Characterizing a Particle Size Distribution with Curve Fitting: No coding experience required

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Introduction

Imagine an experiment where human participants chewed a food product (such as roasted almonds). At the point of swallow, the participants expectorated the food particles. Researchers then captured high-resolution images of these particles to determine their 2-dimensional area (silhouette).

The particles are not uniform in size. To analyze the mastication process that was carried out on this food, researchers decided to characterize the **Particle Size Distribution** of the chewed particles using a mathematical curve-fitting approach.

Objective

The goal of this exercise is to determine a function that represents the particle size distribution of chewed food by curve-fitting the empirical cumulative distribution function.

Suggested Prompts

Copy and paste the following prompts into a chatbot (such as ChatGPT, Gemini, or Claude). Ensure you have the data file `example_particle_areas.csv` ready to upload.

Step 1: Initial Data Extraction

> *Can you please help me curve fit some particle size data from an excel sheet? [Upload your file now]*

> *This contains all the particle sizes in terms of 2D area, from multiple images of food particles, each image in a different column. Can you extract the total list of particle areas, and then express particle area on a cumulative basis? Basically, make the empirical cumulative distribution function for this dataset and show a graph.*

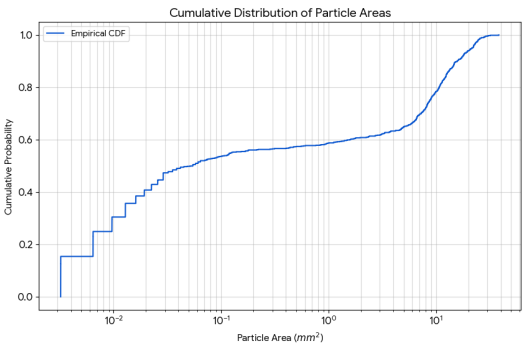

Figure 1: Empirical cumulative distribution of particle sizes

Step 2: Single Weibull Fit

Next, can you please curve fit the cumulative distribution function using the Weibull function, given by: $A_{cumulative} = 1 - \exp\left(-\left(\frac{x}{x_{50}}\right)^{b} \ln(2)\right)$
Add the curve fit to the graph and report the parameter values (x_{50}, b) *and* R^2.

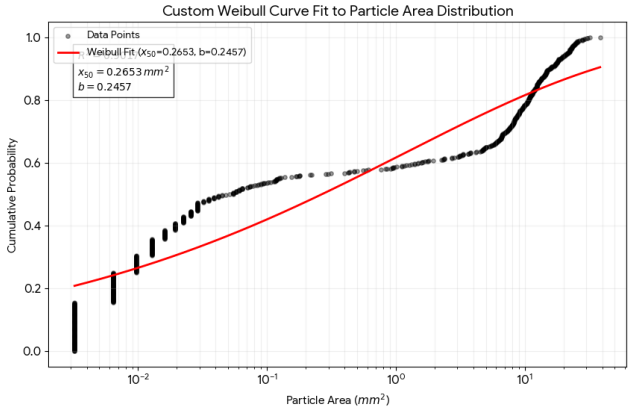

Figure 2: Weibull function fit to the cumulative distribution of particle sizes

Fit Parameters:
x_{50} = Median area = $0.2653\,mm^2$
b = Shape parameter = 0.2457
R^2 = Coefficient of determination = 0.9017

Step 3: Mixed Weibull Fit

OK, can you please curve fit again, but using the mixed Weibull function, given by:

$$A_{cumulative} = a\left[1 - \exp\left(-\left(\frac{x}{x_{50\_1}}\right)^{b_1} \ln(2)\right)\right] + (1-a)\left[1 - \exp\left(-\left(\frac{x}{x_{50\_2}}\right)^{b_2} \ln(2)\right)\right]$$

Fit for five parameters $(a, x_{50\_1}, b_1, x_{50\_2}, b_2)$*, add this new curve to the graph, and report the parameter values and* R^2.

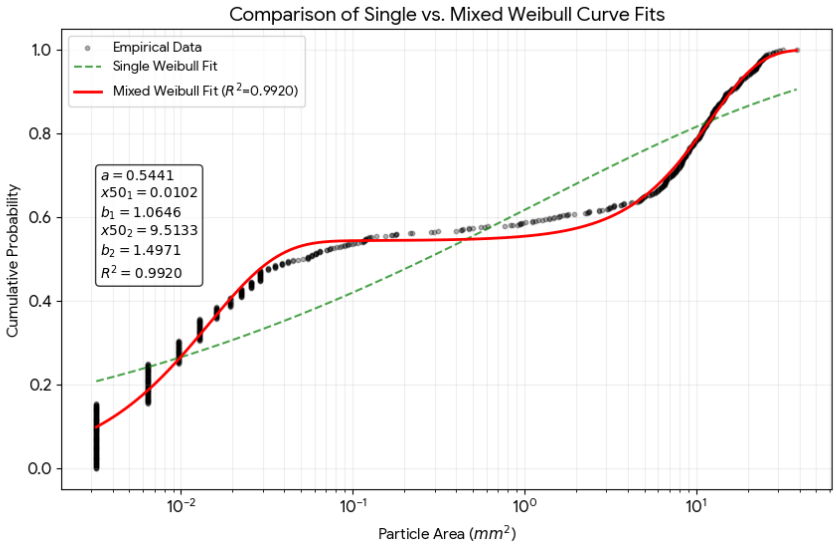

Figure 3: Weibull function fit to the cumulative distribution of particle sizes

Fit Parameters:
a = Percentage of total area contributed by the small population of particles = 0.54 $percent/100$
$x_{50,1}$ = Median area of the population of small particles = 0.01 mm^2
b_1 = Shape parameter for the population of small particles = 1.06 $unitless$
$x_{50,2}$ = Median area of the population of large particles = 9.51 mm^2
b_2 = Shape parameter for the first population of particles = 1.50 $unitless$
R^2 = Coefficient of determination = 0.992

Questions for Humans

1. How did the R^2 change between the single and mixed Weibull models? What does this tell us about the particle size distribution (Hint: is it unimodal or bimodal)?

2. For the standard Weibull function, what do you think would happen to the value of x_{50} if the participants in the study chewed the food twice as long? (Hint #1: smaller x_{50} means that the median particle size was lower. Hint #2: assume that chewing for longer time will generate more small particles)

3. For the Mixed Weibull Function, what do you think would happen to the values of a if the participants in the study chewed the food twice as long?

4. Say this study generated hundreds of spreadsheets of data. How could we go about characterizing their particle size distributions automatically, without uploading the spreadsheets to a chatbot one at a time?

5. Chatbots make a lot of mistakes. How can we reasonably check these results?