

[57, 53, 54]. As an example, a simple scatterplot of variable A against variable B might be described by a specification like this:

$$\text{encodings}(x \text{ position} \leftarrow A, y \text{ position} \leftarrow B) + \\ \text{geometry}(\text{point})$$

Similarly, a bar chart of the same data might be:

$$\text{encodings}(x \text{ position} \leftarrow A, \text{height} \leftarrow B) + \\ \text{geometry}(\text{bar})$$

Importantly, encoding additional variables into other visual channels typically does not require substantial changes to a design. For example, a scatterplot showing two different groups based on a variable $C \in \{c_1, c_2\}$ might simply map the variable C onto the *color* channel, generating a scatterplot where points are colored different depending on which group they belong to (c_1 or c_2):

$$\text{encodings}(x \text{ position} \leftarrow A, y \text{ position} \leftarrow B, \text{color} \leftarrow C) + \\ \text{geometry}(\text{point})$$

$$\text{encodings}(x \text{ position} \leftarrow A, y \text{ position} \leftarrow B, \text{height} \leftarrow P(A|B)) + \\ \text{geometry}(\text{block})$$

$$\text{encodings}(x \text{ position} \leftarrow A, y \text{ position} \leftarrow B, \text{height} \leftarrow P(A|B)) + \\ \text{geometry}(\text{unit})$$

While this works well for straightforward visualizations of data points, visualizing uncertainty in toolkits like ggplot2 requires the use of a whole variety of different geometries and statistics, such as densities, violin plots, histograms, dotplots, intervals, and ribbons [54]². These different plot types, if viewed within a probabilistic grammar of graphics, should not be so different from each other, but rather could be viewed as different variants of a much smaller set of geometries, with probability distributions assigned to different visual channels.

Frequency and proportion visualization grammars: Other visualization formalisms have been proposed for the creation of visualizations of *frequencies* or *proportions*; i.e. visualizations that depict counts or proportions within a dataset. *Product plots* [55] generalize a variety of plot types, including mosaic plots, treemaps, and stacked bar charts within a framework that specifies charts in terms of conditional

elsewhere in the visualization literature.

²but see, in particular, the ggplot2 function reference: <https://ggplot2.tidyverse.org/reference/> and the proliferation of alternative geometries for uncertainty and probability visualization in the ggplot2 ecosystem, such as the ggridges package: <https://cran.r-project.org/web/packages/ggridges/vignettes/introduction.html>