An Interactive Tool to Visualize Results from Uncertainty Quantification

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Outline

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

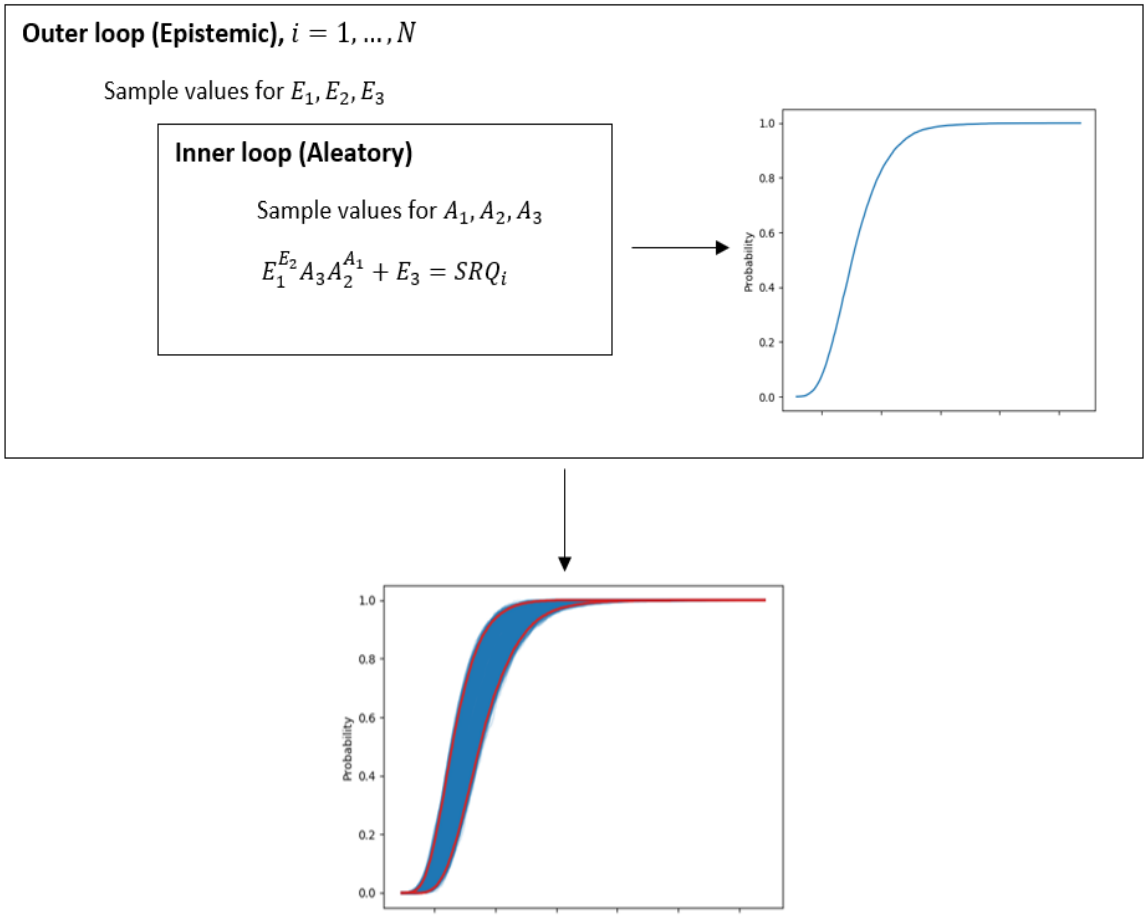
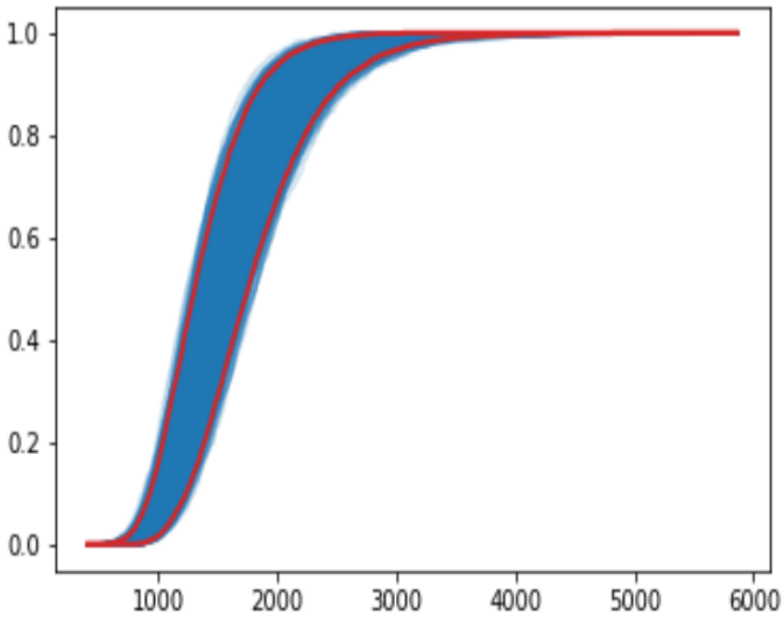


Diagram adapted from Ewing et al. (2018)

Project Goal

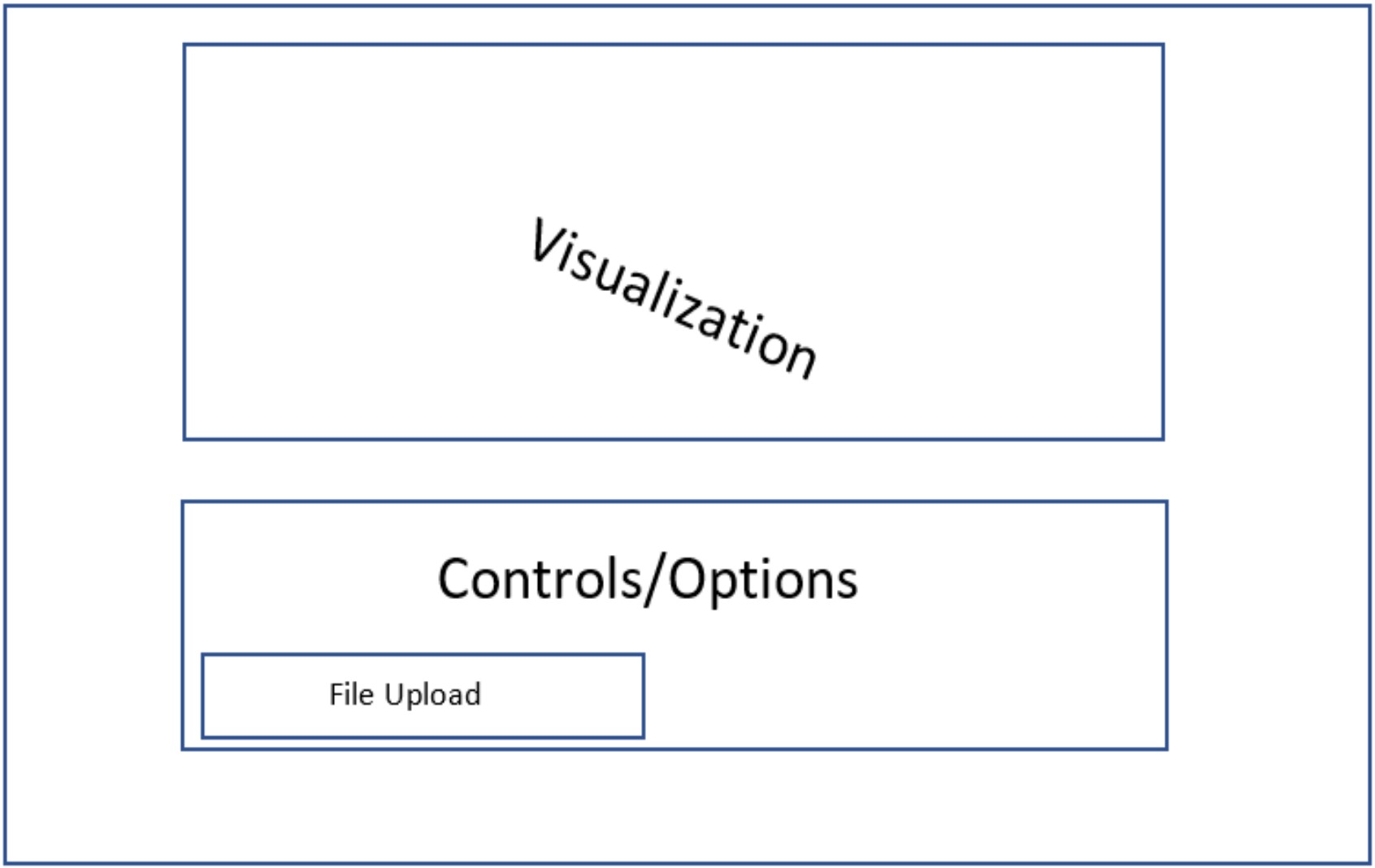
Goal: Develop an interactive tool to create meaningful visualizations (like the one below) and useful interpretations of results from a UQ simulation.



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.

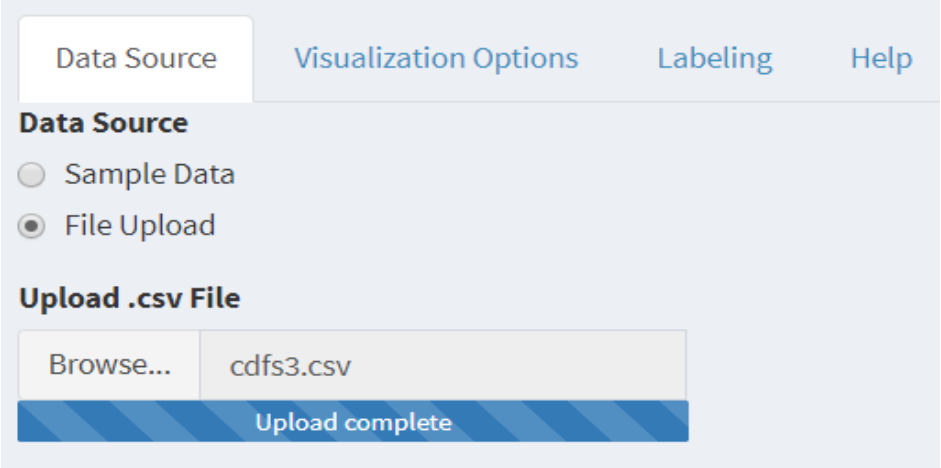
Deployment

Shiny App currently deployed at:

`https://misaac.shinyapps.io/UQViz/`

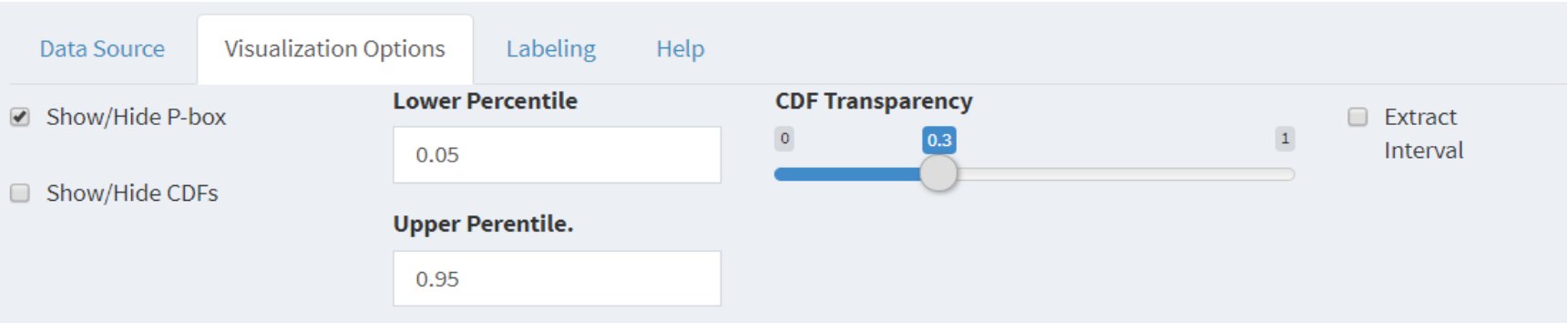
Data Source

- 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

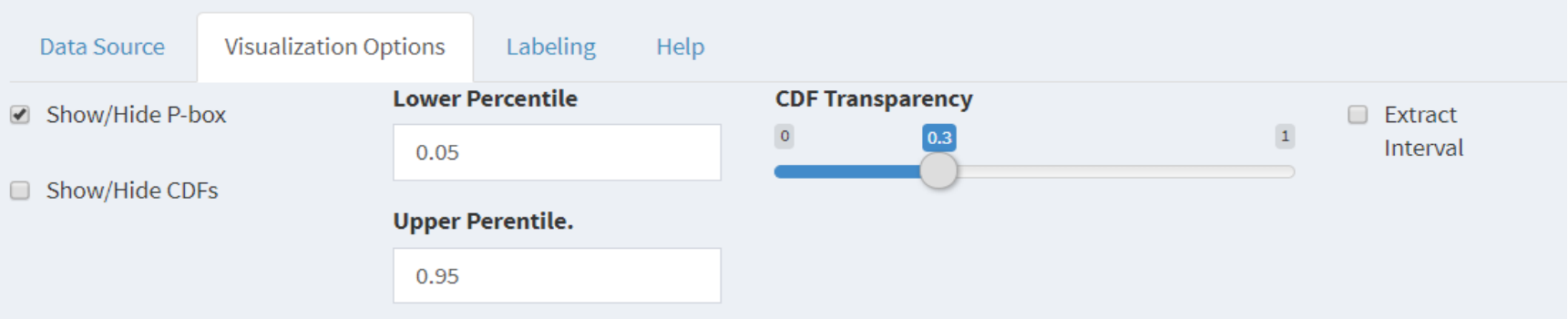


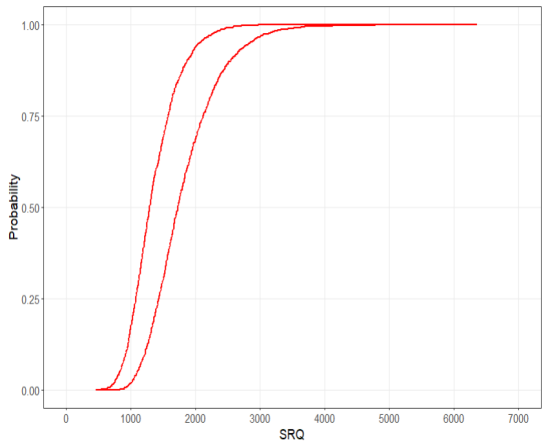
Visualization Options

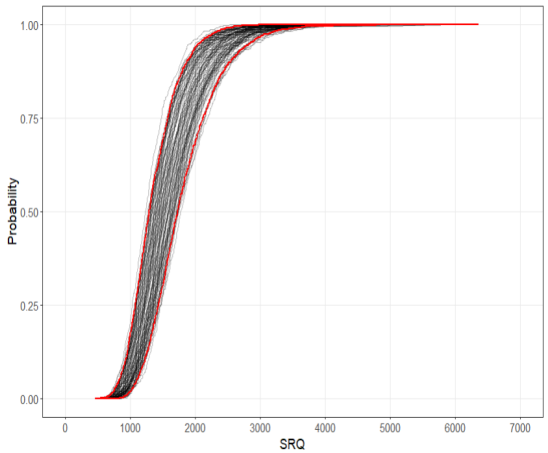
- Several options are provided to allow customized visualizations

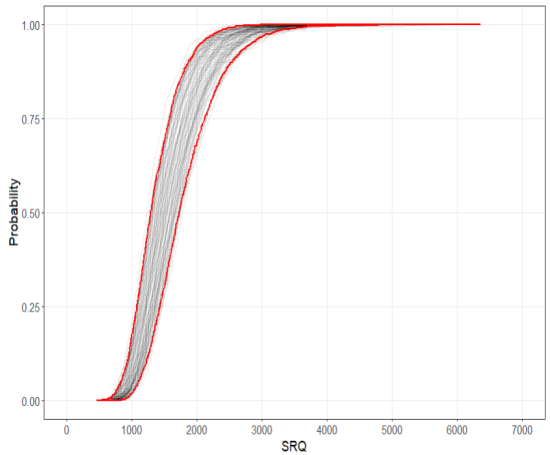


Visualization Options



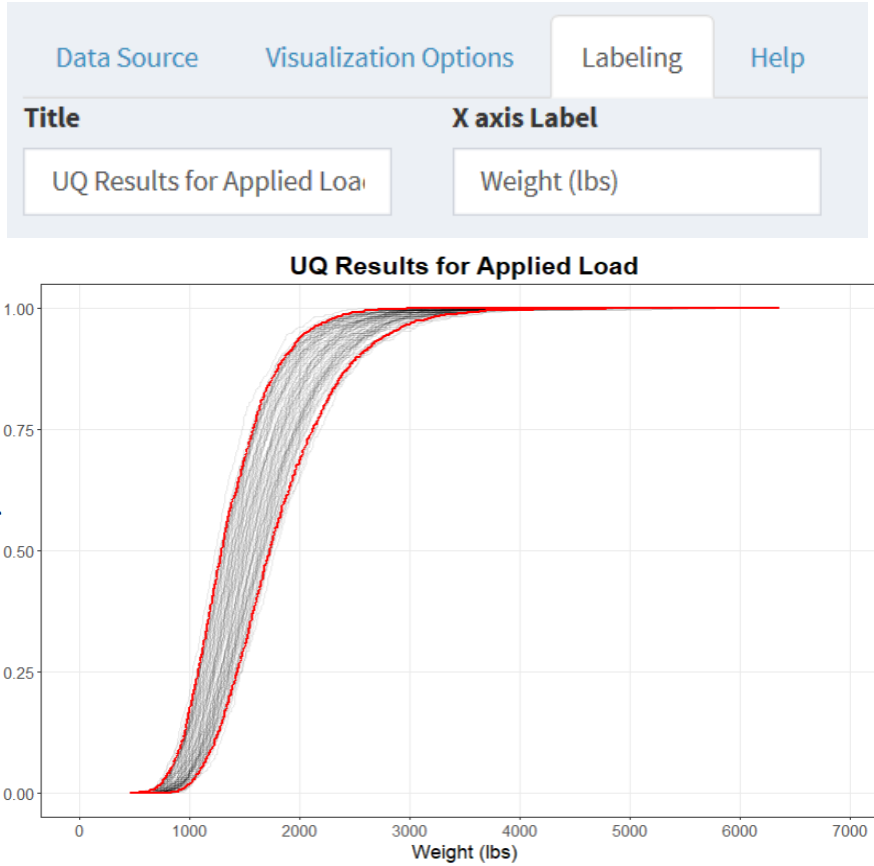






Labeling

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

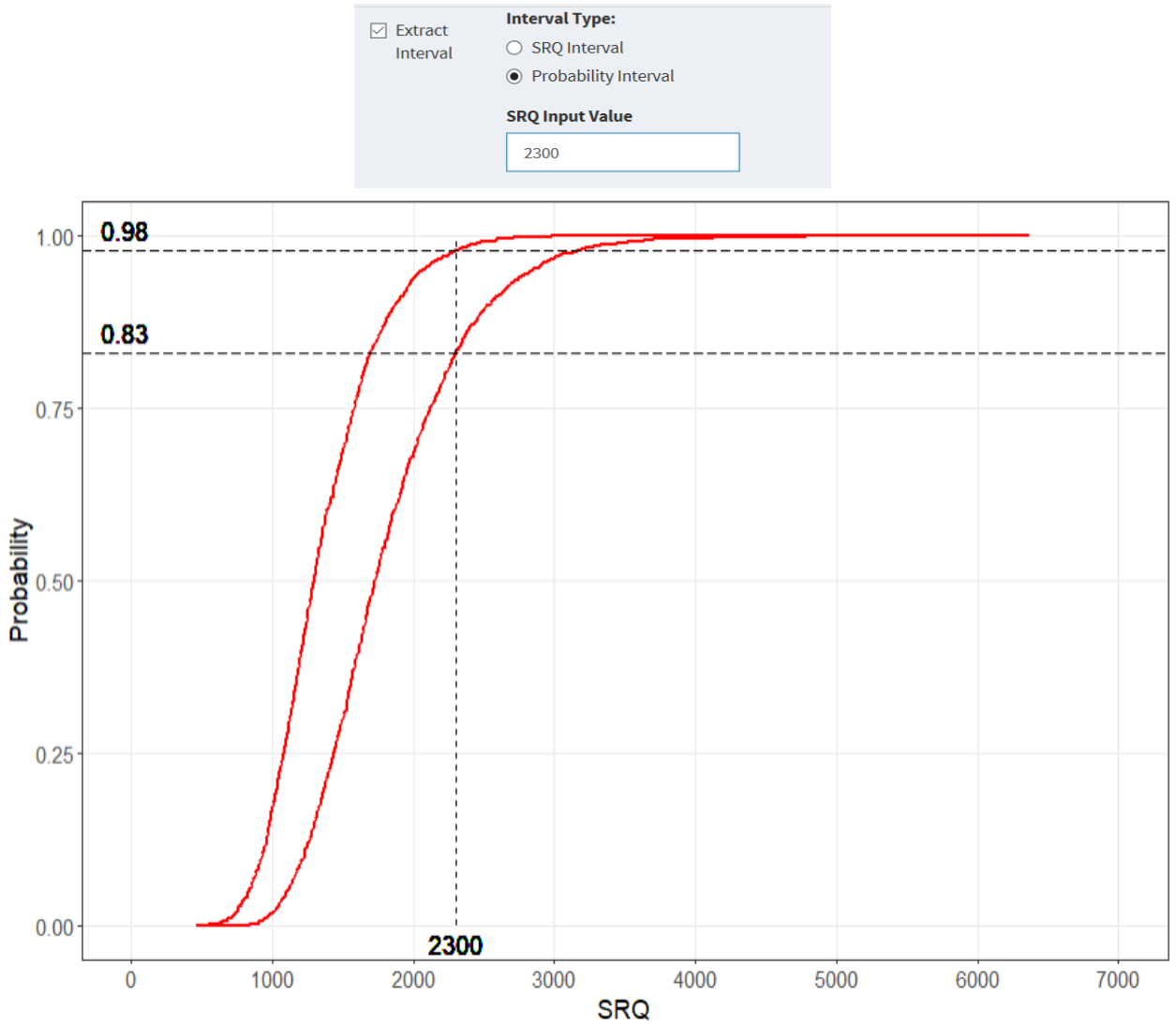


Interpretation - Extract Probability or SRQ Intervals

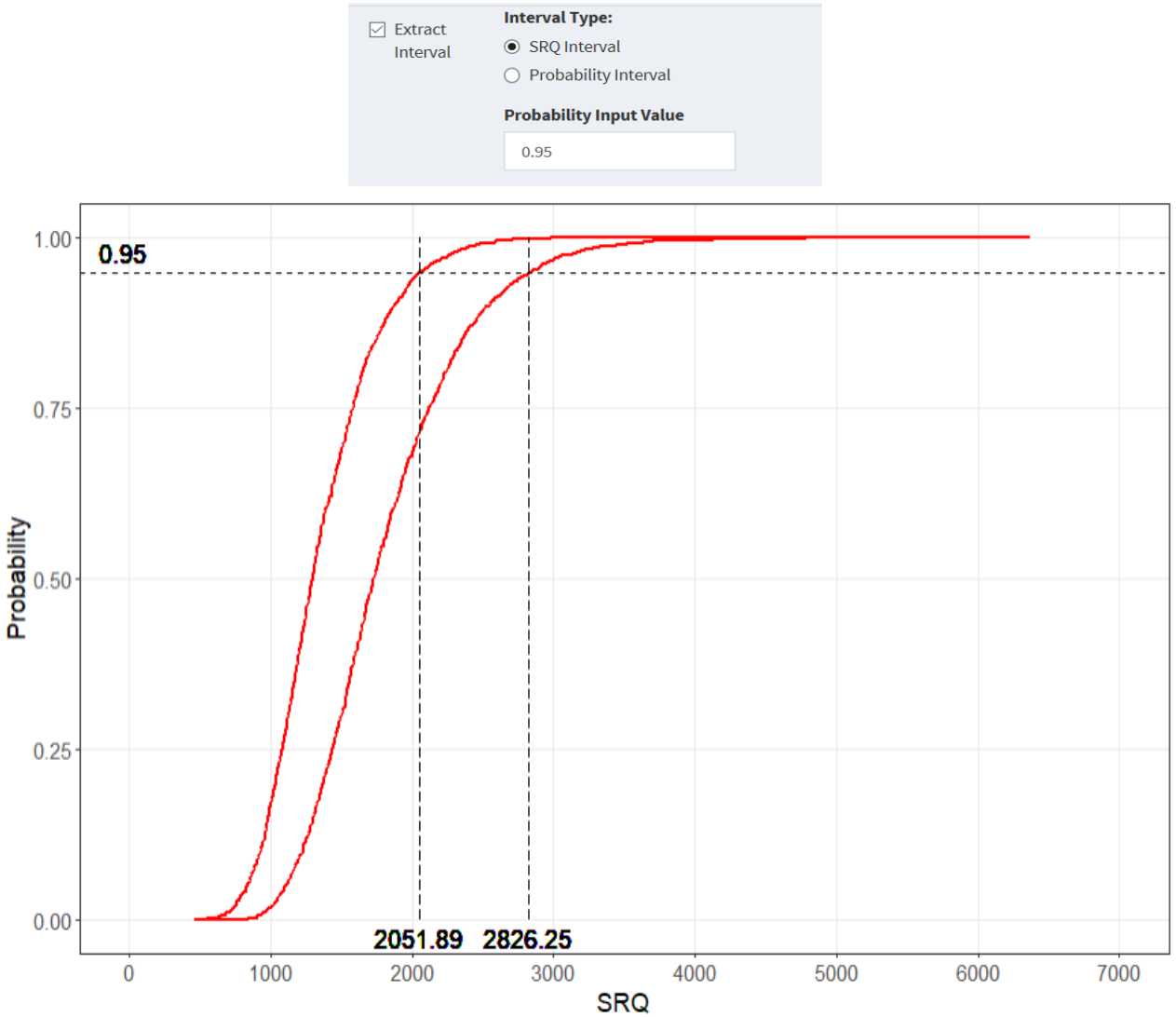
There are two ways a P-box can be used for interpretation:

- 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

Chang, W., Borges Ribeiro, B., 2018. shinydashboard: Create Dashboards with 'Shiny'. R package version 0.7.1 (https://CRAN.R-project.org/package=shinydashboard).

Chang, W., Cheng, J., Allaire, J., Xie, Y., McPherson, J., 2018. shiny: Web Application Framework for R. R package version 1.2.0 (https://CRAN.R-project.org/package=shiny).

Ewing, M., Liechty, B. C., Black, D., 2018. A General Methodology for Uncertainty Quantification in Engineering Analyses Using a Credible Probability Box. Journal of Verification, Validation, and Uncertainty Quantification 3 (2), https://doi.org/10.1115/1.4041490.

Wickham, H., 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, (http://ggplot2.org).

Wickham, H., Francois, R., Henry, L., Muller, K., 2013. dplyr: A Grammer of Data Manipulation. R package version 0.7.6. (https://CRAN.R-project.org/package=dplyr).