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1969 | 2019
Faculty of Industrial
Design Engineering



DINED: from 1D to 4D Anthropometry

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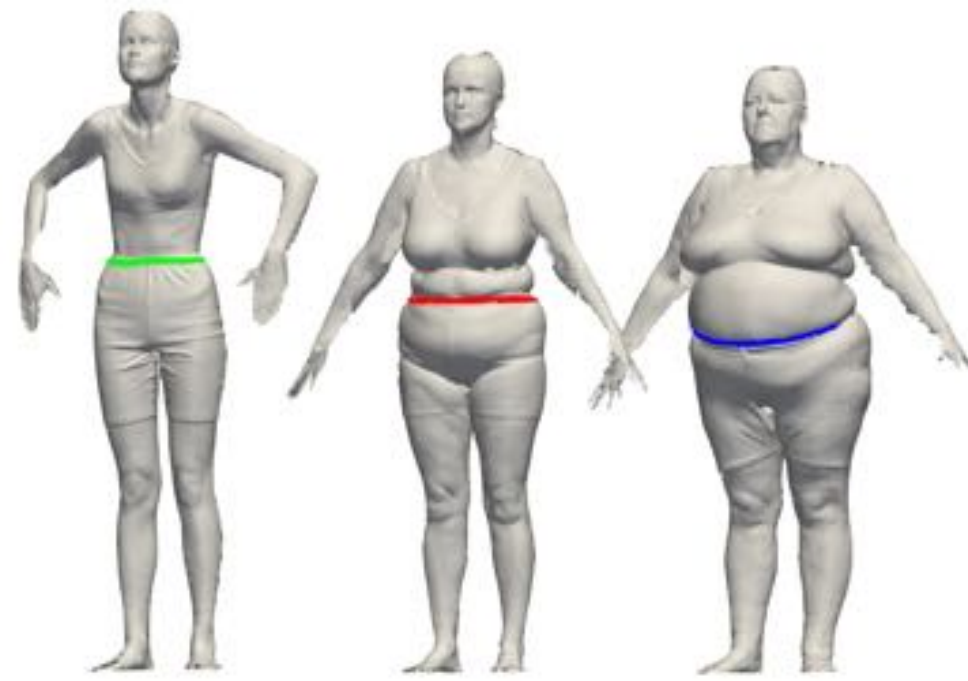
Toon Huysmans, Maxim Smulders, and Johan Molenbroek

3D (and 4D) Anthropometry

- Quick introduction to 3D Anthropometry
- Overview of Dined Mannequin functionality
- Try it out yourself

3D Anthropometry Introduction

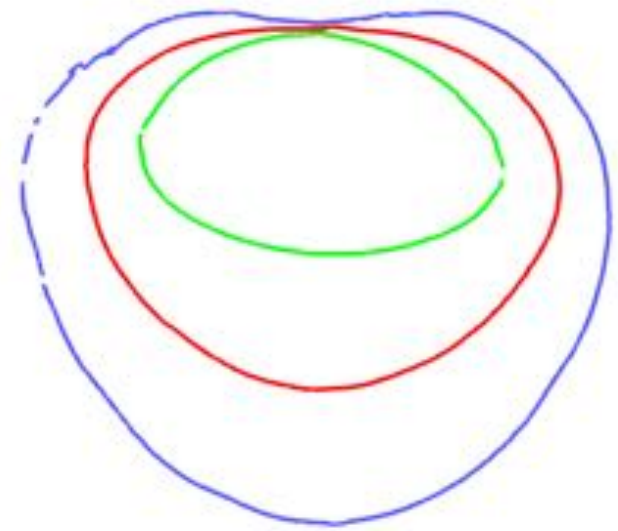
Why 3D Anthropometry



606 mm

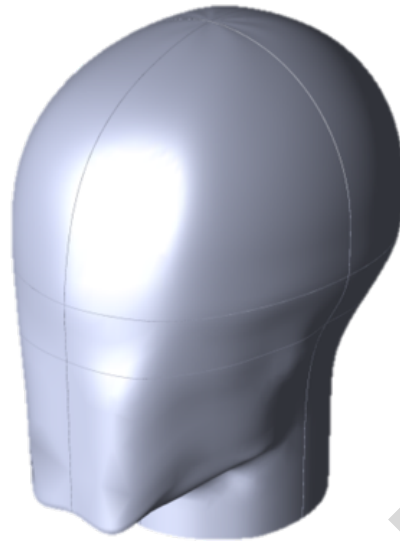
872 mm

1271 mm

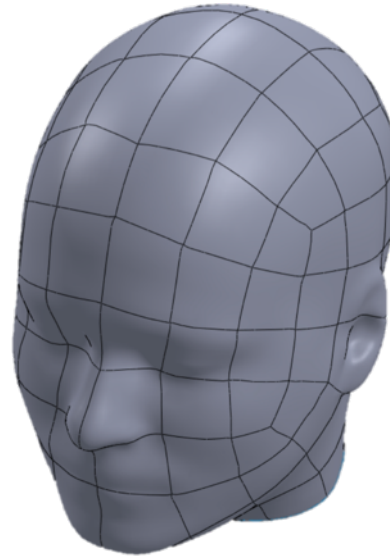


Traditional (1D, 2D) anthropometry poorly represents body shape

Why 3D Anthropometry



EN960 manikin



full 3D manikin



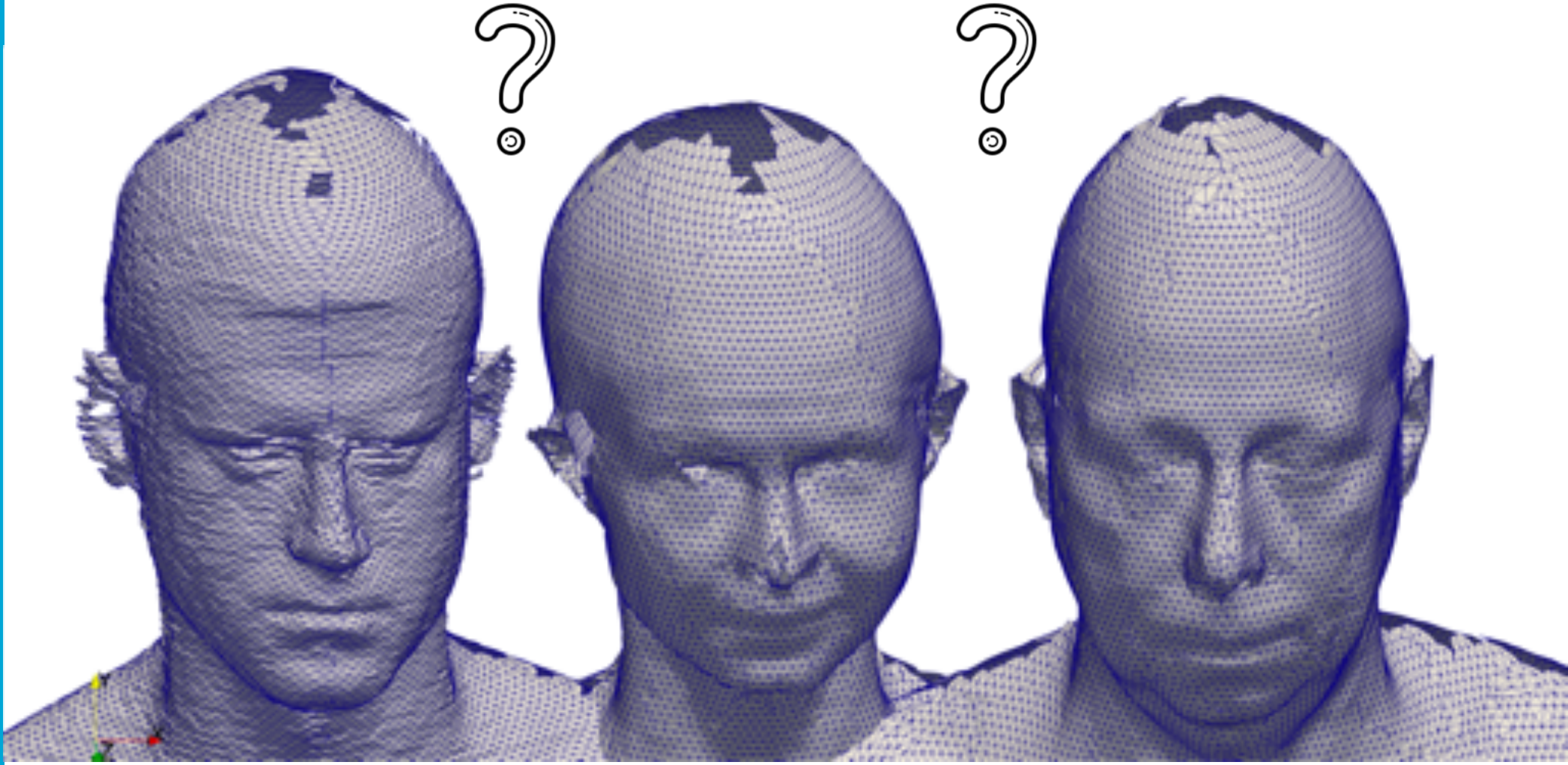
traditional manikin



full 3D manikin

3D Scanning Demo

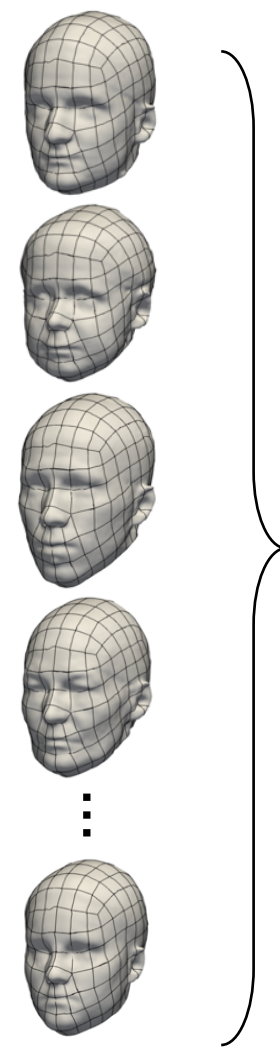
Working with 3D Scans is Challenging



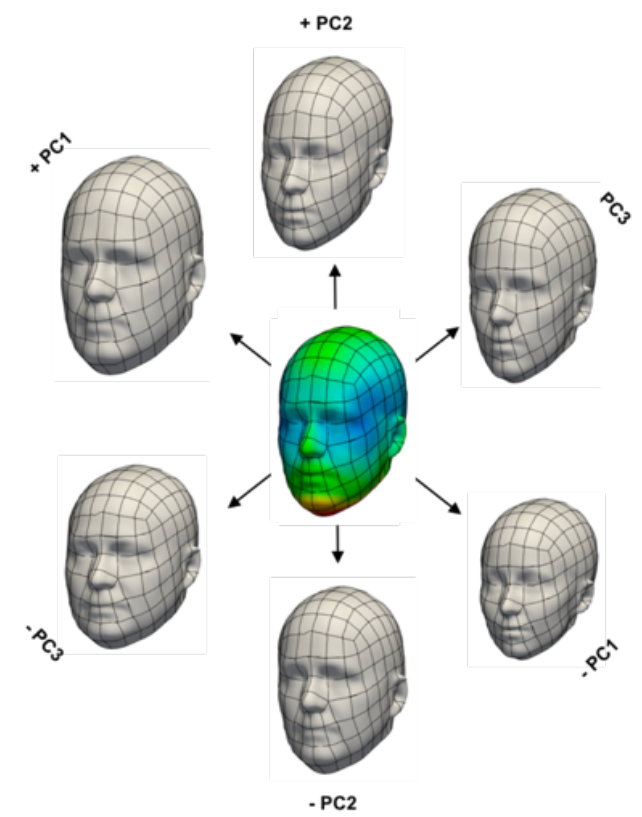
3D Anthropometry Web Platform: Dined Mannequin



Anthropometric Statistical Shape Modeling



population sample



$$\Theta = \bar{\Theta} + \sum_{i=1}^{n_s-1} w_i \ddot{\Theta}_i \longrightarrow$$

B-spline statistical shape model



subject features

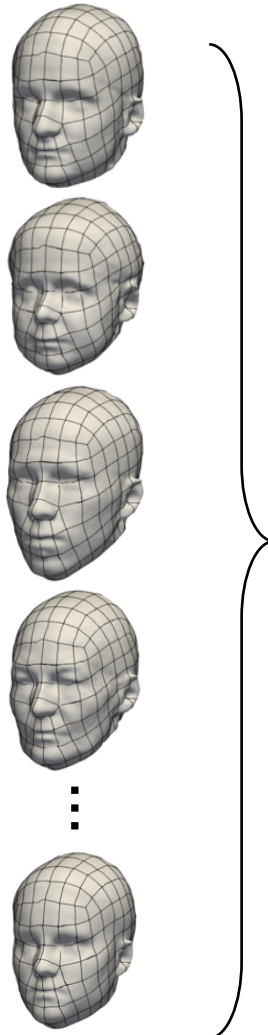
	A	B	C	D
1	bizygomatic breadth	face length	head breadth	head circumference
2	124	103	138	529
3	132	106	149	541
4	120	117	147	559
5	130	108	143	538
6	126	108	143	552
7	131	108	143	532
8	140	108	144	538
9	133	107	146	547
10	143	114	155	583
11	135	102	145	544

$$\Pi[f_1 \dots f_{n_f} 1]^T = \mathbf{w}_i .$$

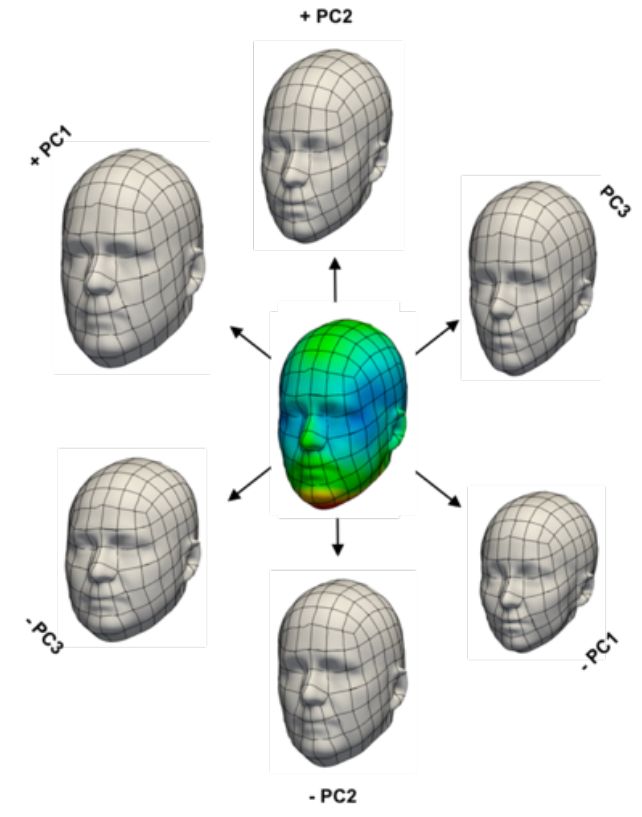


$$\Theta(f_1, \dots, f_{n_f}) = \bar{\Theta} + \ddot{\Theta} \Pi[f_1 \dots f_{n_f} 1]^T$$

Anthropometric Statistical Shape Modeling



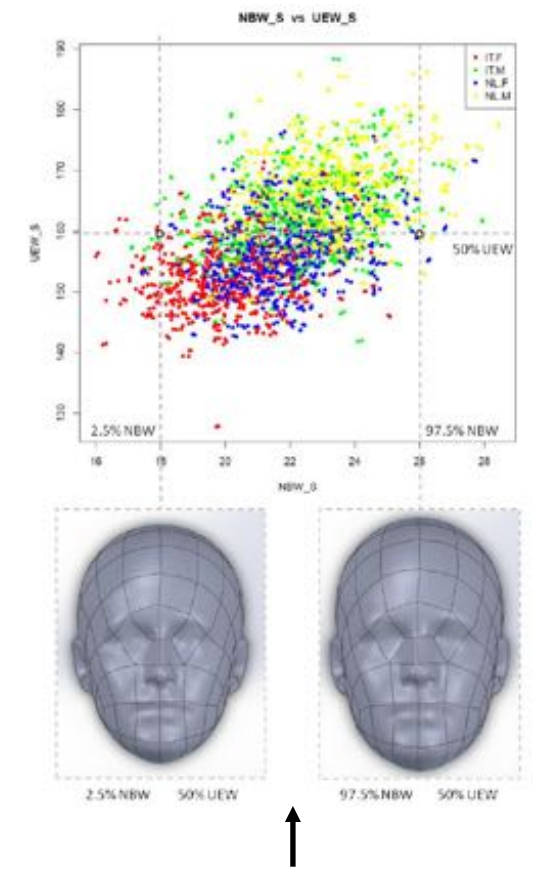
population sample



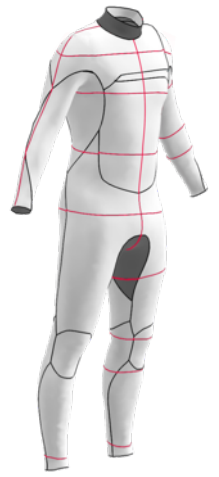
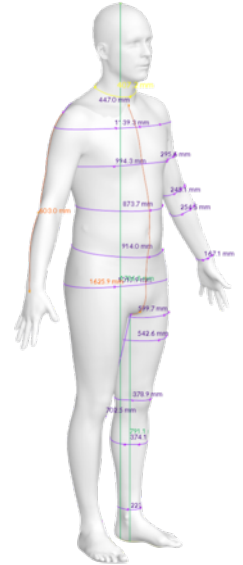
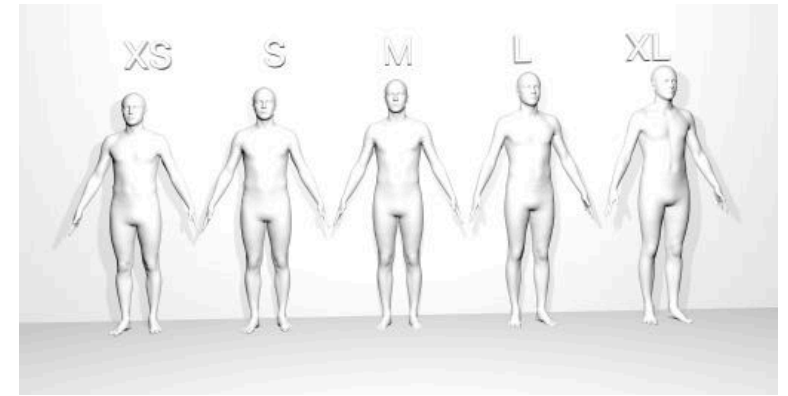
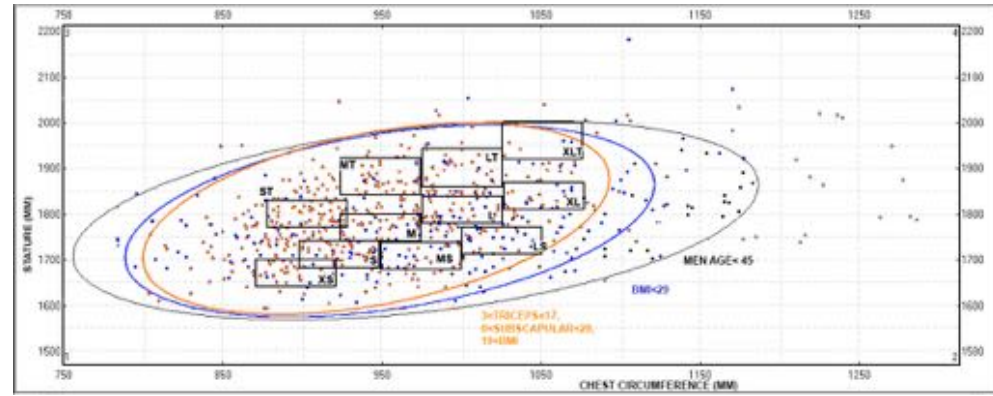
$$\Theta = \bar{\Theta} + \sum_{i=1}^{n_s-1} w_i \ddot{\Theta}_i \longrightarrow$$

$$\Theta(f_1, \dots, f_{n_f}) = \bar{\Theta} + \ddot{\Theta} \Pi [f_1 \dots f_{n_f} 1]^T$$

B-spline statistical shape model



Wetsuit Design: 3D Anthropometric Approach



PATTERN



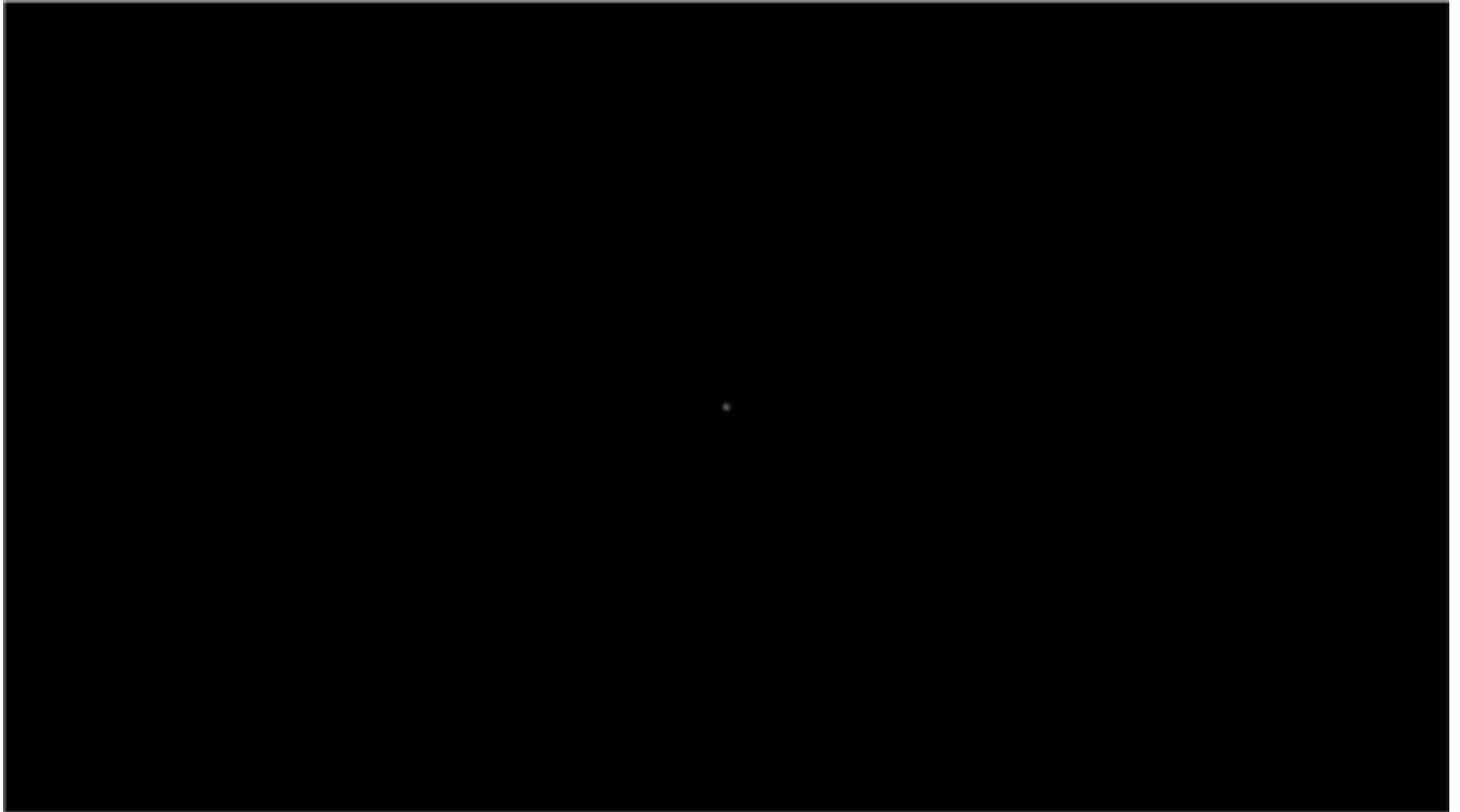
DIGITAL OPTIMIZATION



PHYSICAL PROTOTYPE

DESIGN FOR OUR FUTURE

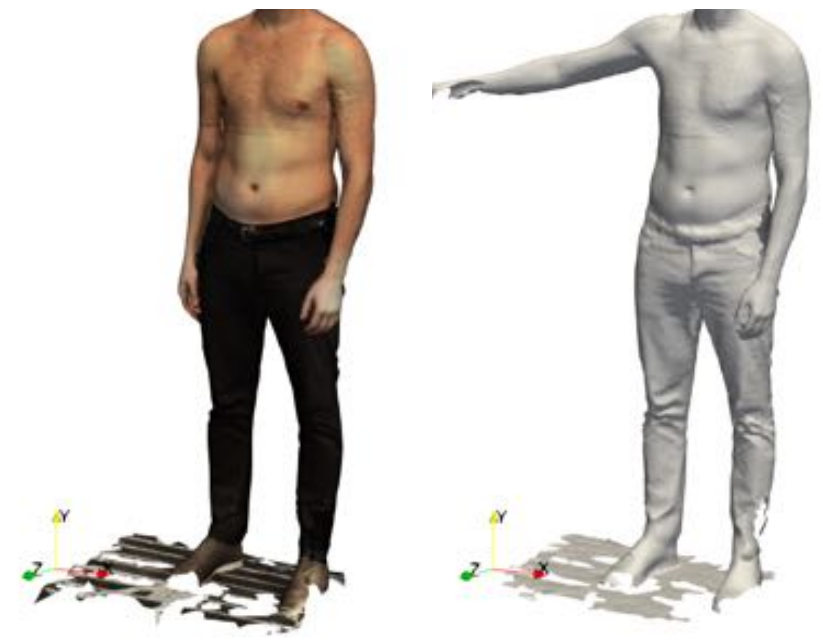
Wetsuit Design: Incorporating Motion (4D)



Future: Dynamic (4D) Anthropometry



Our 4D scanning facility



Dined Mannequin Functionality

3D Anthropometry Web Platform: Dined Mannequin



The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. The main content area is divided into a table of measurements and a scatter plot.

Measure	Persona 1	Persona 2	Persona 3
Body mass	70 kg	70 kg	70 kg
Stature	1700 mm	1700 mm	1700 mm
Waist circumference	890 mm	840 mm	980 mm

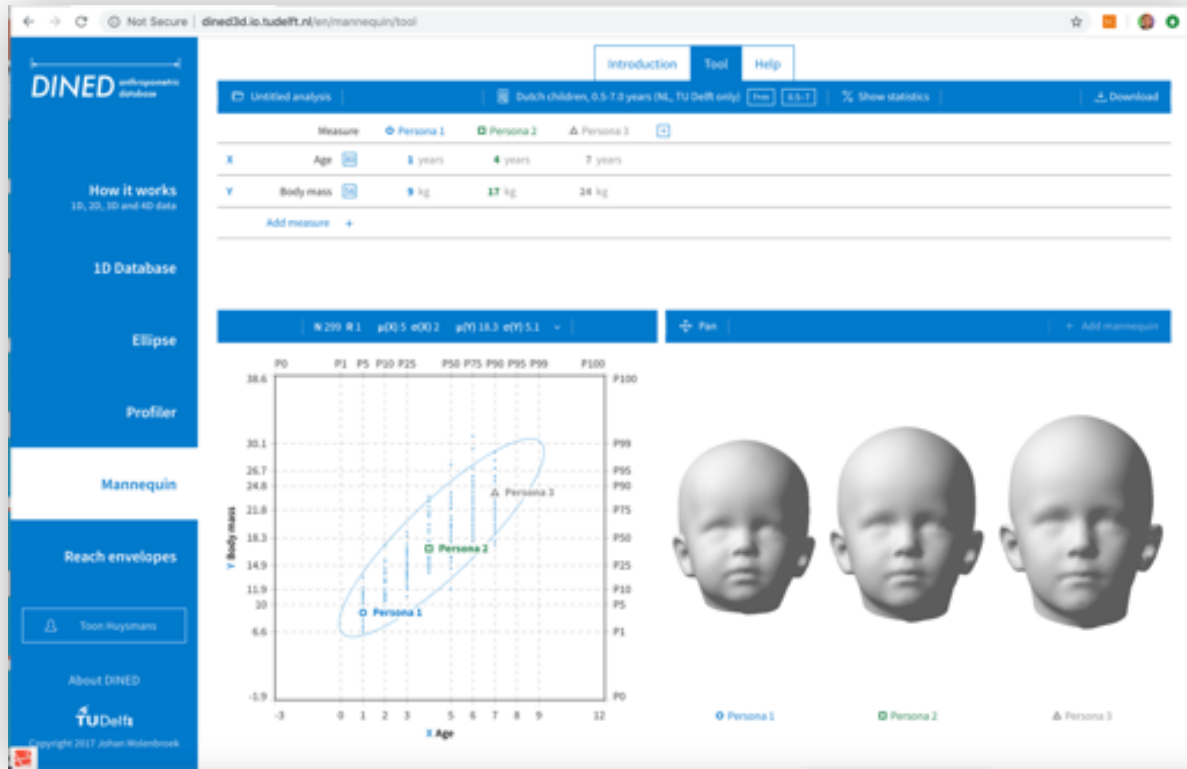
The scatter plot shows 'Waist circumference' on the y-axis (ranging from 544 to 1362) and 'Body mass' on the x-axis (ranging from 12.1 to 122.8). A blue ellipse highlights a cluster of data points. Three specific personas are marked: Persona 1 (blue circle), Persona 2 (green square), and Persona 3 (red triangle).

Below the plot, three 3D mannequin models are shown, each labeled with a persona name: Persona 1 (blue), Persona 2 (green), and Persona 3 (red).

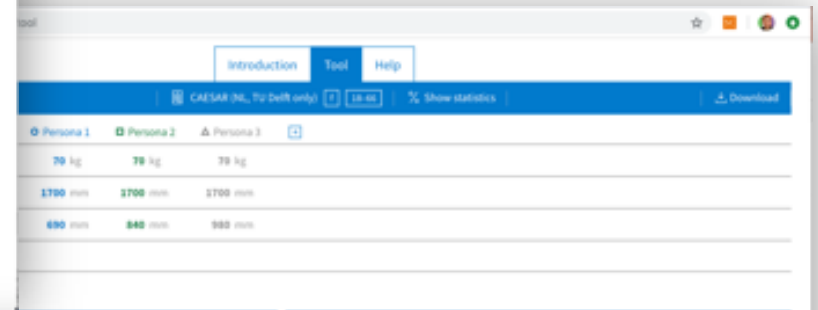
The 'Population Selection' dialog box is open, showing the following options:

- Dataset: CAESAR (NL, TU Delft only)
- Age: 18-66
- Sex: Female (selected)
- Default ranges: 18-66
- Custom range: 18 to 66

Population Selection



Goto, L., Lee, W., Molenbroek, J. F., Cabo, A. J., & Goossens, R. H. (2019). **Traditional and 3D scan extracted measurements of the heads and faces of Dutch children.** International Journal of Industrial Ergonomics, 73, 102828.



Robinette, K. M., Daanen, H., & Paquet, E. (1999, October). **The CAESAR project: a 3-D surface anthropometry survey.** In Second International Conference on 3-D Digital Imaging and Modeling (Cat. No. PR00062) (pp. 380-386). IEEE.



The screenshot shows the DINED software interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header bar with 'Untitled analysis', 'CAESAR (NL, TU Delft only)', '18-48', 'Show statistics', and 'Download'. The main content area features a table with the following data:

Measure	Persona 1	Persona 2	Persona 3
X Body mass	70 kg	70 kg	70 kg
Stature	1700 mm	1700 mm	1700 mm
Y Waist circumference	690 mm	840 mm	980 mm

Below the table is a scatter plot of 'Waist circumference' (Y-axis, 327 to 1145) versus 'Body mass' (X-axis, 12.1 to 133.4). A blue ellipse encloses a cluster of data points, with three specific points labeled: 'Persona 1' (blue circle), 'Persona 2' (green square), and 'Persona 3' (grey triangle). To the right of the plot are three 3D manikin models, each labeled with its corresponding persona: 'Persona 1' (blue circle), 'Persona 2' (green square), and 'Persona 3' (grey triangle).

Measures Selection and Manikin Definition

The screenshot shows the DINED web application interface. The top navigation bar includes 'Introduction', 'Tool', and 'Help'. Below this is a toolbar with 'Untitled analysis', 'CAESAR (NL, TU Delft only)', 'Free', '18-44', 'Show statistics', and 'Download'. The main content area features a 'Measure' dropdown menu with the following categories and items:

- Standing, length/depth
 - 1 Reach height, standing
 - 2 Stature
 - 3 Eye height, standing
 - 4 Shoulder height
- Standing, width/circumference
- Sitting, length/width/depth
- Head
- Hand
- Foot
- Joint excursion
- Force exercise
- Other

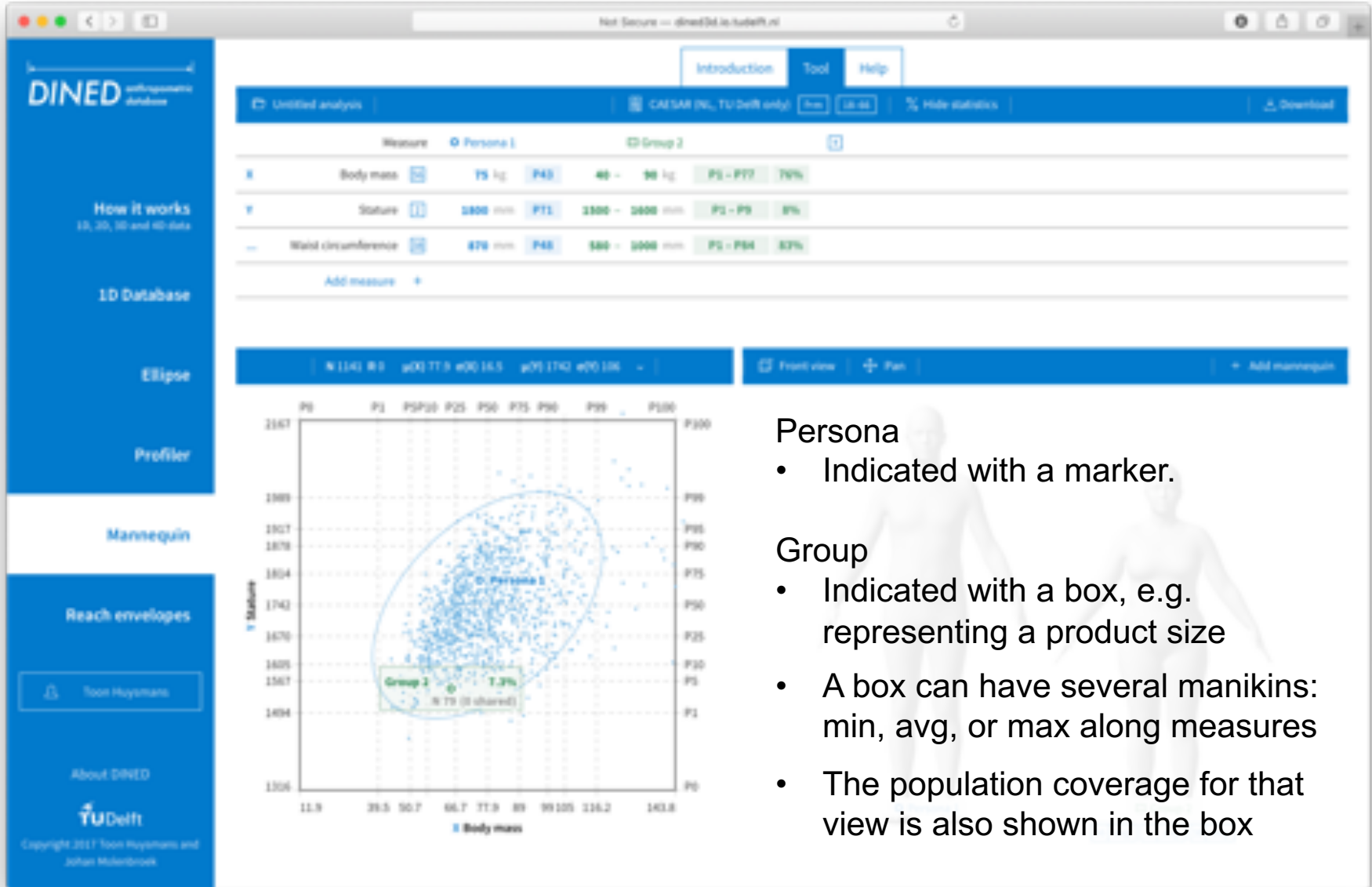
Below the menu, there are two instructions: 'Select a population and two measures to plot.' and 'Add a persona or group, measures, and data to see a 3D mannequin.' A small 3D mannequin icon is visible in the bottom right of the main area.

Typically 1-4 critical measures are selected

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header bar with 'Unclassified analysis', 'CAESAR (NL, TU Delft only)', 'Free', '18-44', 'Show statistics', and 'Download'. A 'Measure' section lists 'Body mass', 'Stature', and 'Waist circumference', with 'Add persona' and 'Add group' buttons. A scatter plot displays 'Stature' on the y-axis (ranging from 1506 to 2167) and 'Body mass' on the x-axis (ranging from 11.9 to 143.8). The plot shows a dense cloud of blue data points with a blue oval highlighting a central region. To the right of the plot is a 3D mannequin icon and the text 'Add a persona or group, measures, and data to see a 3D mannequin.' The left sidebar contains navigation links: 'How it works', '1D Database', 'Ellipse', 'Profiler', 'Mannequin', and 'Reach envelopes'. The bottom of the sidebar includes 'About DINED', 'TU Delft', and 'Copyright 2017 Toon Huysmans and Johan Mulderbroek'.

A number of personas or groups can be added





Persona

- Indicated with a marker.

Group

- Indicated with a box, e.g. representing a product size
- A box can have several manikins: min, avg, or max along measures
- The population coverage for that view is also shown in the box

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header for 'Untitled analysis' and 'CAESAR (NL, TU Delft only)'. A table displays measurement data for two groups:

Measure	Person 1	Group 2
Body mass	75 kg (P43)	48 - 98 kg (P1 - P17) 79%
Stature	1800 mm (P11)	1500 - 2000 mm (P2 - P9) 8%
Waist circumference	870 mm (P43)	580 - 1000 mm (P1 - P84) 57%

Below the table, there is a '3D Manikin' section. It features a scatter plot of 'Stature' (y-axis, 1506 to 2167) versus 'Body mass' (x-axis, 11.9 to 143.8). A large blue oval represents 'Person 1' (N 114) and a smaller green oval represents 'Group 2' (N 79 (3 shared)). To the right of the plot are two 3D manikin models: a male model labeled 'Person 1' and a female model labeled 'Group 2'. Below the female model are buttons for '3D Avg', '1 Avg', and '25 Avg'.

Complete measurement data to generate 3D Manikin

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a table of measurements for three personas:

Measure	Persona 1	Persona 2	Persona 3
Body mass	70 kg	70 kg	70 kg
Stature	1700 mm	1700 mm	1700 mm
Waist circumference	890 mm	840 mm	980 mm

Below the table is a scatter plot showing the relationship between 'X Body mass' and 'Y Waist circumference'. The plot includes a blue ellipse representing the population distribution and three specific data points labeled 'Persona 1' (blue circle), 'Persona 2' (green square), and 'Persona 3' (grey triangle). The plot axes are labeled with percentiles (P0 to P100) and numerical values. The plot statistics are: N 622, R 1, $\mu(X) 72.8$, $\sigma(X) 15.2$, $\mu(Y) 844$, $\sigma(Y) 129$.

To the right of the scatter plot, three 3D mannequin models are shown, representing the physical forms of the three personas.

Population Exploration via Scatter Plotting



The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header bar with 'Untitled analysis', 'CAESAR (NL, TU Delft only)', 'Free', '18-00', 'Hide statistics', and 'Download'.

The main content area is divided into two sections. The top section is a table with columns for 'Measure', 'Person 1', and 'Group 2'. The table contains three rows of data:

Measure	Person 1	Group 2
Body mass	75 kg (P43)	48 - 98 kg (P1 - P77) 76%
Stature	1806 mm (P11)	1500 - 2000 mm (P2 - P9) 8%
Waist circumference	876 mm (P45)	580 - 600 mm (P2 - P5) 0%

Below the table is a 'Add measure' button. The bottom section of the interface features a scatter plot of 'Stature' (Y-axis) versus 'Body mass' (X-axis). The plot includes a blue ellipse representing a confidence interval. A panel menu is overlaid on the plot, providing the following information:

- Population:** Sample size: 1140, Correlation coefficient: 0.458
- Measure:** Mean, Std. deviation
- X Body mass:** 77.9 kg, 16.5 kg
- Y Stature:** 1742 mm, 106 mm
- Ellipse:** Confidence interval: 95%

Below the plot, there are two 3D mannequins: 'Person 1' (male) and 'Group 2' (female). The 'Group 2' mannequin has a control panel with buttons for '1806 mm', '876 mm', and '75 kg'.

Additional sample info is available via the panel menu

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a table of measurements for three personas:

Measure	Persona 1	Persona 2	Persona 3
Body mass	70 kg	70 kg	70 kg
Stature	1700 mm	1700 mm	1700 mm
Waist circumference	890 mm	840 mm	980 mm

Below the table is a scatter plot with 'Waist circumference' on the y-axis and 'Body mass' on the x-axis. The plot shows a distribution of data points with an ellipse overlaid. Three specific points are highlighted: 'Persona 1' (blue circle), 'Persona 2' (green square), and 'Persona 3' (red triangle).

To the right of the scatter plot is a 3D visualization of three manikins, labeled 'Persona 1', 'Persona 2', and 'Persona 3'. Above the manikins is a 'Rotate' button and an 'Add mannequin' button.

Visualisation of 3D Manikins



The screenshot shows the DINED software interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header bar with 'Untitled analysis', 'CAESAR (NL, TU Delft only)', 'Free', 'Log out', 'Hide statistics', and 'Download'.

The main data table is as follows:

Measure	Persona 1	Group 2
Body mass	75 kg, P43	40 - 90 kg, P1 - P77, 79%
Stature	1800 mm, P11	1500 - 2000 mm, P2 - P9, 9%
Waist circumference	870 mm, P43	580 - 600 mm, P3 - P5, 0%

Below the table is a scatter plot of 'Stature' (Y-axis, 1500-2100 mm) vs 'Body mass' (X-axis, 11.9-143.8 kg). A large blue oval encloses the main data cluster, labeled 'Persona 1'. A smaller green oval encloses a specific data point, labeled 'Group 2' with 'N: 79 (1 shared)' and '7.3%'. The plot has a grid with labels P0 through P100 on both axes.

To the right of the plot are two 3D mannequin models. The first is labeled 'Persona 1' and the second is labeled 'Group 2'. A 'Rotate' button is positioned between them. Below the 'Group 2' mannequin are several small icons representing different views or settings.

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header for 'Untitled analysis' with a 'CAESAR (NL, TU Delft only)' logo and a 'Download' button. The main content area is divided into two columns: 'Person 1' and 'Group 2'. A table compares various measures between these two groups.

Measure	Person 1	Group 2
Body mass	75 kg (P43)	46 - 98 kg (P1 - P77) 79%
Stature	1806 mm (P11)	1500 - 2000 mm (P2 - P9) 9%
Waist circumference	876 mm (P45)	580 - 600 mm (P2 - P5) 0%

Below the table is a 'Top view' visualization. It features a scatter plot of 'Stature' (y-axis, 1506 to 2167) versus 'Body mass' (x-axis, 11.9 to 143.8). A large blue oval represents 'Person 1' (N 1141) and a smaller green oval represents 'Group 2' (N 79 (1 shared)). To the right of the plot are two 3D mannequin models, one for 'Person 1' and one for 'Group 2', showing their top-down view. The 'Group 2' model is significantly smaller and rounder than the 'Person 1' model.

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header for 'Untitled analysis' with options for 'CAESAR (NL, TU Delft only)', 'Free', 'Log out', 'Hide statistics', and 'Download'.

A table displays data for two groups:

Measure	Person 1	Group 2
Body mass	75 kg, P43	46 - 98 kg, P1 - P77, 76%
Stature	1806 mm, P11	1500 - 2008 mm, P2 - P9, 8%
Waist circumference	876 mm, P45	580 - 608 mm, P2 - P5, 0%

Below the table is a scatter plot of 'Stature' (Y-axis, 1506 to 2167) versus 'Body mass' (X-axis, 11.9 to 143.8). A blue oval highlights 'Person 1' at approximately (75, 1806). A green oval highlights 'Group 2' at approximately (75, 1600), with a note 'N 79 (shared)' and '7.3%'. The plot also shows a grid of percentile markers (P0 to P100) for both axes.

To the right of the plot are four 3D mannequins representing different body types. A tooltip for 'Group 2' states: 'Note: you can only add extra mannequins for groups as a person can't result in different mannequins.' Below the mannequins are controls for 'Person 1' and three 'Group 2' entries, each with a 'Add mannequin' button.

Additional manikins can be added to a group

The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a header bar with 'Untitled analysis', 'CAESAR (NL, TU Delft only)', 'Free', 'Use it', 'Hide statistics', and 'Download'. The main content area is divided into two sections. The top section, titled 'Your analyses', contains a table with the following data:

Name	Measures	Last saved	Actions
Untitled analysis	Body mass, Stature, Waist circumference	2019-09-29	Save Revert ...
Untitled analysis	Stature, Body mass	2019-09-29	...
Untitled analysis	Body mass, Stature	2019-09-17	...
Untitled analysis	Stature	2019-09-04	...
Untitled analysis	Body mass, Stature	2019-09-04	...

The bottom section of the main content area displays a scatter plot of 'Stature' (Y-axis, ranging from 1506 to 2167) versus 'Body mass' (X-axis, ranging from 11.9 to 143.8). A blue oval highlights a cluster of points labeled 'Persona 1'. A green box highlights a smaller cluster of points labeled 'Group 2' with 'N: 79 (3 shared)' and '7.3%'. To the right of the plot are four 3D mannequin models representing different body types, with a legend below them identifying 'Persona 1' and 'Group 2'.

Saving Analyses



The screenshot shows the DINED web application interface. At the top, there are navigation tabs for 'Introduction', 'Tool', and 'Help'. Below this is a 'Unified analysis' section with a 'CAESAR (NL, TU Delft only)' label and a 'Hide statistics' button. A table displays data for two groups:

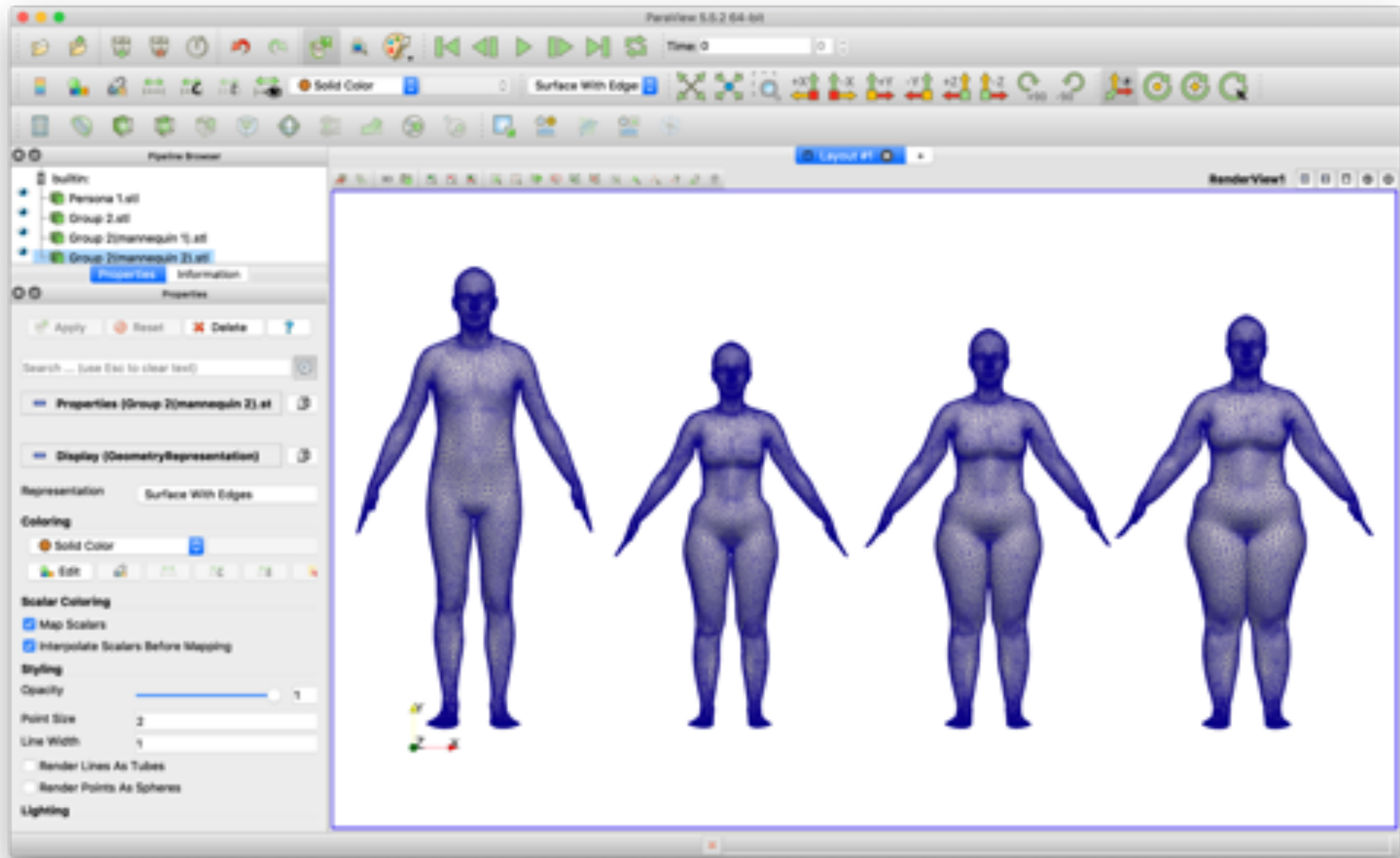
Measure	Persona 1	Group 2
Body mass	75	89 (118.7%)
Stature	1800 mm	1800 - 1800 mm
Waist circumference	870 mm	880 - 880 mm

Below the table is a scatter plot of 'Stature' (y-axis, 1306 to 2167) versus 'Body mass' (x-axis, 11.9 to 143.8). The plot shows two clusters: 'Persona 1' (blue) and 'Group 2' (green). A 'Download' button is visible in the top right corner of the interface.

Overlaid on the screenshot is a large white text box with the text: **Download STL-files of 3D Manikins**. To the right of this text is a smaller white box containing a 'Download' button and a 'Data Table' button. Below these buttons is a text prompt: 'Download all your manikins in STL format.' and another 'Download' button.

At the bottom of the interface, there are four 3D manikin models representing different body types, labeled 'Persona 1' and 'Group 2'.





Dined Mannequin Try It Yourself

Try Out Dined Mannequin!



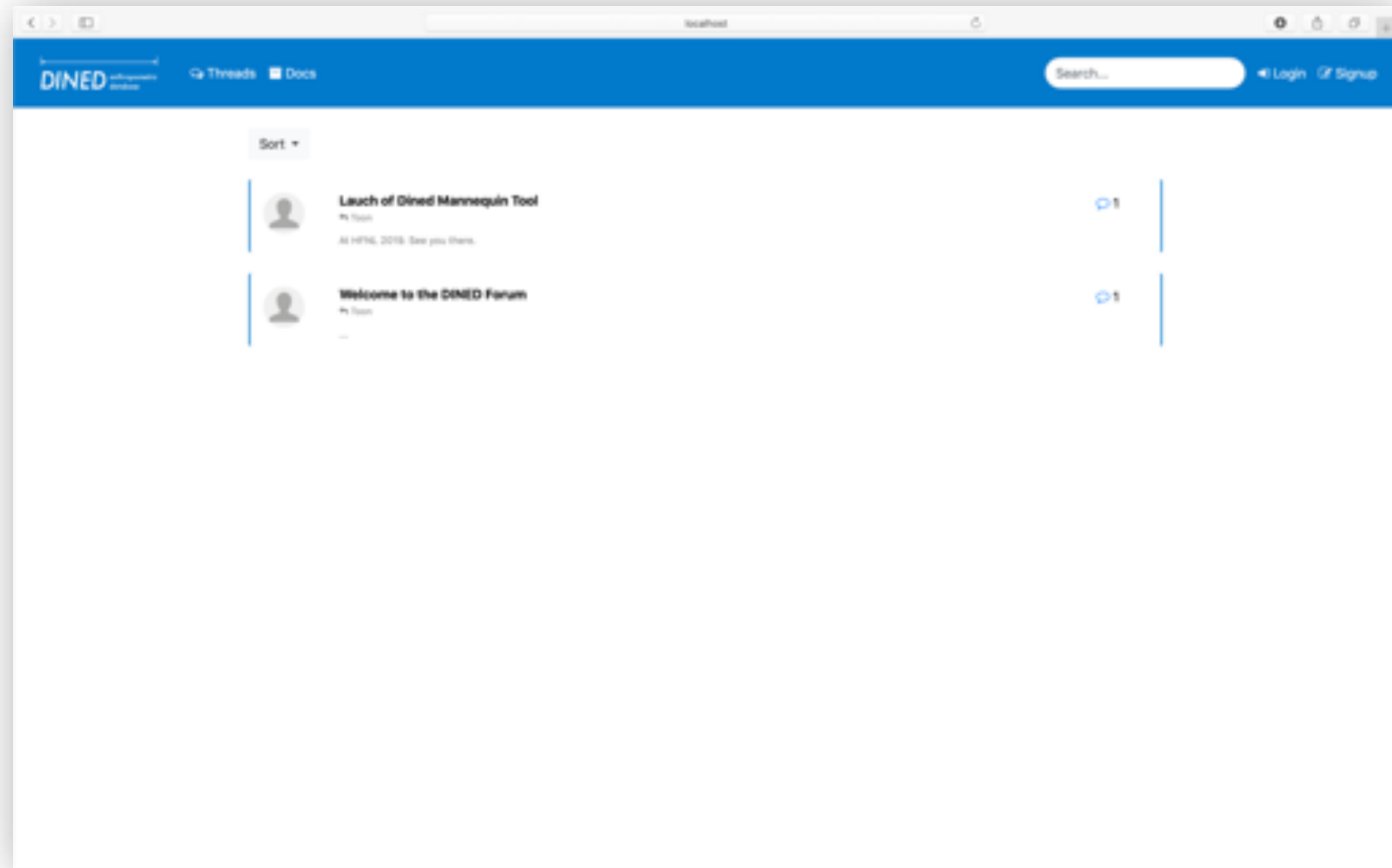
<https://dined3d.io.tudelft.nl>

1. Sign in or Sign up
2. Click acknowledge link in your mailbox
3. Go to Dined Mannequin tool

Try Out Dined Mannequin!

1. Select CAESAR population (specify Gender and Age)
2. Add a few measures, e.g.
 - Stature, body mass, waist circumference
3. Add a persona and fill in your measurements
4. Behold your 3D mannequin
5. Explore
 - Change measurements, choose other measures
 - Add more personas or create a group
 - Explore the population via the scatter plot
 - Download the STL file of your mannequins

Dined Forum (Available End of December)



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Faculty of Industrial
Design Engineering



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Thank You