Dealing with extreme requirement values

What methods to design school chairs and offshore wind turbines have in common

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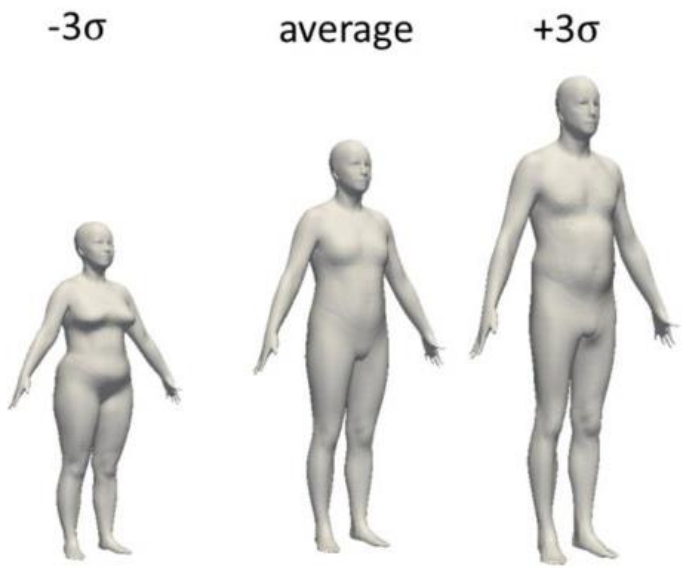
The natural world is full of variation

Geometries of oak leaves

Body dimensions

Digital mannequins from Danckaers et al. (2019)



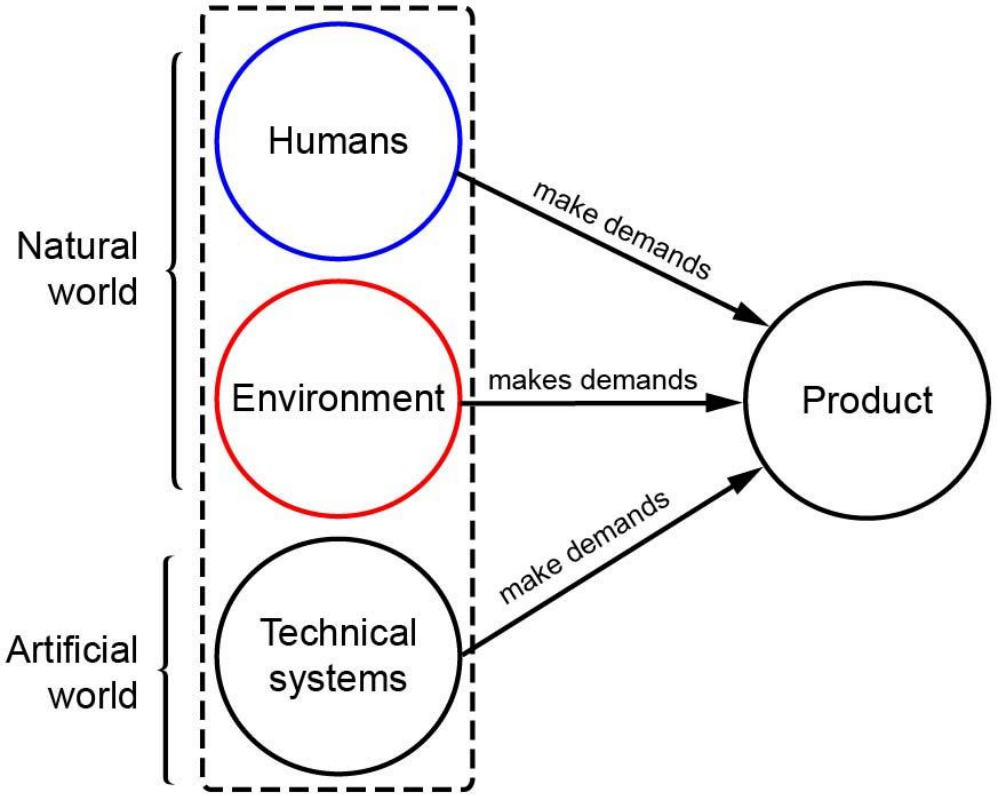
Wind speeds

https://iiif.wellcomecollection.org/image/V0043939/full/300,/0/default.jpg

Danckaers, F., Huysmans, T., Hallemans, A., De Bruyne, G., Truijen, S., & Sijbers, J. (2019). Posture normalisation of 3D body scans. Ergonomics, 62(6), 834–848. https://doi.org/10.1080/00140139.2019.1581262

https://www.dw.com/en/climate-storms-cyclones-hurricanes-typhoons-explained/a-55521226

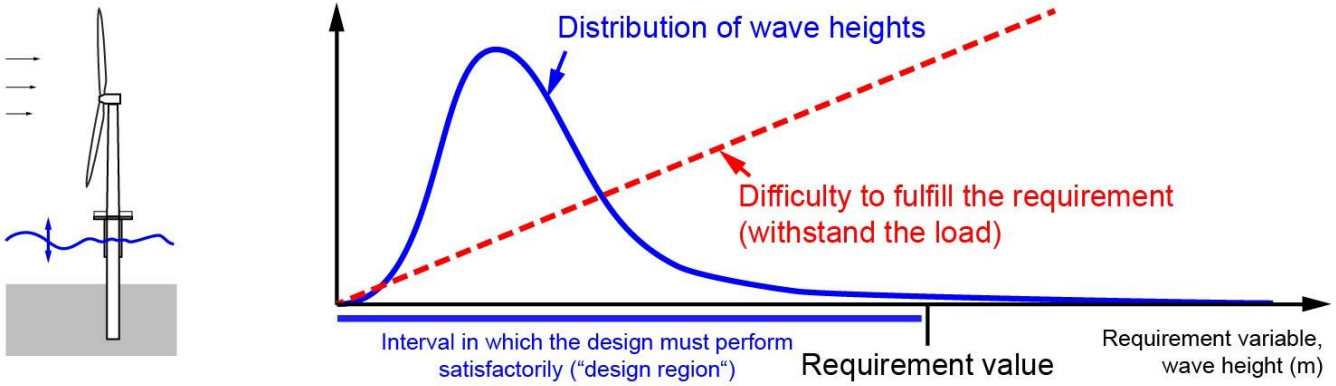
Products interact with the natural world



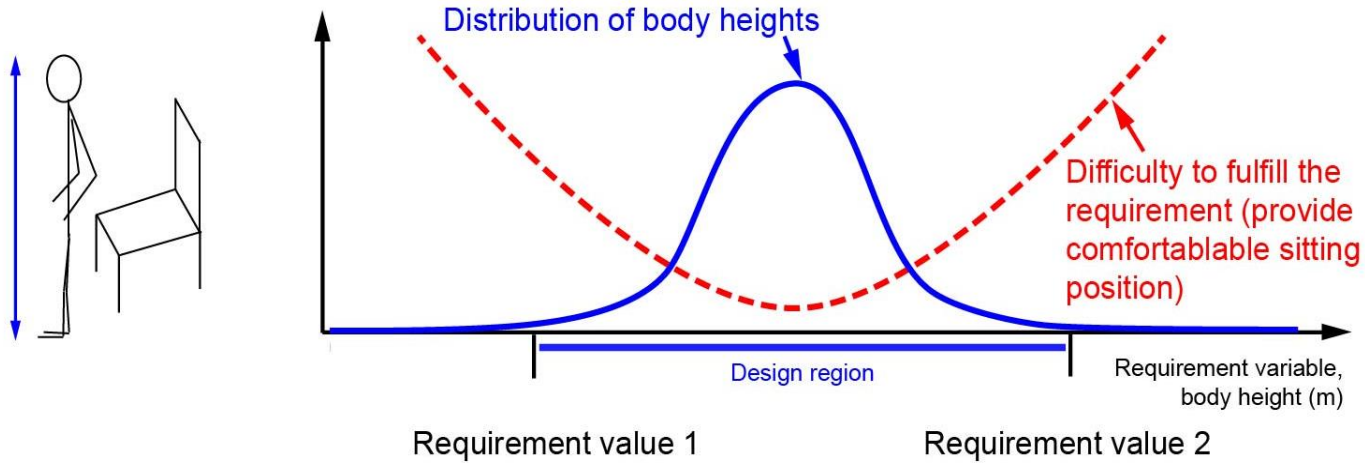
… and expected interactions are the basis for formulating requirements in the design process.

Image sources:
school chair: https://schwarzweller.de/Zuiver-CHAIR-BACK-TO-SCHOOL-MATTE
offshore wind turbine: https://www.iea.org/reports/offshore-wind-outlook-2019

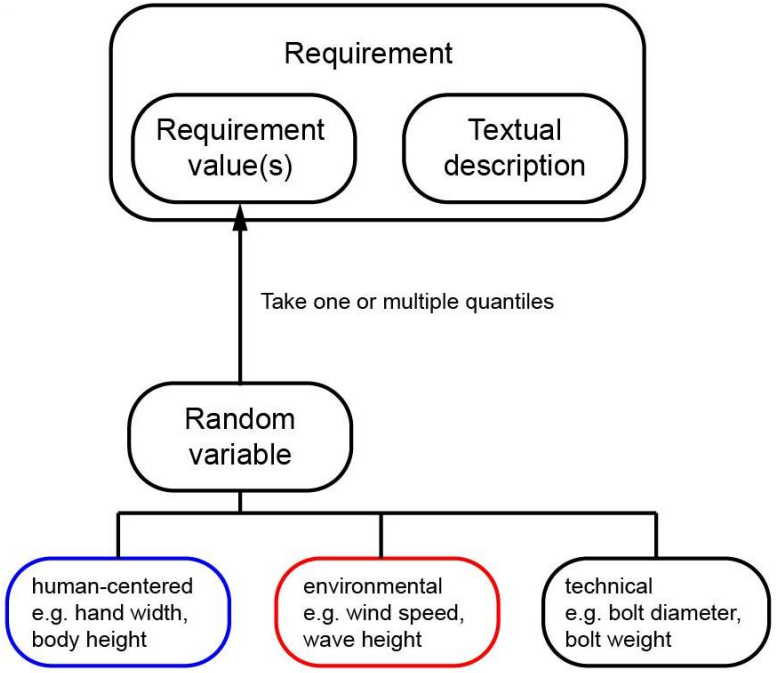
To deal with a high-variability variable, a requirement value is derived from a distribution



A design region can be limited by multiple requirement values



Representation of requirements in this work



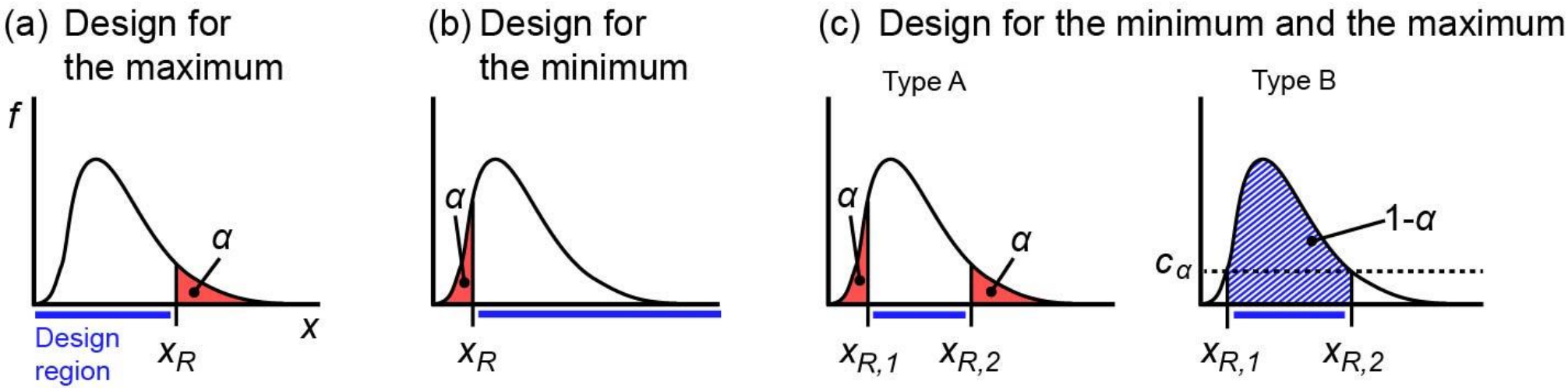
The chair is comfortable for pupils with body heights between 120 and 160 cm

Textual description — Requirement values

The wind turbine preserves structural integrity at a 10-min wind speed of 30 m s^{-1}

Textual description — Requirement value

Concepts to define extreme requirement values



For joint distributions, quantiles become curves (2D), surfaces (3D) or hypersurfaces (>3D)

General term: "exceedance boundary"

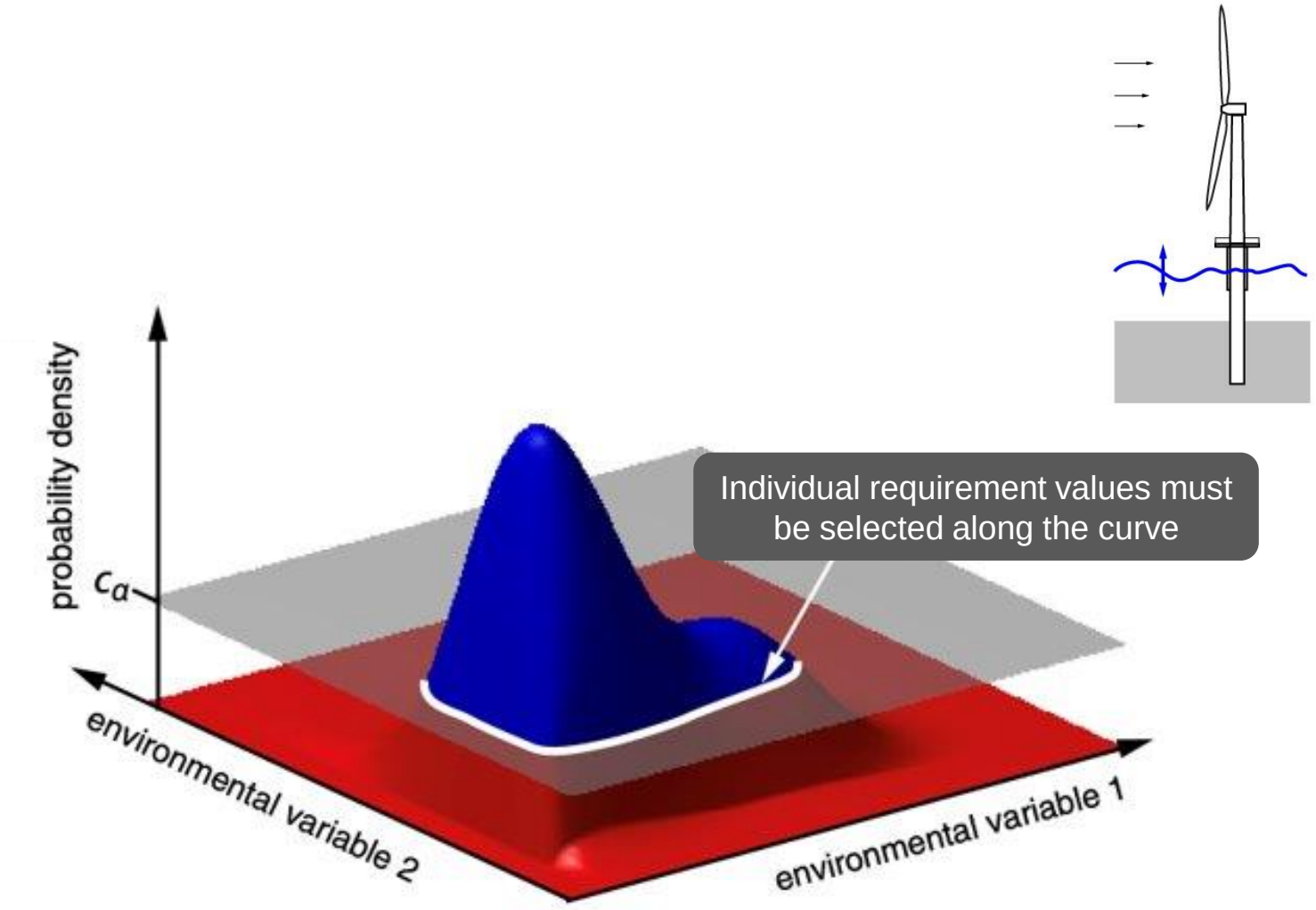


Image adapted from Haselsteiner, A. F., Reisenhofer, R., Ohlendorf, J.-H., & Thoben, K.-D. (2019). Design for extremes: A contour method for defining requirements based on multivariate extremes. In Proc. 22nd International Conference on Engineering Design (ICED19) (pp. 1433–1442). https://doi.org/10.1017/dsi.2019.149

Which methods are being used to set extreme requirement values?

Methods in ergonomics and structural design

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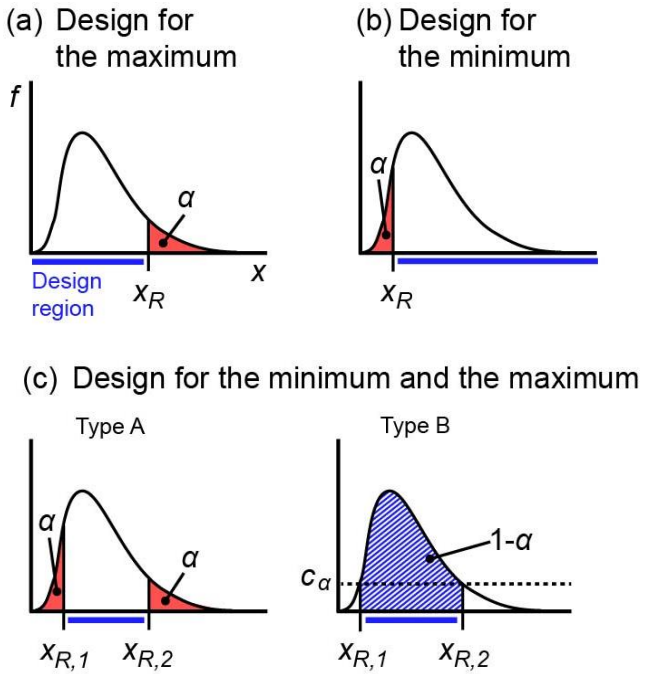

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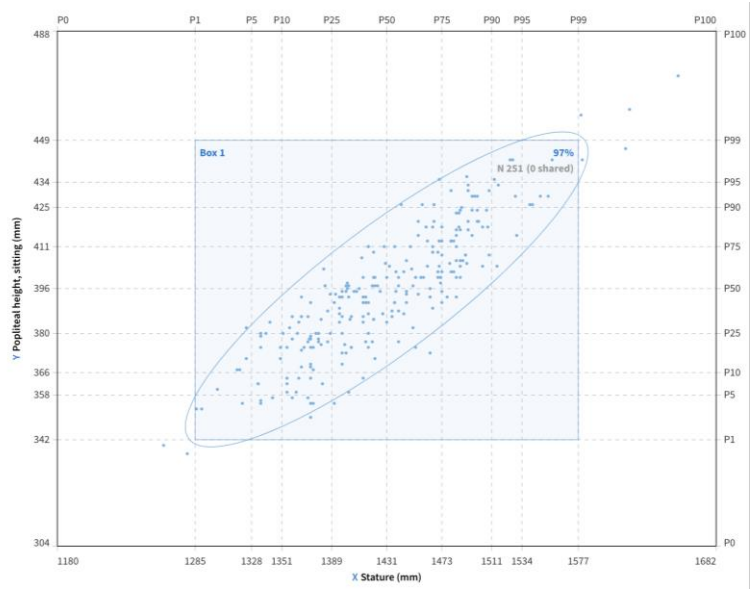

Image source: https://dined.io.tudelft.nl/en/ellipse/tool

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Population

Dutch children m+f 10

Measures

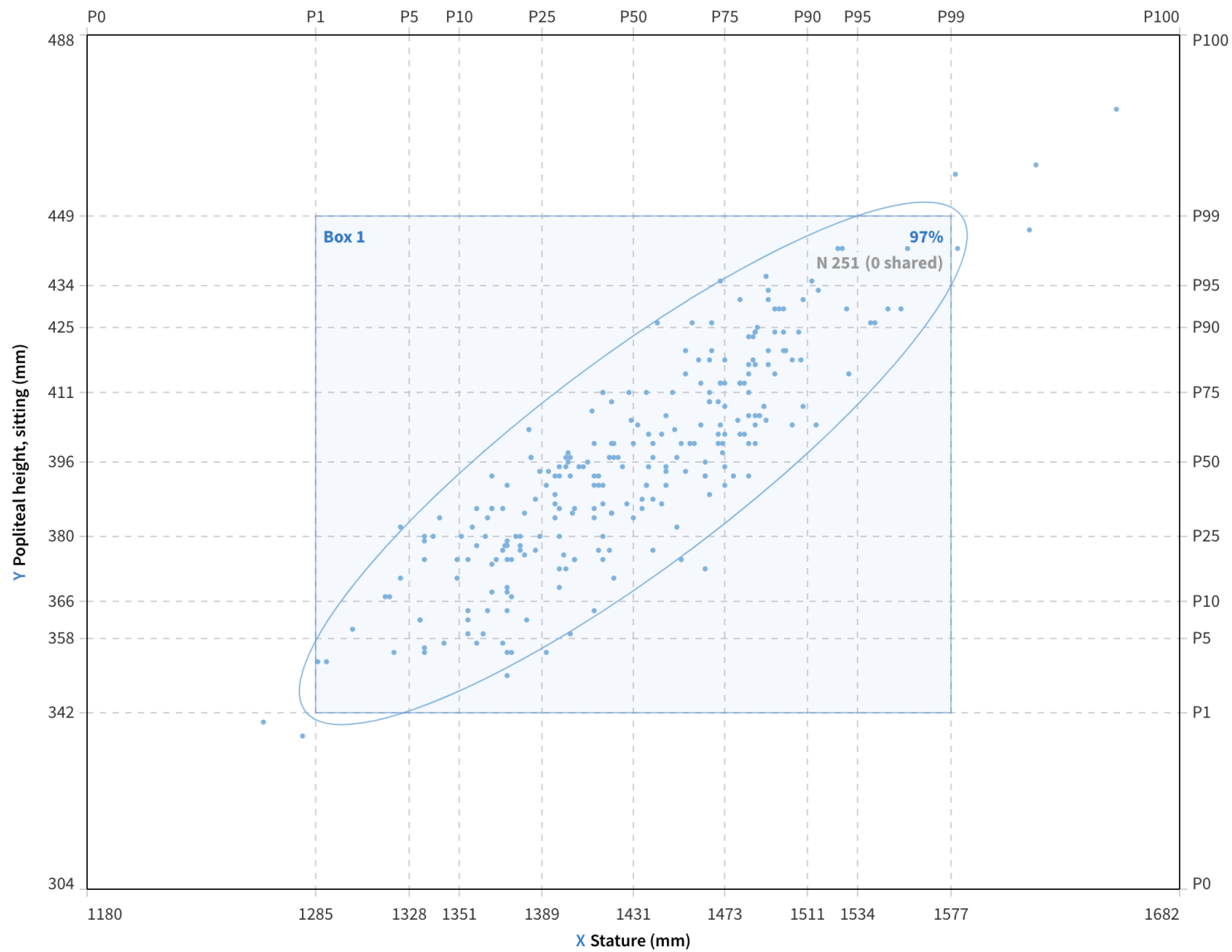
X Stature

Y Popliteal height, sitting

Annotations

Box 1

+ Add Box + Add Point



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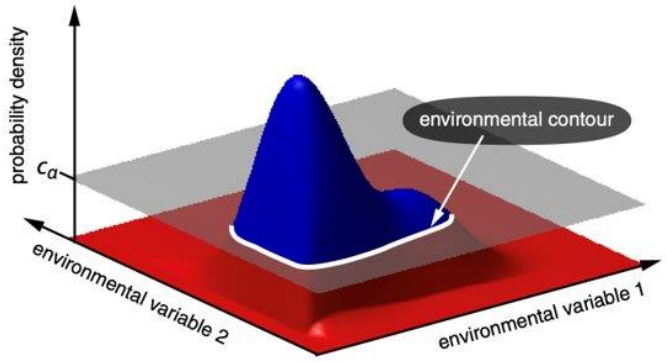

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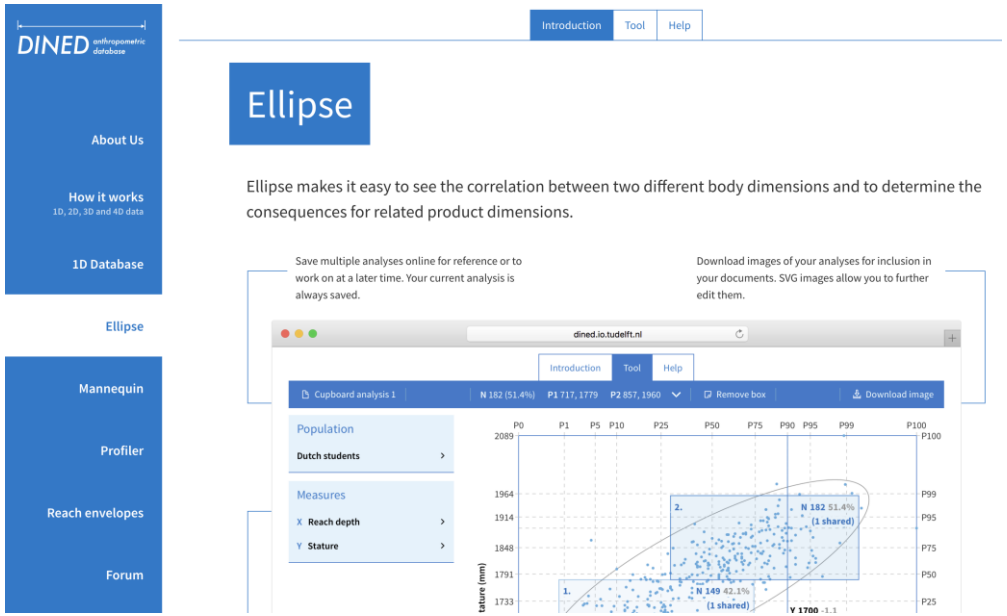
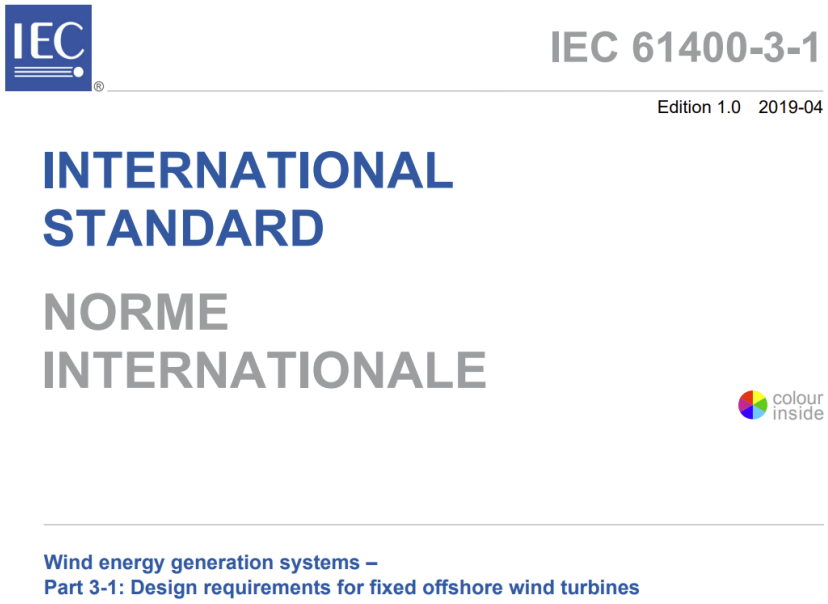
These requirement methods are widely used



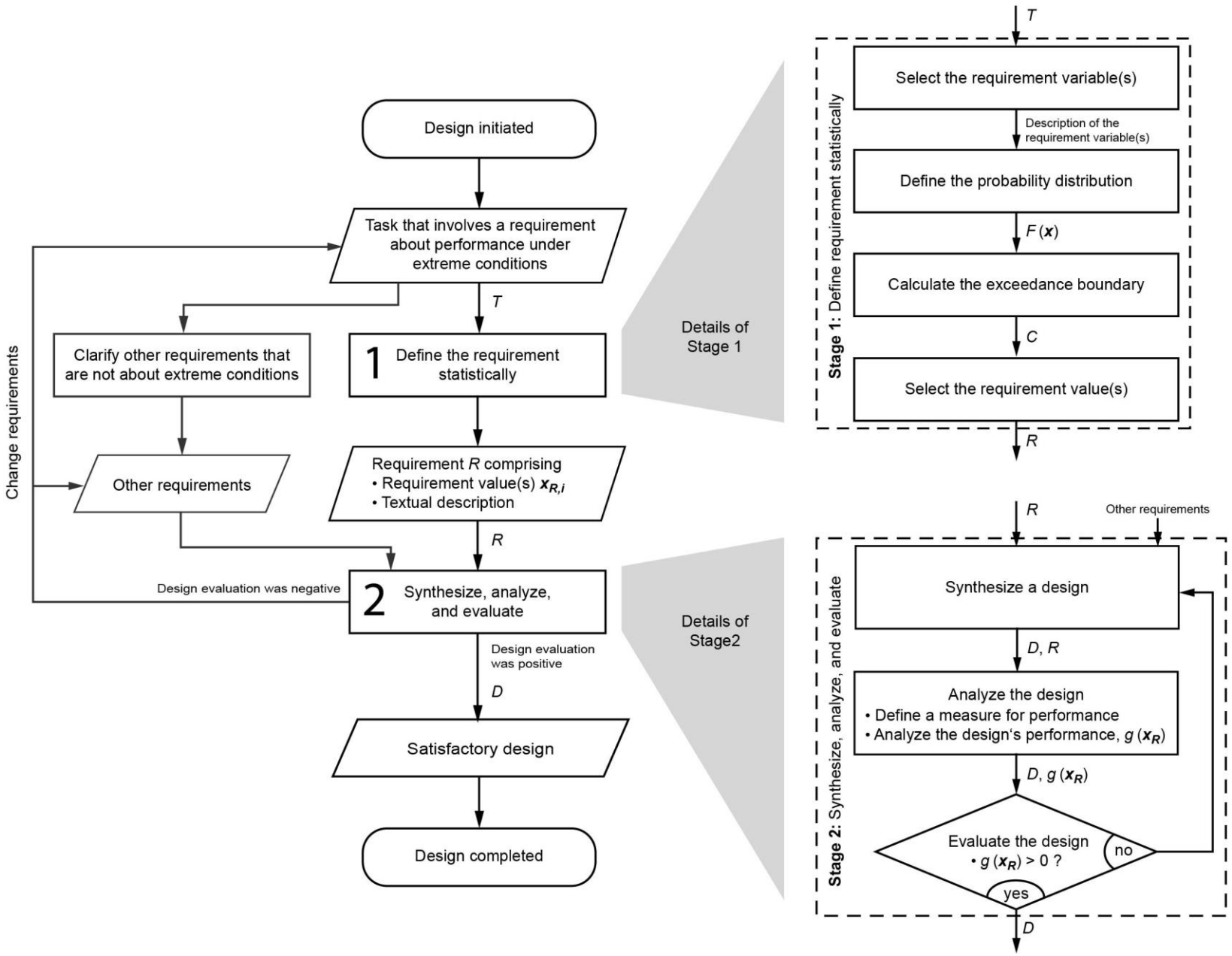


The database and tool DINED that implements statistical methods for anthropometric data such as the **Ellipse methods** has thousands of users[1].

The international offshore wind turbine standard prescribes the use of **univariate return period methods** and recommends the **environmental contour method**.

1 https://dined.io.tudelft.nl/en/about

A model for the process of dealing with extreme requirement values

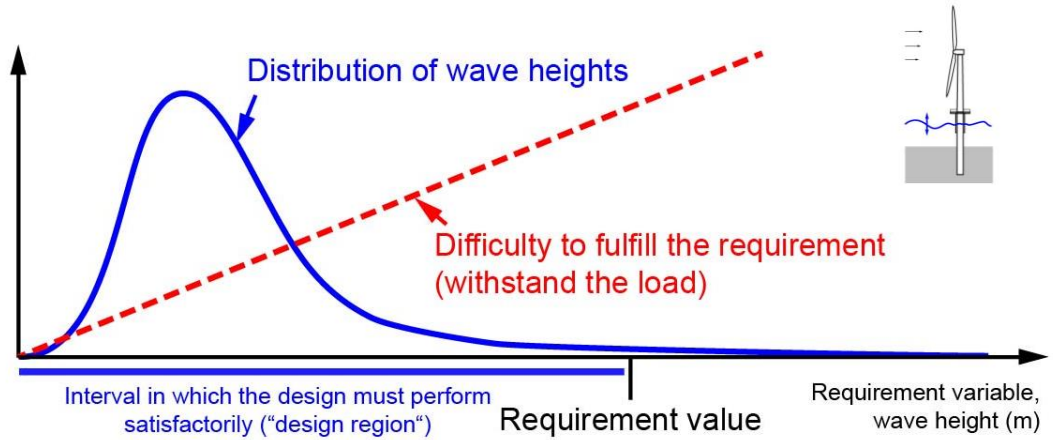


Summary and conclusions

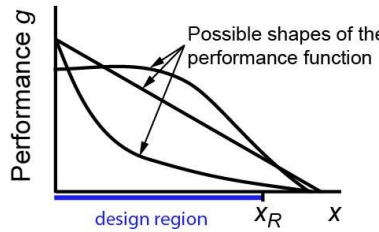
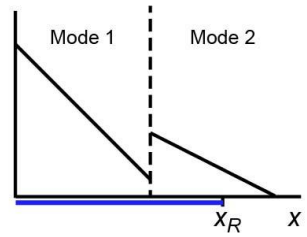
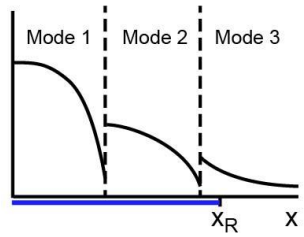
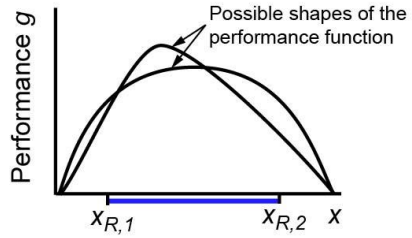
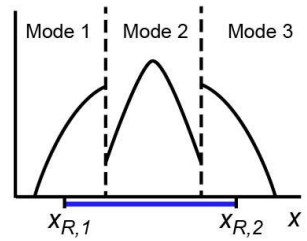
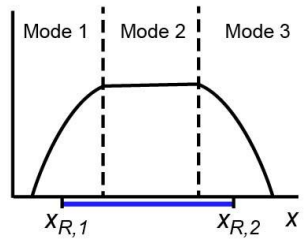
→ Many designs are „driven“ by requirements that describe maximum or minimum values of high-variability variables

→ Unifying terminology and a model for the process of dealing with such requirements in the general design process was proposed

→ The process model can serve as a “wrapper” of the various methods used in ergonomics and structural design



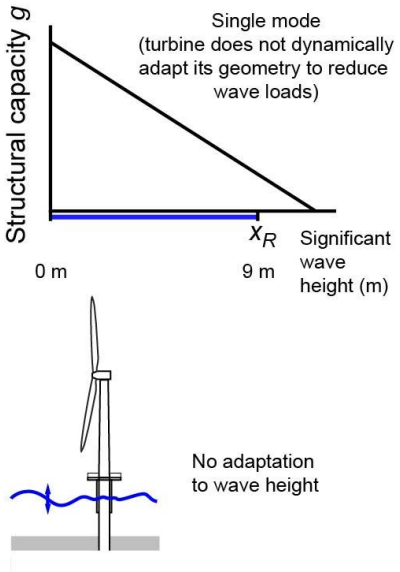
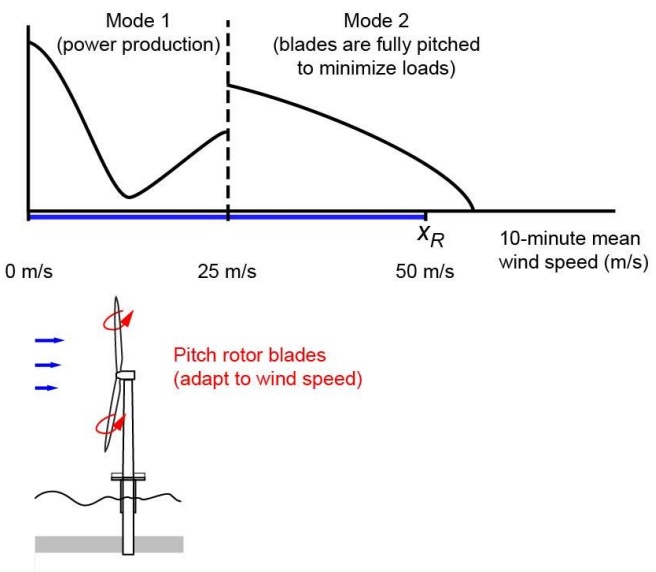
Static and adaptive designs

Case	Static design	Adaptive design
Design for the maximum		 
Design for the minimum and maximum		 

A static design does not actively change with the requirement value, it behaves similarly for low and high requirement values.

An adaptive design changes with the requirement value to achieve improved performance at high (or low) values. It usually has multiple operation modes.

Offshore wind turbine

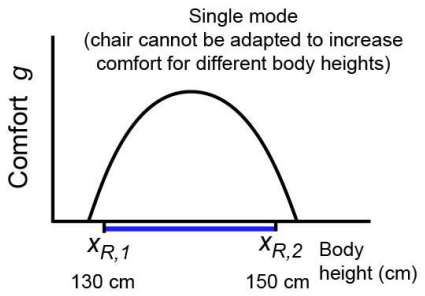
Case	Static design	Adaptive design
Example 1: Offshore wind turbine		

School chair

Case

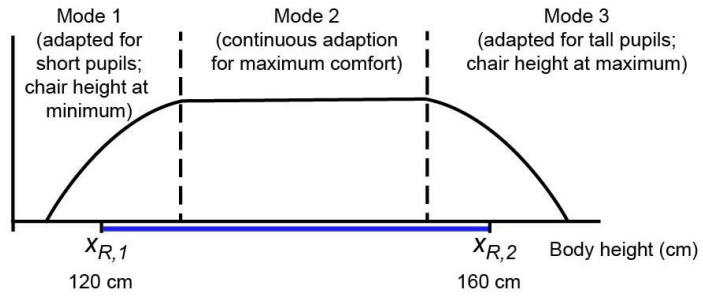
Example 2:
Ergonomic chair

Static design



No adaptation
to body height

Adaptive design



Change chair height
(adapt to body height)

Chair images were kindly provided by backwinkel.de, access: Nov 28, 2022

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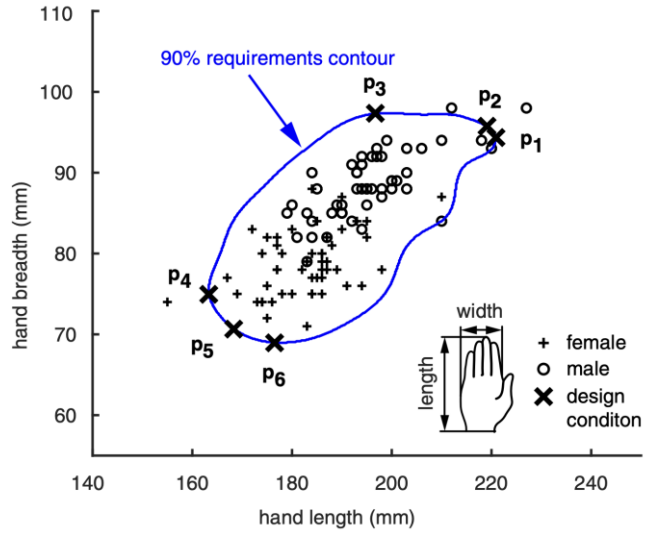

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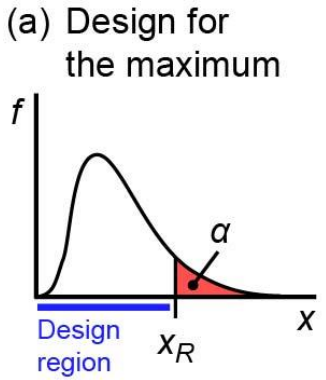

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