

An Interactive Tool to Visualize Results from Uncertainty Quantification

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Outline

- 1 Introduction
- 2 Methods
- 3 Results
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Motivation

Uncertainty Quantification (UQ):

- Is a branch of simulation analysis that is used often in engineering contexts;
- Assists engineers and decision-makers in finding a balance between design efficiency and design sufficiency (avoid under/over designing);
- Provides a quantification of how variability in a system can influence the end state of that system.

UQ Overview - Terminology

aleatory uncertainty: Uncertainty resulting from randomness inherent to a given parameter. Gaining more knowledge about the parameter will not reduce the uncertainty of the parameter.

epistemic uncertainty: Uncertainty resulting from a lack of knowledge about a given parameter. Gaining more knowledge about the parameter could reduce the uncertainty of the parameter.

engineering model: A mathematical model that defines the relationship between the parameters (model inputs) and SRQ (model output).

system response quantity (SRQ): A parameter of particular interest directly related to the engineering system in question. The SRQ is the output (i.e. prediction) from the engineering model.

UQ Overview - Algorithm

Aleatory model inputs: $A_k, k = 1, 2, 3$

Epistemic model inputs: $E_k, k = 1, 2, 3$

$$SRQ = E_1^{E_2} A_3 A_2^{A_1} + E_3$$

- Probability distributions for each input is selected by subject matter expert

Example adapted from Ewing et al. (2018)

UQ Overview - Algorithm

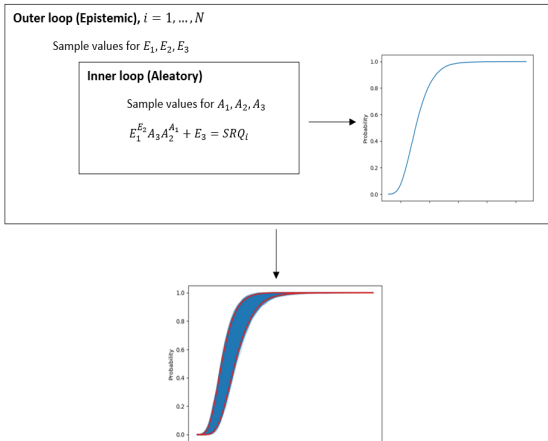
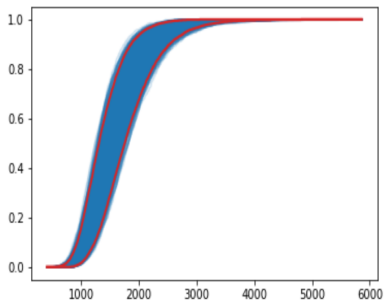


Diagram adapted from Ewing et al. (2018)

Project Goal

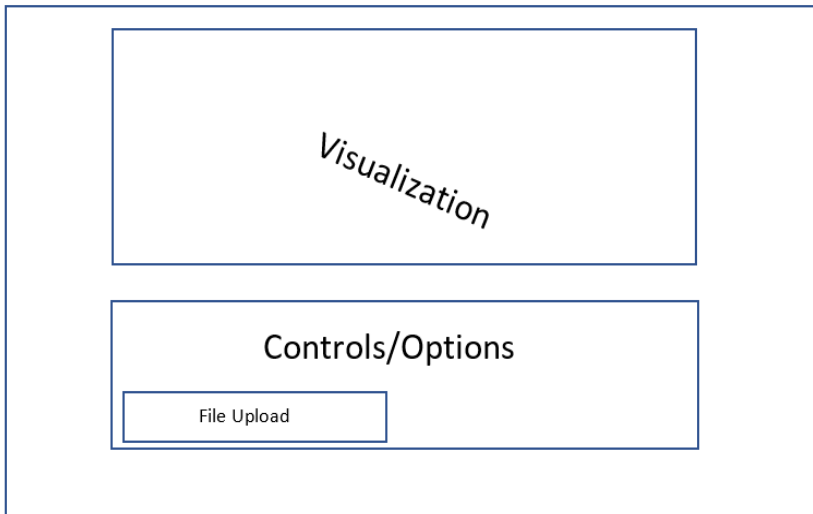
Goal: Develop an interactive tool to create meaningful visualizations (like the one below) and useful interpretations of results from a UQ simulation.



Key Features

- upload data via a `.csv` file
- toggle P-box and CDF's on/off
- select upper/lower percentiles to be used in P-box calculation
- adjustable transparency for CDF ensemble
- extract either a probability interval or an SRQ interval from P-box
- download and save visualization as a `.png` file

Planned Layout



R Packages

dplyr: The `dplyr` package (Wickham et al. 2013) was used for data wrangling and data manipulation

shiny: The `shiny` package (Chang et al. 2018) provided the framework on which the application was developed and deployed. It also contains the implementations for all user-interface components (toggle buttons, check boxes, numeric inputs, sliders, etc.).

shinydashboard: The `shinydashboard` package (Chang and Borges Ribeiro 2018) was used as a wrapper around the `shiny` framework to give a clean, polished appearance to the application.

ggplot2: The plotting functionality of the `ggplot2` package (Wickham 2016) was used to generate the actual visualization and to add, remove, or adjust components on the plot.

Deployment

Shiny App currently deployed at:
`https://misaac.shinyapps.io/UQViz/`

Data Source

- Users can upload `.csv` files for visualization. The files should have the x values in the 1st column, and the CDFs in subsequent columns.
- For convenience, a sample data set is also provided

The screenshot shows a web interface with four tabs: "Data Source", "Visualization Options", "Labeling", and "Help". The "Data Source" tab is active. Under the "Data Source" heading, there are two radio buttons: "Sample Data" (unselected) and "File Upload" (selected). Below this, under the "Upload .csv File" heading, there is a "Browse..." button and a text box containing "cdf3.csv". At the bottom of the interface, a blue banner displays the text "Upload complete".

Visualization Options

- Several options are provided to allow customized visualizations

The screenshot shows a software interface with a top navigation bar containing four tabs: "Data Source", "Visualization Options", "Labeling", and "Help". The "Visualization Options" tab is currently selected. Below the tabs, there are two checkboxes on the left: "Show/Hide P-box" (checked) and "Show/Hide CDFs" (unchecked). To the right of these checkboxes are two input fields for percentiles. The first is labeled "Lower Percentile" and contains the value "0.05". The second is labeled "Upper Percentile." and contains the value "0.95". Further to the right is a "CDF Transparency" slider. The slider has a range from 0 to 1, with a blue segment from 0 to 0.3 and a light orange segment from 0.3 to 1. A circular handle is positioned at the 0.3 mark. To the right of the slider is a checkbox labeled "Extract Interval", which is currently unchecked.

Data Source Visualization Options Labeling Help

☒ Show/Hide P-box

☐ Show/Hide CDFs

Lower Percentile

0.05

Upper Percentile.

0.95

CDF Transparency

0 0.3 1

☐ Extract Interval

Visualization Options

Data Source Visualization Options Labeling Help

☒ Show/Hide P-box

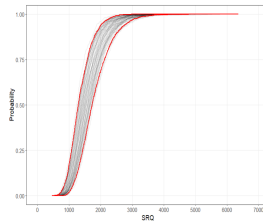
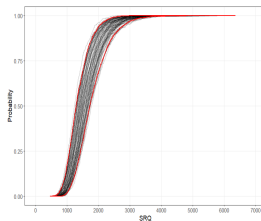
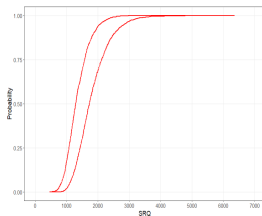
☐ Show/Hide CDFs

Lower Percentile

Upper Percentile.

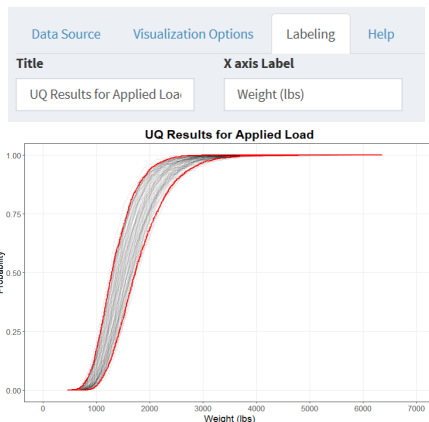
CDF Transparency
0 0.3 1

☐ Extract Interval



Labeling

- Custom title and x-axis label can be added to adapt visualization to domain.

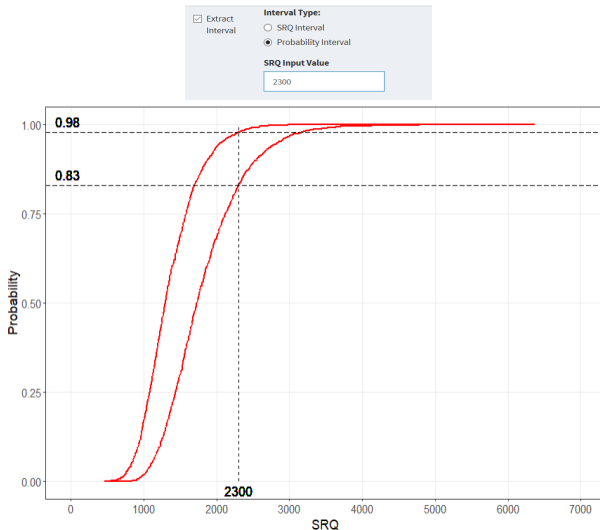


Interpretation - Extract Probability or SRQ Intervals

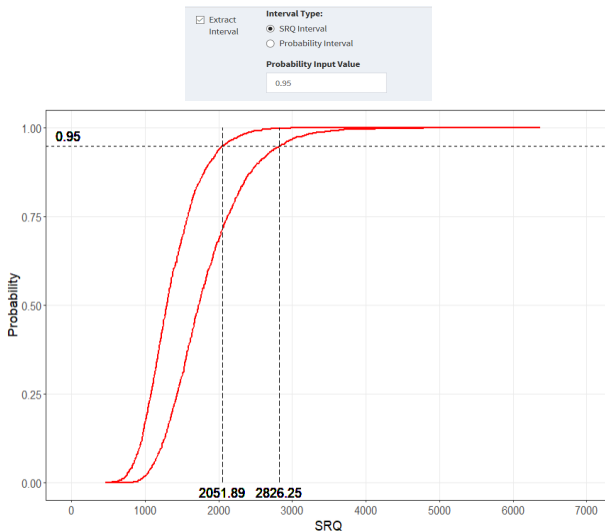
There are two ways a P-box can be used for interpretation:

- Input SRQ value to extract probability interval
- Input probability value to extract SRQ interval

Interpretation - Extract Probability Interval



Interpretation - Extract SRQ Interval



Challenges

- Long render time for hundereds (or thousands!) of traces on a plot
- File upload size limit to `shiny` web applications

Future Work

- Create a self contained UQ simulation tool – perform entire process, start to finish
 - Choose an SRQ function
 - Define inputs as aleatory or epistemic
 - Specify the number of inner and outer loop iterations
 - Visualization generated automatically

Questions ?? —

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Sources

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