} : R_{40} = \sum_i x_{i10} : \sum_i x_{i20} : \sum_i x_{i30} : \sum_i x_{i40}$$

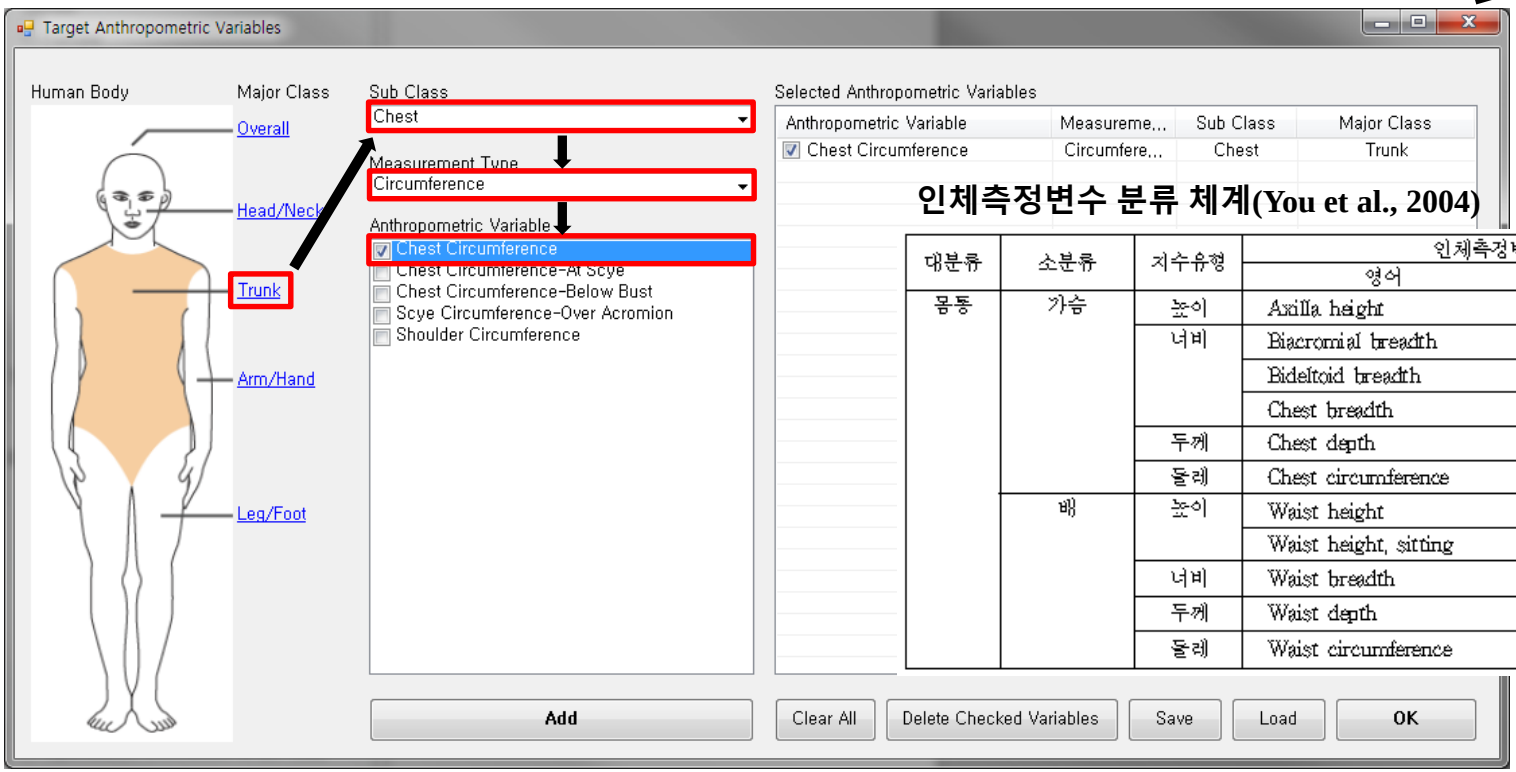
$$x_{ij} > 0 \quad \text{for all } i, j$$

Target Anthropometric Variables

- 인체변수를 대분류, 소분류, 치수유형으로 분류(You et al., 2004) 하여 용이한 선택이 가능하도록 인터페이스 구현



예: 가슴둘레(Chest circumference)를 선택하는 경우

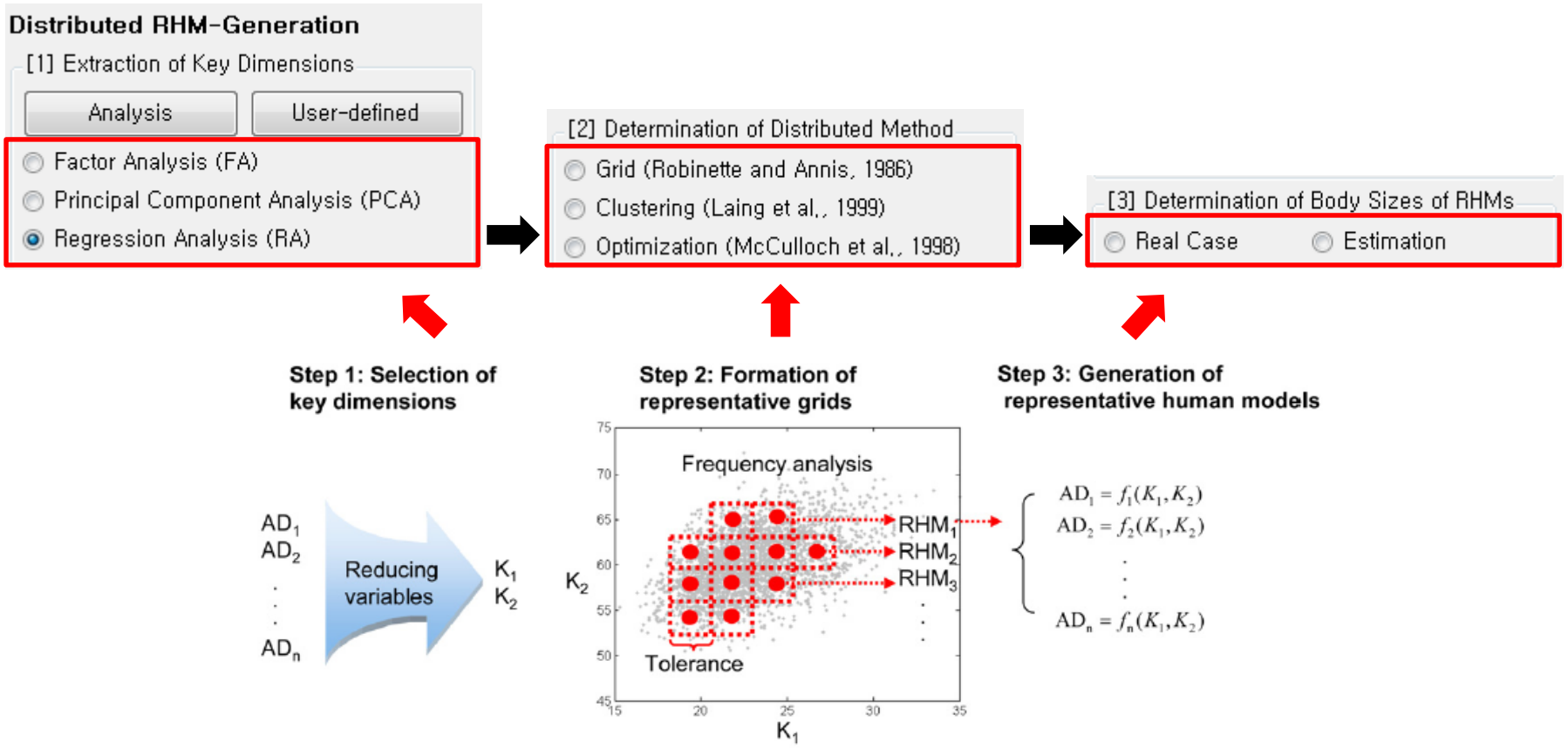


인체측정변수 분류 체계(You et al., 2004)

대분류	소분류	치수유형	인체측정변수 명칭	
			영어	한글
몸통	가슴	높이	Axilla height	겨드랑높이
		너비	Biacromial breadth	어깨너비
			Bideltoid breadth	몸통너비
			Chest breadth	윗가슴너비
		두께	Chest depth	가슴두께
		둘레	Chest circumference	가슴둘레
	배	높이	Waist height	허리높이
			Waist height, sitting	앉은허리높이
		너비	Waist breadth	허리너비
		두께	Waist depth	허리두께
		둘레	Waist circumference	허리둘레

Distributed RHM Generation

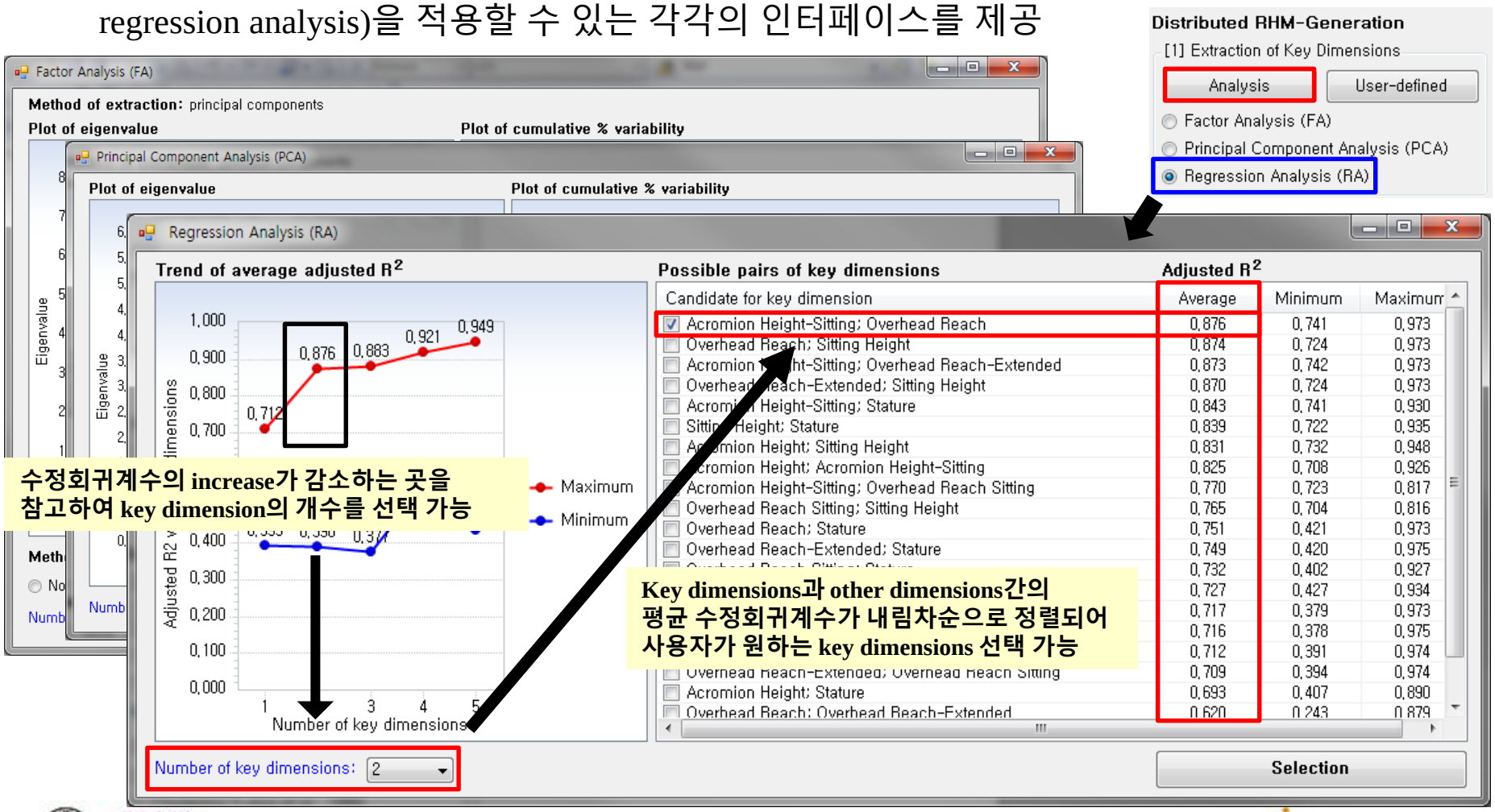
- 3단계 distributed RHM 생성 절차(Jung et al., 2010)를 따라 각 절차에서 적용되는 통계적 기법을 제공



RHM generation process of the grid method (Jung et al., 2010)

Step 1: Extraction of Key Dimensions

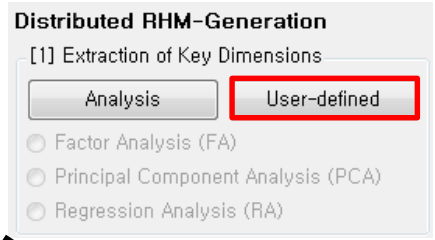
- 대표적으로 사용되는 3가지 통계적 분석방법(factor analysis, principal component analysis, regression analysis)을 적용할 수 있는 각각의 인터페이스를 제공

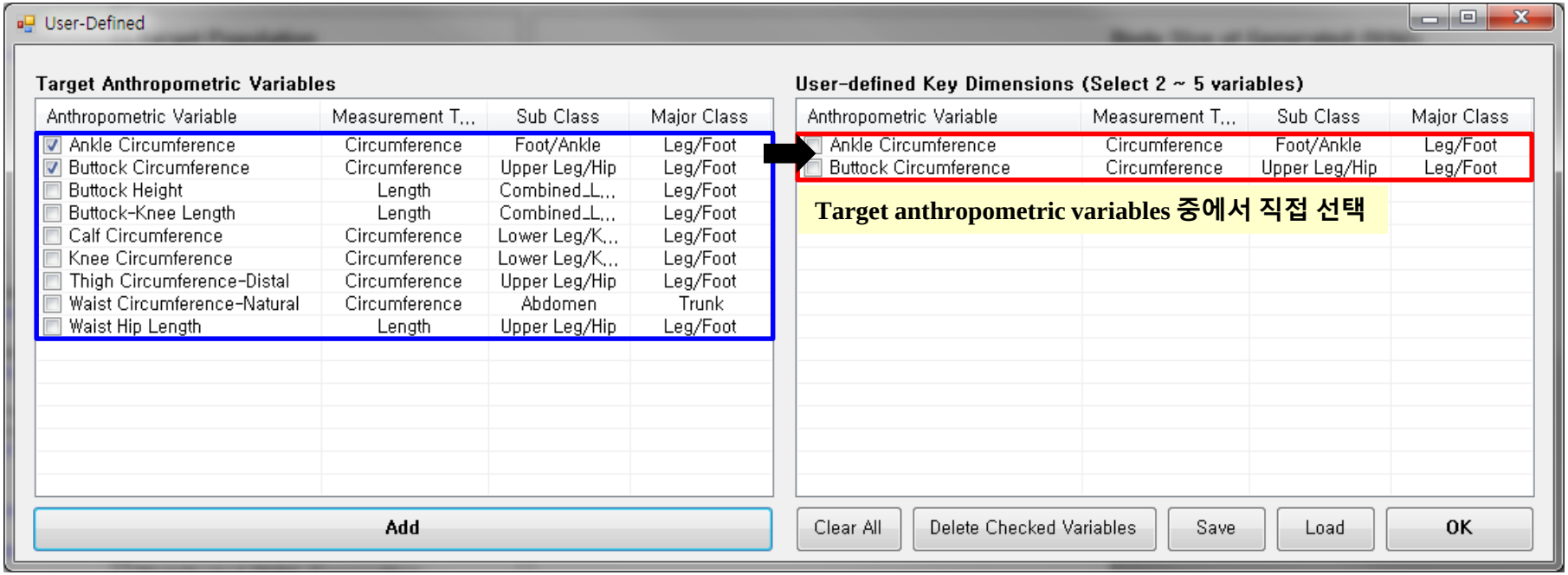


Step 1: Extraction of Key Dimensions

- 사용자가 중요변수를 알고 있는 경우 직접 선택할 수 있도록 인터페이스 구현

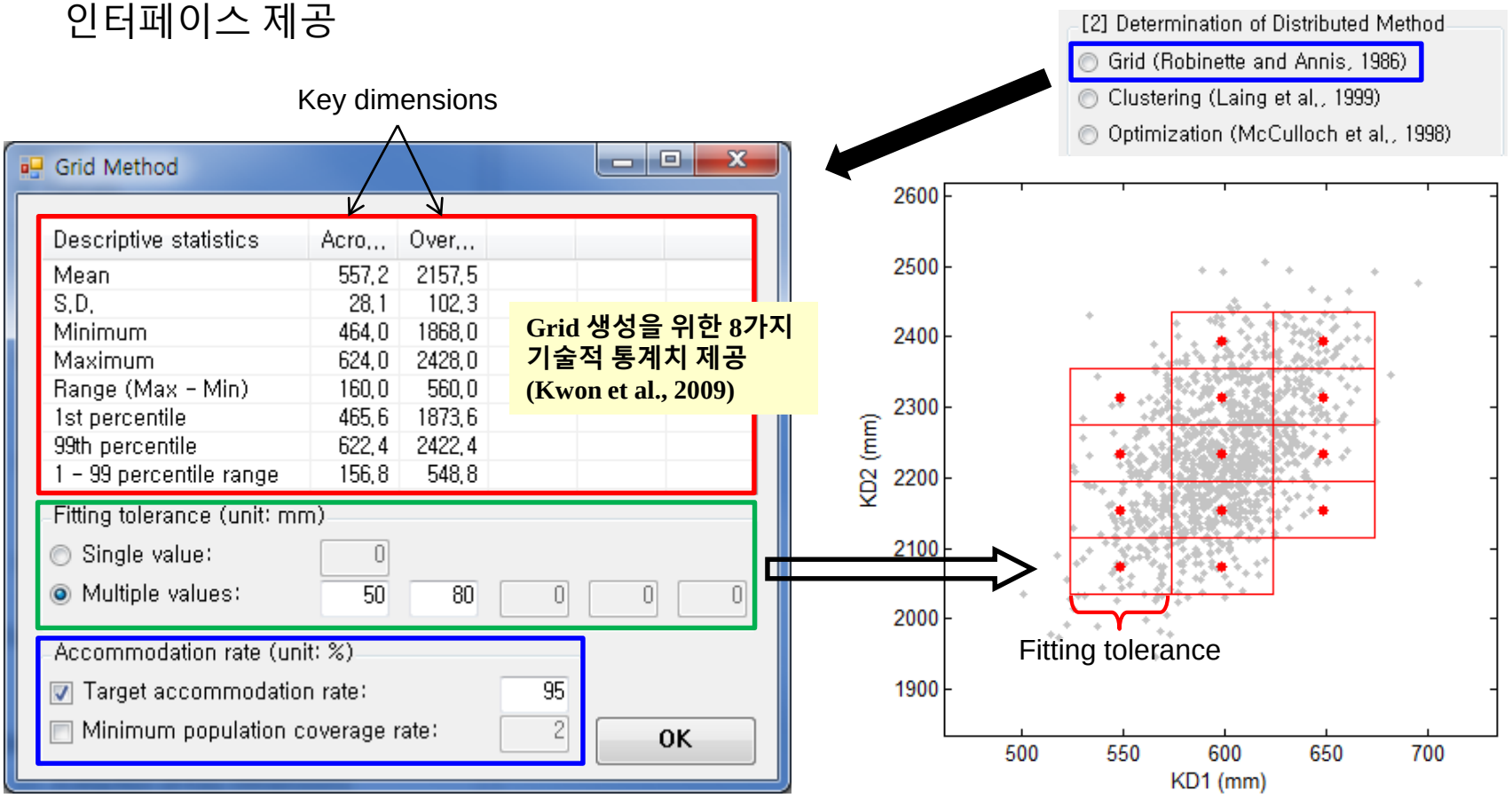
예: Kwon et al. (2009)는 기존 문헌 조사를 통해 3가지 중요변수 선정
(hand length, hand circumference, hand breadth)





Step 2: Determination of Distributed Method

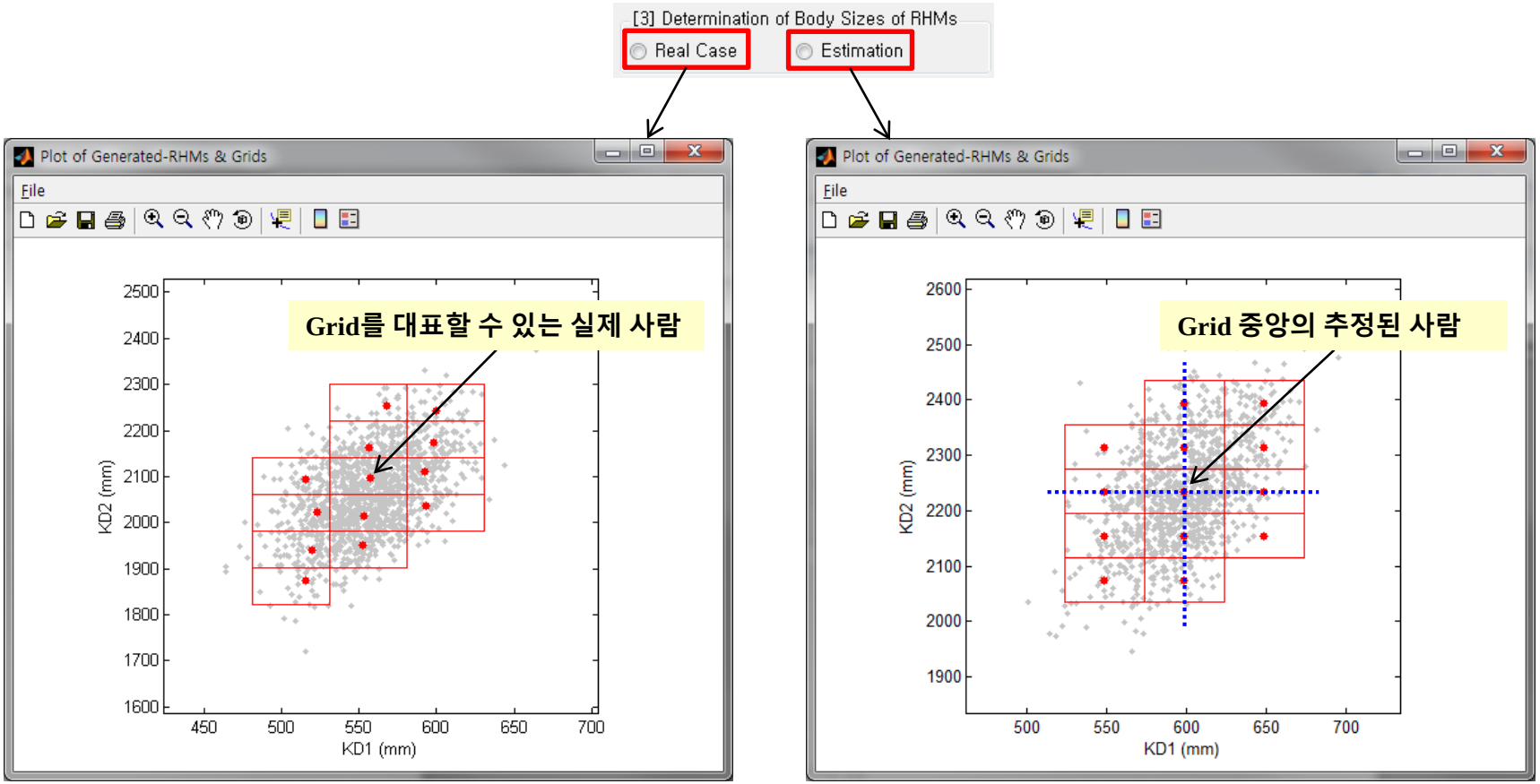
- 3가지 distributed RHM 생성 방법(grid, cluster, optimization method) 적용을 위한 각각의 인터페이스 제공



Sum of coverage rates of grids > 95%
(Jung et al., 2010)
A grid of coverage rate > 2%
(Kwon et al., 2009)

Step 3: Determination of Body Sizes of RHM

- 2가지 인체크기 추정방법(real case or estimation)을 제공



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

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

Result View *(under development)*

Distributed RHM-Generation & Accommodation Evaluation System

File View Help

Target Population

Database: US army (1988)

Gender

Female

Male

Ratio (%) F : M = 70 : 30

Visualization part

Ages: 10s, 20s, 30s, 40s

Ratio (%): 20 40 30 10

Target Anthropometric Variables

Re-selection

Distributed RHM-Generation

[1] Extraction of Key Dimensions

Analysis User-defined

Factor Analysis (FA)

Analysis part

Regression Analysis (RA)

[2] Determination of Distributed Method

Grid (Robinette and Annis, 1986)

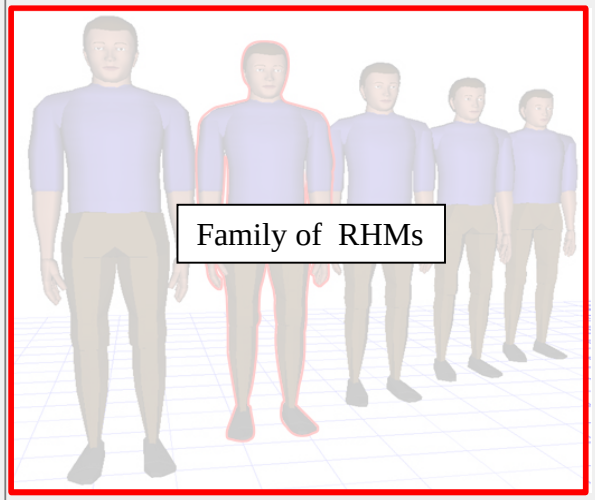
Clustering (Laing et al., 1999)

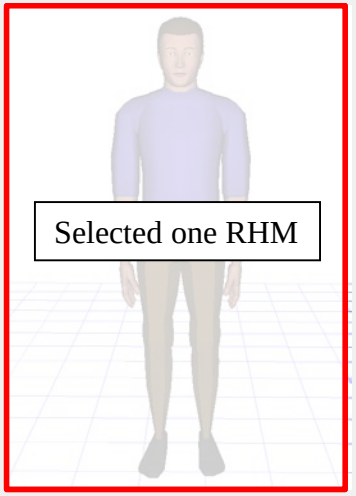
Optimization (McCulloch et al., 1998)

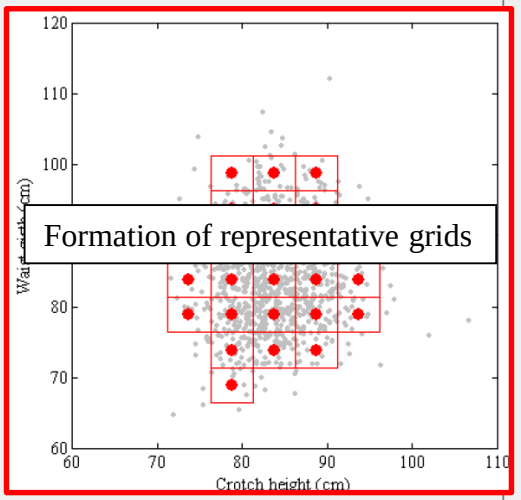
[3] Determination of Body Sizes of RHMs

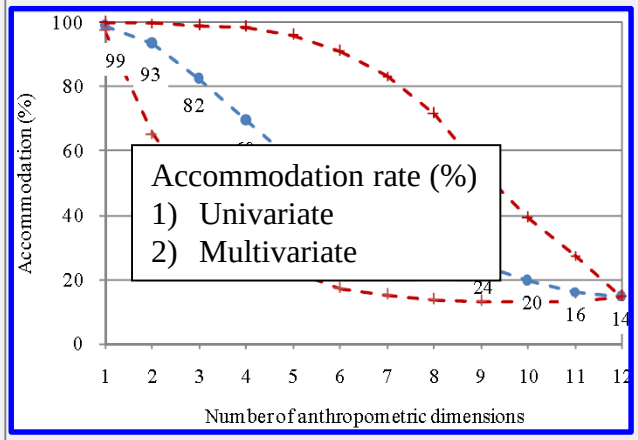
Real Case Estimation

Addition part









Body sizes of RHMs

No	Key dimensions		Non-key anthropometric dimension[b]									
	Crotch height (AD5)	Waist girth (AD7)	Waist height (AD1)	Waist-to-ankle length (AD2)	Waist-to-knee length (AD3)	Outside leg length (AD4)	Crotch length (AD6)	Hip girth (AD8)	Thigh girth (AD9)	Knee girth (AD10)	Calf girth (AD11)	Ankle girth (AD12)
1	73.8 (2)	74.1 (9)	101.0 (1)	94.8 (1)	51.3 (2)	96.8 (1)	69.9 (11)	89.5 (8)	53.5 (11)	35.5 (8)	34.9 (13)	20.7 (14)
2	73.8 (2)	79.1 (25)	101.9 (2)	95.6 (2)	51.8 (3)	97.6 (2)	72.9 (25)	93.0 (19)	56.1 (24)	36.5 (17)	36.0 (24)	21.2 (22)
3	73.8 (2)	84.1 (50)	102.8 (3)	96.4 (3)	52.3 (5)	98.4 (3)	75.8 (44)	96.4 (38)	58.7 (42)	37.5 (31)	37.1 (39)	21.6 (34)
4	78.8 (15)	69.1 (2)	105.2 (7)						51.4 (5)	35.0 (5)	34.2 (8)	20.6 (11)
5	78.8 (15)	74.1 (9)	106.0 (10)						54.0 (13)	36.0 (12)	35.3 (16)	21.0 (19)
6	78.8 (15)	79.1 (25)	106.9 (13)	10					56.6 (27)	37.1 (24)	36.4 (29)	21.5 (29)
7	78.8 (15)	84.1 (50)	107.8 (17)	101.3 (17)	54.6 (21)	103.4 (17)	76.3 (47)	97.4 (44)	59.2 (46)	38.1 (40)	37.5 (45)	21.9 (42)
8	78.8 (15)	89.1 (75)	108.7 (22)	102.1 (22)	55.0 (26)	104.2 (22)	79.2 (68)	100.9 (66)	61.8 (67)	39.1 (59)	38.6 (62)	22.3 (55)
9	78.8 (15)	94.1 (91)	109.6 (27)	102.9 (27)	55.5 (31)	105.1 (27)	82.2 (84)	104.4 (83)	64.4 (83)	40.2 (75)	39.7 (77)	22.8 (68)
10	83.8 (51)	69.1 (2)	110.2 (31)	103.7 (32)	55.5 (32)	105.8 (32)	67.8 (6)	88.0 (5)	51.9 (6)	35.6 (8)	34.6 (10)	20.9 (16)
11	83.8 (51)	74.1 (9)	111.1 (38)	104.5 (38)	56.0 (38)	106.7 (38)	70.8 (14)	91.5 (13)	54.5 (15)	36.6 (18)	35.6 (20)	21.3 (25)
12	83.8 (51)	79.1 (25)	112.0 (44)	105.3 (45)	56.4 (44)	107.5 (45)	73.7 (30)	95.0 (29)	57.1 (30)	37.6 (33)	36.7 (34)	21.7 (37)
13	83.8 (51)	84.1 (50)	112.9 (51)	106.1 (51)	56.9 (51)	108.4 (51)	76.7 (50)	98.4 (50)	59.7 (50)	38.7 (50)	37.8 (50)	22.2 (50)
14	83.8 (51)	89.1 (75)	113.7 (58)	106.9 (57)	57.4 (58)	109.2 (58)	79.7 (71)	101.9 (72)	62.3 (70)	39.7 (68)	38.9 (67)	22.6 (64)
15	83.8 (51)	94.1 (91)	114.6 (64)	107.8 (64)	57.8 (64)	110.0 (64)	82.6 (86)	105.4 (87)	64.9 (86)	40.7 (83)	40.0 (81)	23.1 (75)

Example: Information of grids button Regression equation button

Discussion

- **대표적인 digital human model simulation (DHMS) system의 대표인체모델 생성 인터페이스 특성 종합 및 한계 파악**

  ⇒ 기존 DHMS System의 한계점을 보완하여 시스템 개발에 반영

- **다중치수제품 설계를 위한 산포대표인체모델 생성 및 분석 시스템 개발**
  - ✓ Distributed RHM 생성 절차 및 기법에 적용되는 통계적 기법을 총체적 제공: 시간 ↓
  - ✓ 생성된 distribute RHM의 고급 분석기능(예: accommodation rate 등) 제공

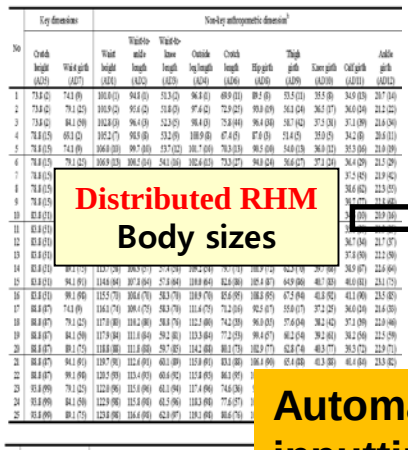
  ⇒ 인간공학적 제품의 치수체계(sizing system) 개발 시 유용하게 활용될 수 있음

- **다양한 인체측정 DB와 연동한 시스템 확장**

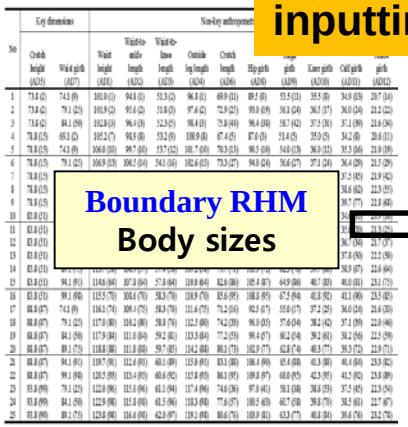
  ⇒ 다양한 제품 설계대상인구(target population)에 대하여 치수체계 설계 가능

Follow-Up Study

1. 주변부대표인체모델(boundary representative human model) 생성 및 분석 시스템 개발
2. DHMS system (예: Jack®, RAMSIS®) RHM 생성 인터페이스와 연동

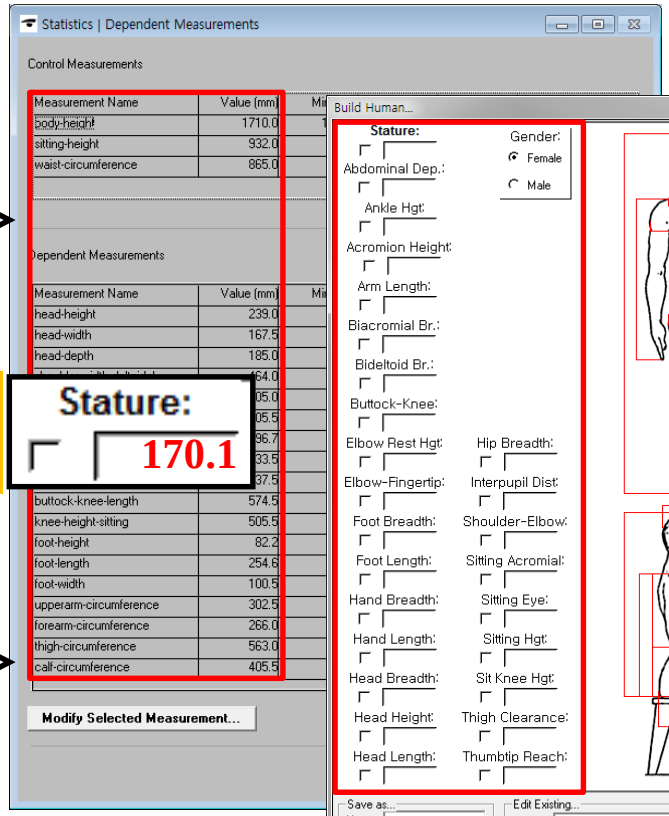


Distributed RHM
Body sizes



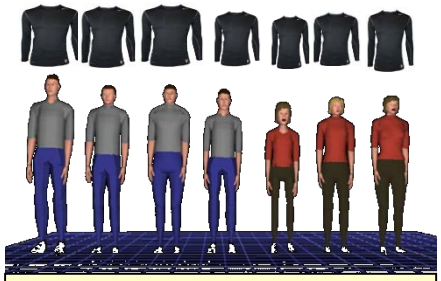
Boundary RHM
Body sizes

Automatic inputting



RAMSIS

Jack



다중치수제품 설계에 활용
(예: 의복, 장갑 등)

단일치수제품 설계에 활용
(예: 자동차, 헬리콥터 등)

Q & A

Thank You ☺