Poddar, Madhav; Beck, Fabian

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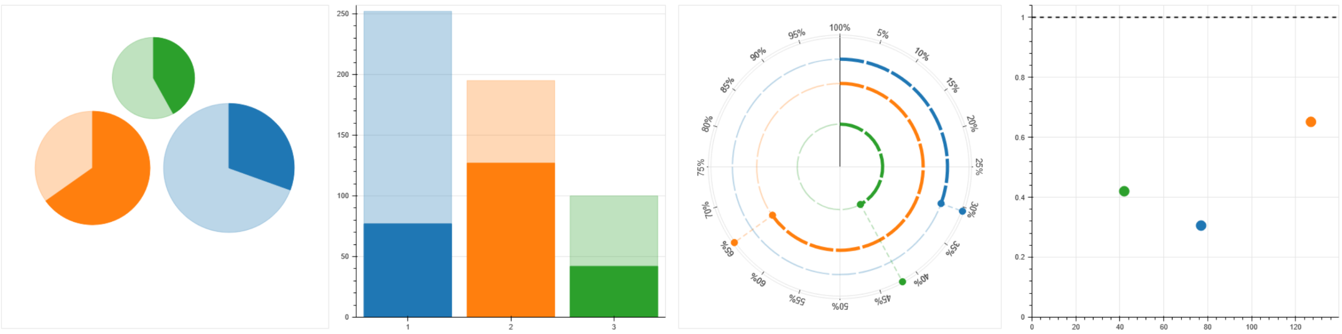
# Exploring Designs for Combined Visual Encoding of Absolute and Fractional Values

Madhav Poddar [†] and Fabian Beck [‡]



**(a) Glyph Pie Charts**
$\mathbb{A}$: Area (sector); $\mathbb{F}$: Angle (sector)
$\mathbb{W}$: Area (circle)
Encoding format: $A_{\mathbb{A}} \propto \theta_{\mathbb{F}} \cdot A_{\mathbb{W}}$
Aligned: None

**(b) Progress Bar Chart**
$\mathbb{A}$: Length (opaque); $\mathbb{F}$: Part-to-whole
$\mathbb{W}$: Length (translucent+opaque)
Encoding format: $L_{\mathbb{A}} = f_{\mathbb{F}} \cdot L_{\mathbb{W}}$
Aligned: $\mathbb{A}$

**(c) Arc Bar Chart**
$\mathbb{A}$: Length (arc); $\mathbb{F}$: Angle (arc)
$\mathbb{W}$: Length (circumference)
Encoding format: $L_{\mathbb{A}} \propto \theta_{\mathbb{F}} \cdot L_{\mathbb{W}}$
Aligned: $\mathbb{F}$

**(d) Scatterplot**
$\mathbb{A}$: Position (X-axis); $\mathbb{F}$: Position (Y-axis)
$\mathbb{W}$: Not visualized
Encoding format: $L_{\mathbb{A}}$, $L_{\mathbb{F}}$
Aligned: $\mathbb{A}$, $\mathbb{F}$

**Figure 1:** *Four visualization designs showing three data points with absolute values $\mathbb{A}$=[77, 127, 42], fractional values $\mathbb{F}$=[0.31, 0.65, 0.42], and respective whole values $\mathbb{W}$=[252, 195, 100].*


**Abstract**

*Datasets with absolute values that represent fractions of a whole are commonplace. To visualize these datasets, one can decide between visualizations highlighting the absolute value or the fractional value, but there are variants of visualizations that account for both. In this work, we explore the design space of such visualizations that show both the absolute and fractional values. Along with this, we include an initial assessment on what analysis tasks pertain to these designs and how these tasks might be influenced by the input data characteristics.*


## 1. Introduction

Visually comparing, for instance, vaccination rates between countries relies on encoding the **absolute values** ($\mathbb{A}$), representing the number of vaccinated individuals, and the **fractional values** ($\mathbb{F}$), representing the proportion of vaccinated individuals relative to the total population (i.e., the **whole values** $\mathbb{W}$). The absolute values $\mathbb{A}$ provide insight into the scale disparity and emphasize equality among individuals. However, a fair comparison between countries will require an analysis of fractional values $\mathbb{F}$. Hence, more desirable might be a combined visual encoding of both absolute values $\mathbb{A}$ and fractional values $\mathbb{F}$. It is important to highlight that these data attributes along with $\mathbb{W}$ are not independent, but rather connected by the part-to-whole relation given by ($\mathbb{F} = \frac{\mathbb{A}}{\mathbb{W}}$).

The four possible designs shown in Figure 1 serve as examples of such visualizations. While these designs might not be novel, however, we could not find literature that systematically describes possible design options. Some empirical work on the comparison of bar and pie charts [Eel26, SL91, SFK*20] and other part-to-whole visualizations [Red19, BBB*23] exists, but we are not aware of any design space description for such visualizations, which also discusses less well-known options such as Arc Bar Charts (Figure 1c). Hence, we explore the design space for this combined visual encoding (Section 2), followed by an initial assessment of these visualizations (Section 3) and discussing how certain data characteristics can impact the assessment (Section 4).


† madhav.poddar@uni-bamberg.de
‡ fabian.beck@uni-bamberg.de



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## 2. Design Space Exploration

In our study, we investigate single-view 2D visualizations of absolute and fractional numeric values for multiple data points. To visually encode absolute quantities $\mathbb{A}$, we consider position/length ($L$) or area ($A$), and for encoding fractional values $\mathbb{F}$, respectively position/length ($L$), angle/slope ($\theta$), or implicit encoding as a part-to-whole relationship ($f$). Although it is also possible to use hue, saturation, or curvature, they are perceptually not as effective [Mun14, Chapter 5] and are hence not included in this initial exploration. To structure the design space for our analysis, we differentiated the designs based on two parameters:

**Encoding format** We see different options to visually encode the variables $\mathbb{A}$, $\mathbb{F}$, and $\mathbb{W}$.

1. *Independent:* Both $\mathbb{A}$ and $\mathbb{F}$ are explicitly encoded independent of each other; $\mathbb{W}$ may not be explicitly visualized (e.g., Figure 1d).
2. *Proportional:* Both $\mathbb{A}$ and $\mathbb{F}$ are explicitly encoded in a proportional relationship, such as $A_{\mathbb{A}} \propto \theta_{\mathbb{F}} \cdot A_{\mathbb{W}}$ (e.g., Figure 1a), $L_{\mathbb{A}} \propto \theta_{\mathbb{F}} \cdot L_{\mathbb{W}}$ (e.g., Figure 1c), or $A_{\mathbb{A}} \propto L_{\mathbb{F}} \cdot L_{\mathbb{W}}$.
3. *Part-to-whole:* values $\mathbb{F}$ are implicitly encoded as part of a whole, such as $L_{\mathbb{A}} = f_{\mathbb{F}} \cdot L_{\mathbb{W}}$ (e.g., Figure 1b) or $A_{\mathbb{A}} = f_{\mathbb{F}} \cdot A_{\mathbb{W}}$.

**Alignment** Spatially, the encoded data points might be (or not be) aligned regarding the encoded absolute values $\mathbb{A}$ and fractional values $\mathbb{F}$, which creates four possible combinations (see examples for each in Figure 1). As indicated by Section 3, alignment plays a key role in the comparability of values and design flexibility.

So far, we have explored and implemented 26 different designs, out of which four are shown in Figure 1, while the rest are provided in the supplementary material.

## 3. Initial Assessment

For reading data from such visualizations, there are two main analysis tasks: inspecting individual data points and the comparison of data points. We expect the visualizations to perform differently in these tasks, as discussed in the following. Furthermore, ease of understanding and options to flexibly integrate the design with other visualizations are important criteria to consider. According to these criteria, we assess the four designs in Figure 1 as examples.

a. *Glyph Pie Charts:* Using pie charts to represent the fractional values $\mathbb{F}$, absolute values $\mathbb{A}$ can be encoded in area. Both encodings give a rough impression of the magnitudes, but might not allow directly reading precise values, most notably for the area encoding. The non-alignment of $\mathbb{A}$ and $\mathbb{F}$ makes comparing data points difficult, especially for $\mathbb{A}$. For example, determining if the blue sector's area is larger than the green one is hard. Despite these challenges, the chart is easy to understand and offers flexibility in glyph positioning (e.g., on a map).
b. *Progress Bar Chart:* Using partially filled bars, inspecting and comparing absolute values $\mathbb{A}$ is straightforward since they are encoded as length and aligned along the Y-axis. However, fractional values $\mathbb{F}$ are challenging to inspect and compare as they are implicitly encoded. Like the previous example, the design is easy to understand; however, relying on alignment, data points cannot be as flexibly arranged.
c. *Arc Bar Chart:* This design is made of a superimposition of donut charts (used for encoding fractional values $\mathbb{F}$) with circumference (or radius) scaled proportional to values $\mathbb{W}$, all aligned around a common center. Comparing and interpreting fractional values $\mathbb{F}$ is aided by radial segments extending from arc endpoints to outer circles with fractional ticks, and therefore easier than in the Glyph Pie Charts. While discretization helps interpret values $\mathbb{A}$ (e.g., in Figure 1c, each mini-arc represents 10 units), comparison and interpretation of absolute values $\mathbb{A}$ are more challenging compared to the Progress Bar Chart due to non-alignment. A downside of the design might be the somewhat uncommon encoding that takes a moment to understand, as well as that it is difficult to integrate with other visualizations.
d. *Scatterplot:* A scatterplot—for instance, encoding absolute values $\mathbb{A}$ on the X-axis and fractional values $\mathbb{F}$ on the Y-axis—excels at the two analysis tasks. However, the assignment of the axes is arbitrary and needs to be remembered, limiting the ease of use. Moreover, using the same length-based encoding for both sets of values, $\mathbb{A}$ and $\mathbb{F}$, does not create a cohesive, interpretable visual object like in the other designs. It is not flexible in its layout, but would allow the encoding of further attributes in the glyphs that encode the data points.

## 4. Data Characteristics

However, depending on the characteristics of the data, our initial assessment of these designs for the same analysis tasks may differ. We consider the following scenarios as relevant for future analysis.

**Large differences in scale:** In Figure 1, the dataset's scale variation is limited, but it may not always be the case. Non-linear scales or methods akin to Scale-Stack Bar Charts [HSBW13] could be considered for addressing scale differences in $\mathbb{A}$, $\mathbb{F}$, and $\mathbb{W}$.

**Low fractional values:** Fractional values $\mathbb{F}$ of 0.01 and below are possible to encode with the designs in Figure 1, but will not be readable as they are encoded too small or in the same position.

**Higher number of data points:** Increasing data points from 3 to, for instance, 60 may render many designs unusable because of visual scalability issues (e.g., overdraw). Additionally, it may shift analysis tasks toward the variation of fractional values $\mathbb{F}$.

**Extended data attributes:** The data points may include various attributes beyond $\mathbb{A}$ or $\mathbb{F}$, and the sequence of data points could also be of interest (e.g., temporal). Furthermore, we have not yet considered scenarios where the whole is divided into multiple categories.

## 5. Conclusion

We have started to systematically explore the design space of joint visual encodings of absolute and fractional values. To this end, we have established a formalism that supports describing various visualization designs. This not only allows defining uncommon chart types such as the Arc Bar Chart (Figure 1c), but also brings attention to this particular combined visual encoding. Although our list of design choices might not yet be exhaustive, it provides a basic framework for design choice categorization, which may help develop new designs. Similarly, the discussed analysis criteria and data characteristics could serve as the basis for conducting further research in this area.

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