Development of a Generation Method of Digital Human Models with Various Sizes

Ergonomic Design Technology Lab

Heecheon You, Ph.D.

T. Ryu, I. Jung, and K. Kim

Department of Industrial Engineering
Pohang University of Science & Technology

Agenda

- Ergonomic Design with Digital Human Models
- Objectives of the Study
- Generation Method of Digital Human Models
- Web-Based Human Model Generation System
- Discussion

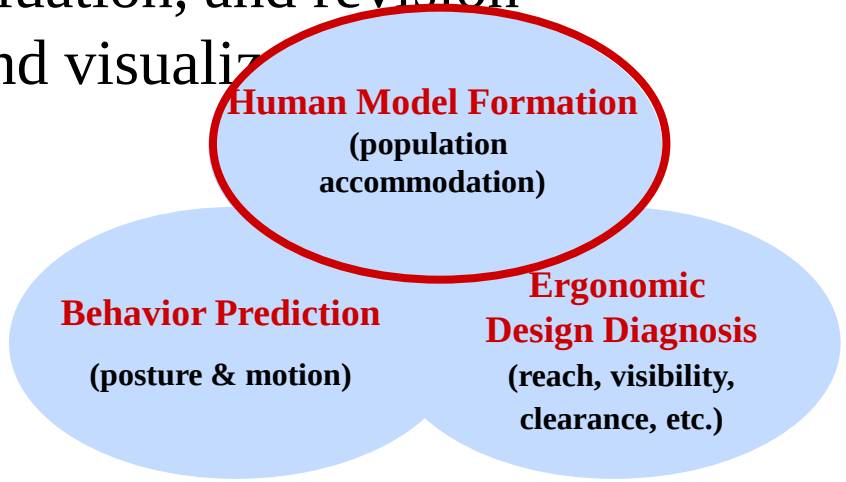
Ergonomic Design with Digital Human Models

JACK™

RAMSIS™

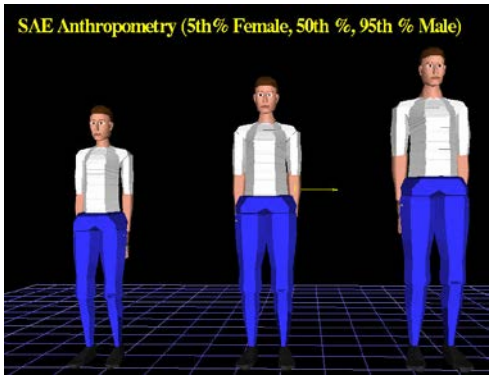
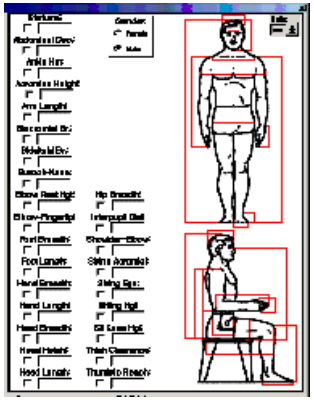
SAFEWORK™

- Benefits
  - Concurrent design, evaluation, and revision
  - Efficient prototyping and visualiz
- Key Ergonomic Issues



Human Model Generation Methods

Ergonomic Design Technology Lab

Conventional Methods		Limitations
Typical human models (5th, 50th, 95th %ile) stored		- Ambiguous in defining the sizes of percentile models in multivariate design context - Lacking representativeness of the population
Customized human models		- Inefficient to input the sizes of the body segments - Not indicate how to form a representative group of human models for the population
Customization (stature, weight) + Body segment sizes estimated by regression models with stature and/or weight		- Not indicate how to form a representative group of human models for the population

Objectives of study

- Develop a method to generate a group of human models in various sizes which statistically represents the target population.

- Develop a generation system of human models in a fast and easy manner.

Generation Procedure of Human Models

Ergonomic Design Technology Lab

Accommodation range (%)

Number of human models (*n*)

S1: Generate pairs of stature and weight

HM_1(stature, weight)

HM_2(stature, weight)

...

HM_n(stature, weight)

S2: Estimate the sizes of the body segments by using hierarchical regression models

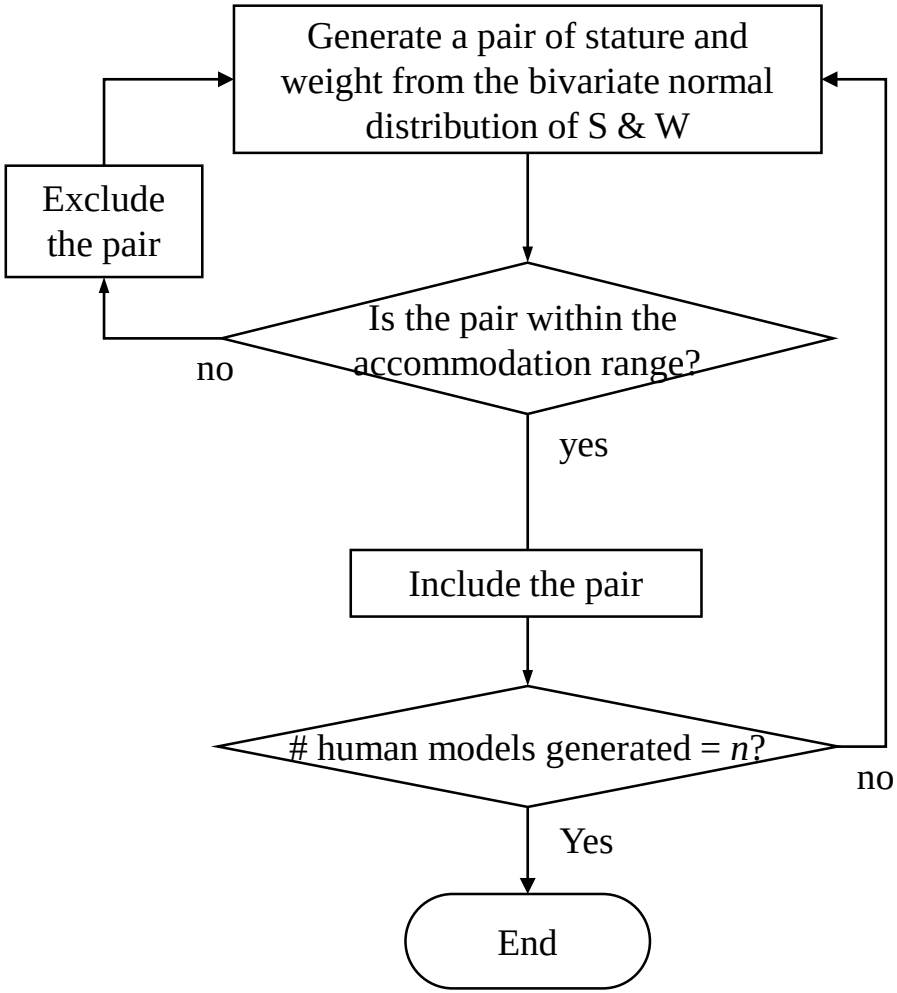
HM_1(acromial height, waist height, ... , sitting height)

HM_2(acromial height, waist height, ... , sitting height)

...

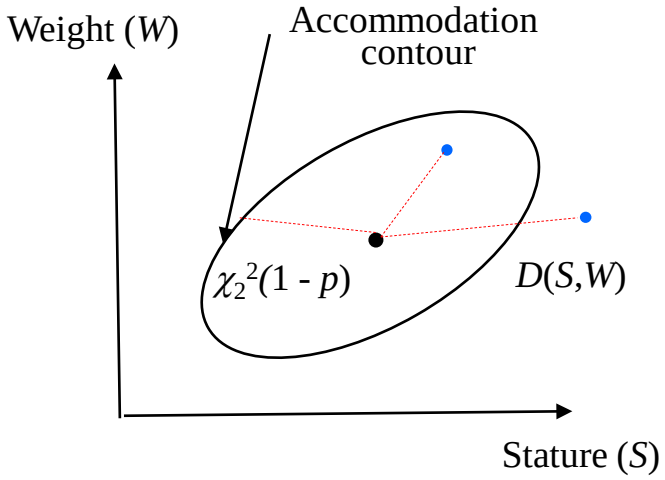
HM_n(acromial height, waist height, ... , sitting height)

S1: Generation of Pairs of Stature and Weight



Normalized squared distance of (S, W)

$$D(S,W) = \begin{pmatrix} S-\mu_s & W-\mu_w \end{pmatrix} \begin{pmatrix} \sigma_s^2 & \sigma_{sw} \\ \sigma_{sw} & \sigma_w^2 \end{pmatrix}^{-1} \begin{pmatrix} S-\mu_s \\ W-\mu_w \end{pmatrix}$$



Generated Pairs of Stature and Weight

- 1988 US Army Anthropometric Survey: 1773 males

S & W ~ bivariate normal distribution

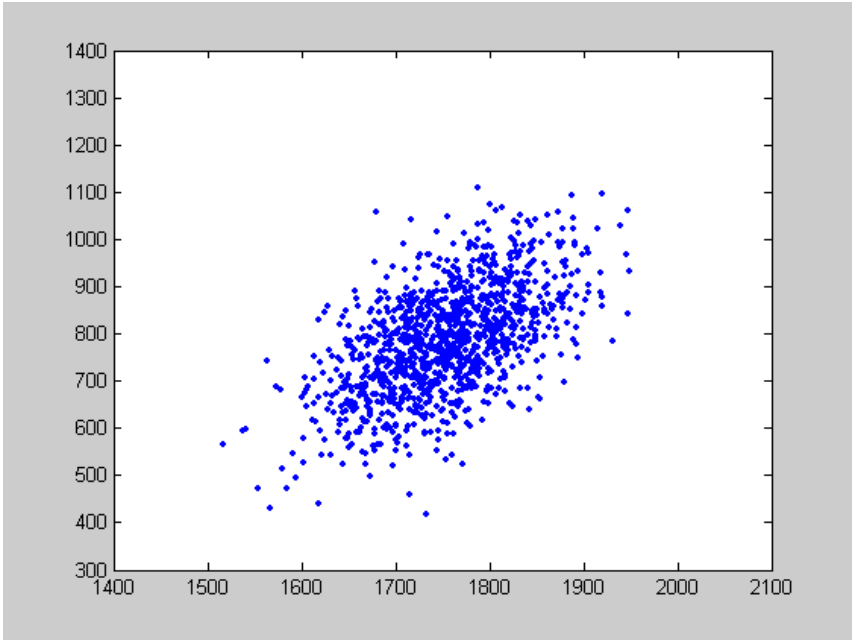
$(\chi_9^2 = 9.66,\ p = 0.379)$

$\mu_S = 175.6\,\text{cm}$ $\mu_W = 78.5\,\text{kg}$ $r_{S,W} = 0.5$

$\sigma_S^2 = 6.7^2$ $\sigma_W^2 = 3.5^2$

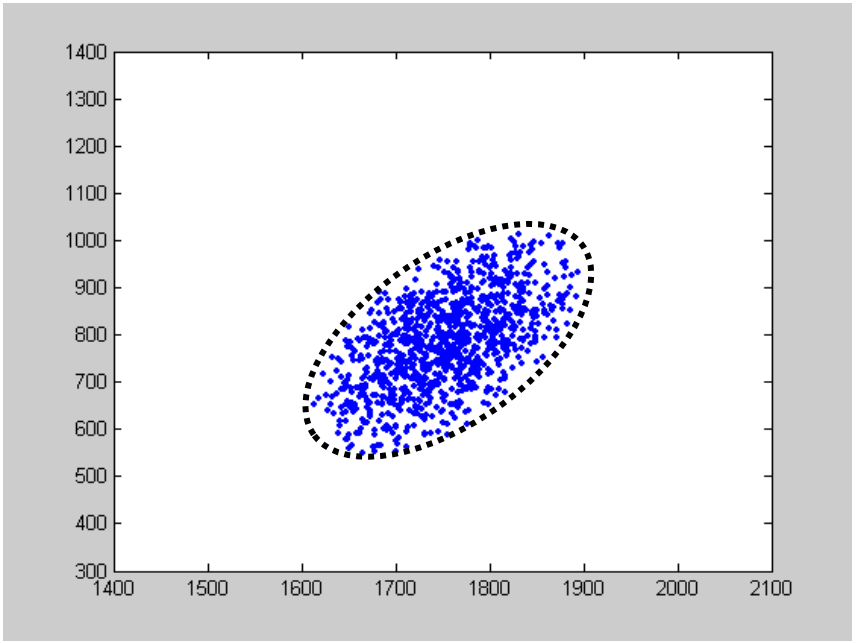
(e.g.) 1000 pairs of S & W within 90% of accommodation range

Weight (10^{-1}kg)



Stature (mm)

Weight (10^{-1}kg)



Stature (mm)

Flat vs. Hierarchical Estimation Methods

Ergonomic Design Technology Lab

Flat estimation

trochanterion height = f_1(stature)

upper leg length = f_2(stature)

knee height at midpatella = f_3(stature)

shank length = f_4(stature)

lateral malleneous height = f_5(stature)

Hierarchical estimation

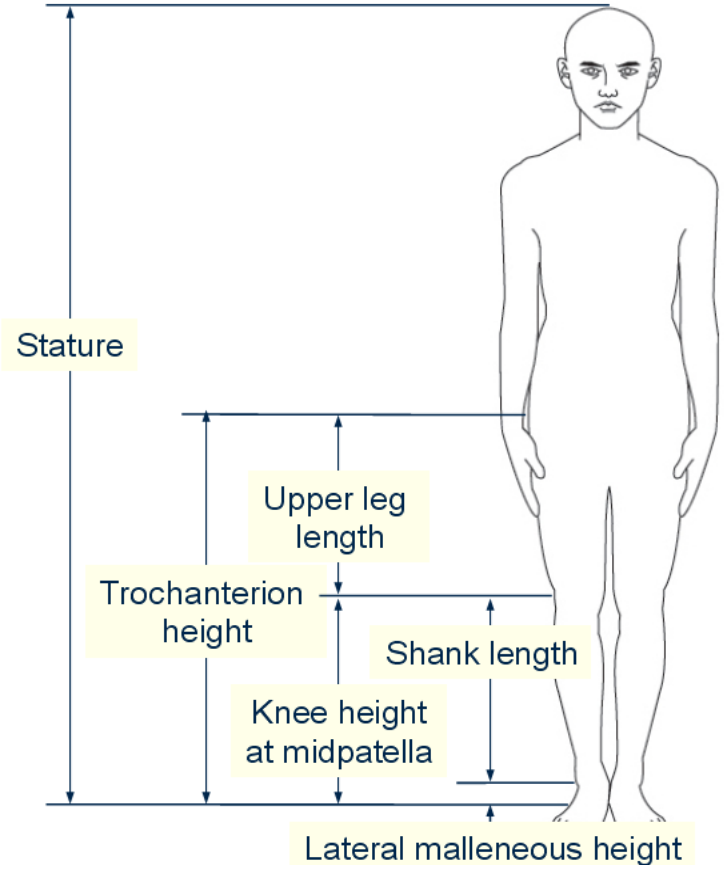
trochanterion height = g_1(stature)

upper leg length = g_2(trochanterion height)

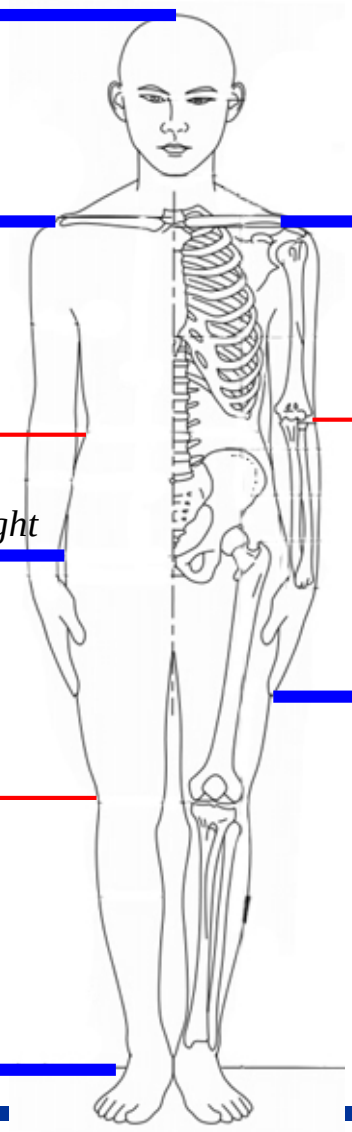
knee height = g_3(trochanterion height)

shank length = g_4(knee height)

lateral malleneous height = g_5(knee height)



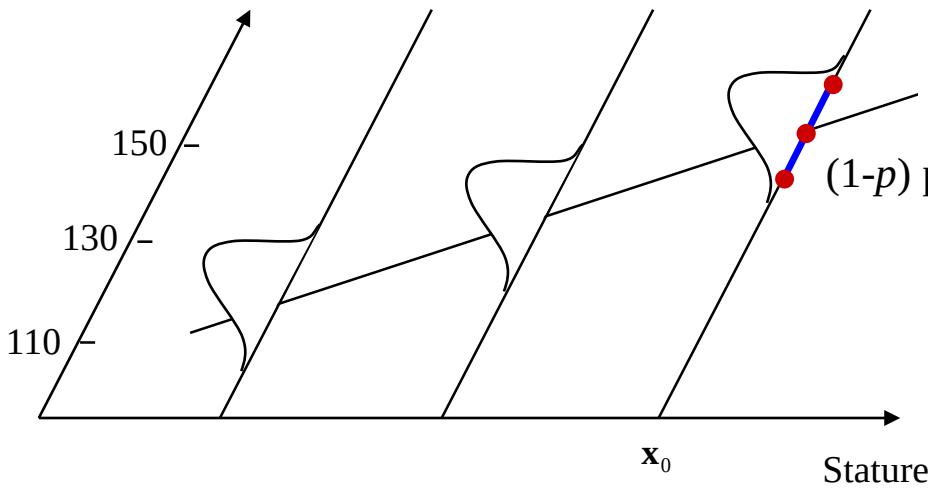
Hierarchical Regression Models (examples)



S2: Estimation of Body Segment Sizes

- By using the sampling distribution of an individual observation for an anthropometric variable (Y) given a value of regressor(s) ($\mathbf{x} = \mathbf{x}_0$), establish a (1-$p$) prediction interval of $Y_{\mathbf{x}=\mathbf{x}_0}$.
- Select a value for Y in the prediction interval at random.

$$Y_{\mathbf{x}=\mathbf{x}_0} \sim N\left(\hat{\boldsymbol{\beta}}'\mathbf{x}_0,\quad MSE\left(1+\mathbf{x}_0'(\mathbf{X}'\mathbf{X})^{-1}\mathbf{x}_0\right)\right)$$



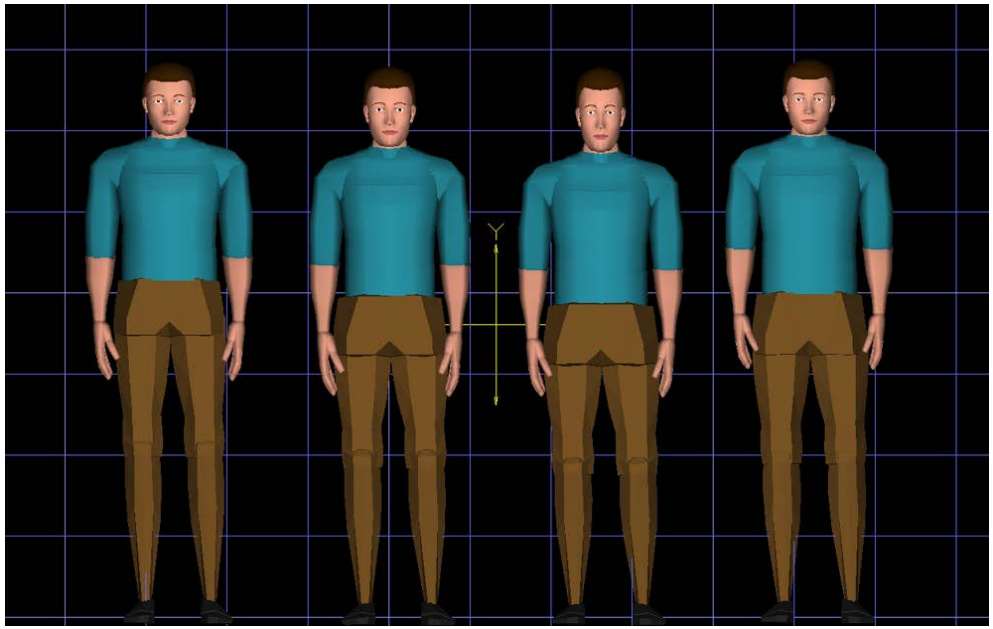
acromial height = -101.311 + 0.863 × stature + 0.036 × weight

(1-p) prediction interval

Generation of Human Models (example)

- Human models of the same stature and weight with various proportions of body segments could be defined.

(e.g.) human models of S = 175.6 cm and W =78.5 kg, having different sizes of body segments



Development of a Human Model Generation System

Ergonomic Design Technology Lab

Web-based user interface (HTML)

59 AVs (selected to design an occupant packaging layout)

1988 US Army anthropometric survey data

Generation of pairs of S & W within a designated accommodation range from the bivariate normal distribution of S & H (Matlab®)

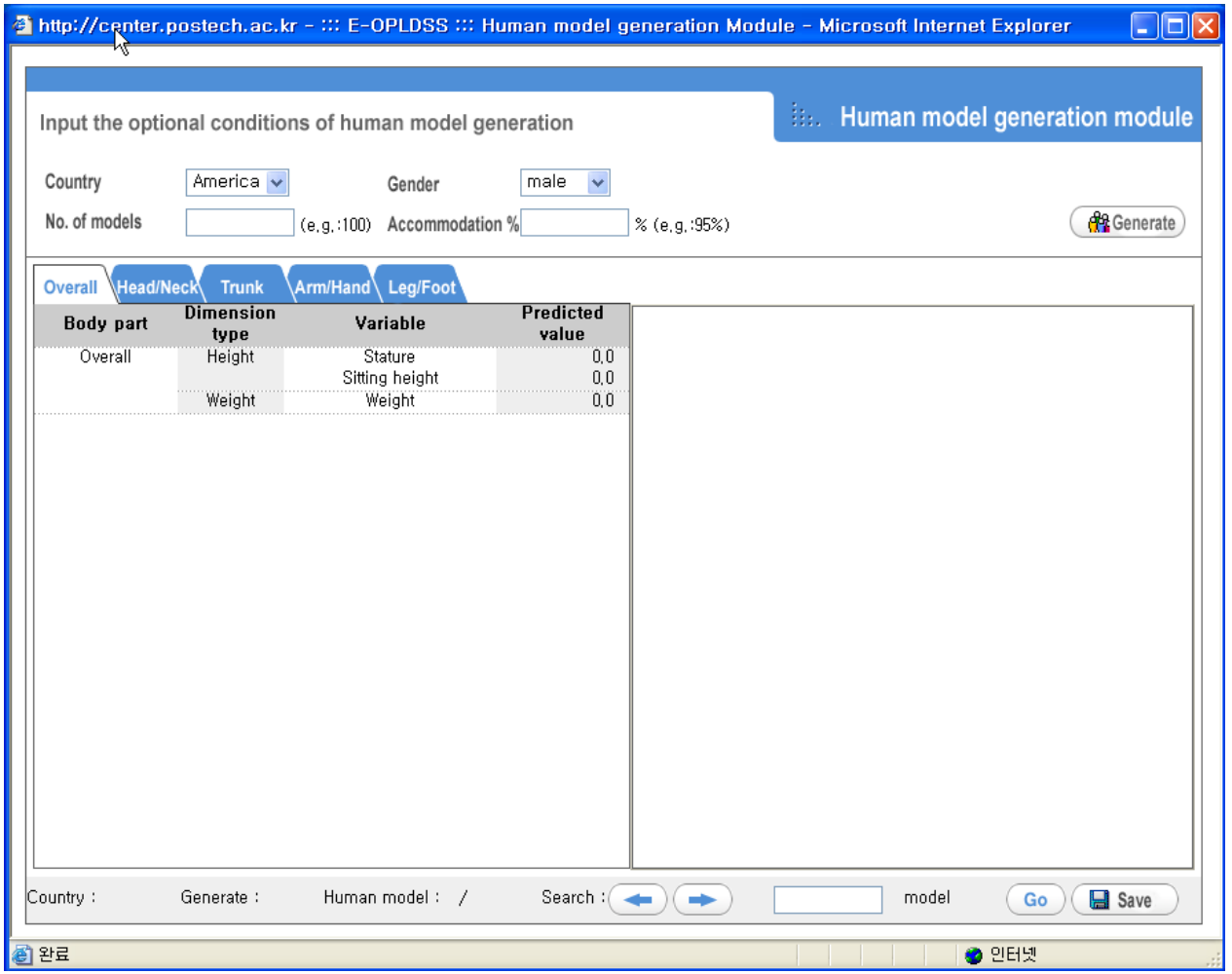
Estimation of the sizes of body segments by using hierarchical regression models (Matlab®)

Visualization of human models in various sizes (VRML)

Web-Based Human Model Generation System

Ergonomic Design Technology Lab

- Simple inputs
  - ✓ Nationality
  - ✓ Gender
  - ✓ # human models
  - ✓ Accommodation %
- Generating human models in a short time
- Easy access to body segment size information
- Visualizing human models
- Saving data in Excel file format for other applications



Discussion

- Developed a method which generates human models having
  - Heights and weights within a designated accommodation range from the corresponding bivariate normal distribution
  - Different proportions of the body segments for the same height and weight by using hierarchical regression models and the corresponding sampling distributions of individual observations

- Developed a web-based system which generates a group of human models which represents the population in terms of height and weight with simple inputs of nationality, gender, accommodation range, and # human models.

- The human model generation system can be of use for ergonomic design and evaluation with digital human models in various sizes to properly accommodate the designated level of the body size variability of the user population.

Q & A