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Is There Consistency in Visualising Missing Data? A Review of Existing Approaches

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Missing data is the absence of data in a dataset and can be encountered in almost every field. It is crucial to address this element of any given dataset, because missing data has the potential to impact the entire data lifecycle, such as data collection, cleaning, processing, analysis and results. Consequently, visualising missingness is also important for analysing and interpreting patterns of absence. Visualisation approaches, as part of data processing, offer several ways to handle missingness, such as encoding missing values or imputing them (Song & Szafir, 2018). Although some techniques exist for visualising missing values, it remains challenging to evaluate the appropriateness of these approaches for users' needs (Alsufyani et al., 2024).

The lack of a systematic approach to representing missing data needs to be addressed, as it may have the potential to cause miscommunication or mislead decision-making. From a geospatial perspective, spatial data plays an important role in areas such as decision-making, policy development, urban planning, and transportation; therefore, missing spatial data can become a significant issue due to its potential to influence outcomes in these contexts. This highlights the need for a consistent approach, in the same way that cartographic principles have been established, and led us to consider the following question: Can the visualisation methods used in the literature to represent missing data across many fields be consistently interpreted when evaluating visualisation approaches in cartography?

To understand, from a broader perspective, how missing data and patterns that can lead to missingness are represented in visualisations across different approaches in the literature, we adopted a structured review approach of these studies through academic databases and platforms such as Scopus, Web of Science, Google Scholar, IEEE Xplore and SpringerLink. Studies without visual representation were excluded from the review. Studies were selected that included at least one visualisation method representing missing data, such as a map, chart, or diagram, and those missingness could be identified using keywords such as "missing data", "missingness", "no data", "data absence", "incompleteness", and "uncertainty". As a result of this search, 61 papers were selected for analysis of visualisation approaches for representing missingness. These studies showed that there are several approaches to represent missingness in visualisations across different fields. When examining visualisation techniques, especially in cartographic contexts, Robinson's paper (Robinson, 2019) is particularly noteworthy as a comparative study for evaluating the most effective approach. Eight static techniques were presented on a map to enable comparative analysis.

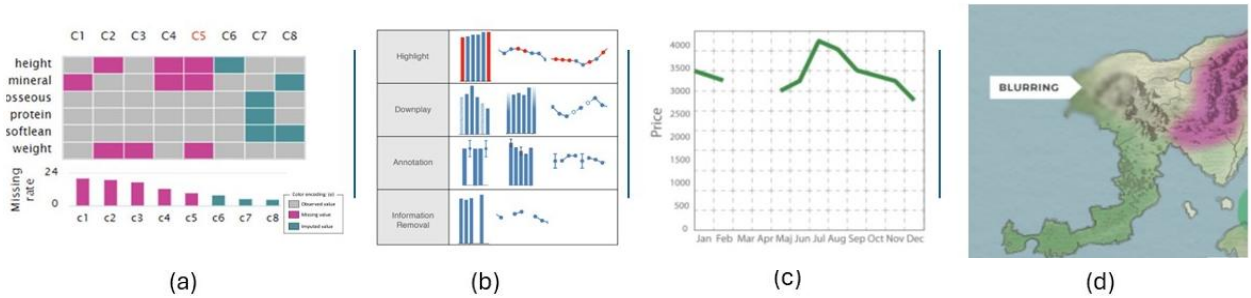

Figure 1. Examples of Missingness Representations

While some papers visualised using hue (Figure 1a: (Song & Szafir, 2018; Yeon et al., 2020) and blank (Figure1b and c: (Cort & Riveiro, 2014; Torre et al., 2012)), others used transparency (Newman & Lee, 2004) and blur (Figure 1d: (Levontin et al., 2020). Another group of studies represented by value and texture (MacEachren et al., 2012).

Figure 2. Eight visualisations of missing data approaches from Robinson (2019)

Visualisation Approach	Number of Papers
Hue	43
Blank	14
Transparency	15
Blur	8
Saturation	7
Texture	8
Value	6
Shadow	1

Table 1. Number of papers using these visualisation approaches

Our study aims to compare these techniques with those reported in 61 papers in the literature to assess whether they constitute a consistent approach. To assess consistency in the use of the eight visualisation approaches proposed in Robinson's work, the papers we selected for review were mapped against these approaches. These approaches are: Blank (emptiness), Hue (colours), Saturation (saturation encoding), Value (lightness variation), Transparency (opacity), Blur (clarity), Texture (patterns), and Shadow (shading) (Figure 2).

In conclusion, while a dominant approach to representing missingness across various fields and visualisation examples (such as maps, charts, diagrams, etc.) can be observed among these studies (Table 1), a consistent standard and consensus remain unclear. This study revealed that, despite the use of several techniques for the visual representation of missing data and the inclusion of many of the visualisation techniques proposed by Robinson in a comparative manner, there remains a need for further empirical investigation. Furthermore, user-based research on the effectiveness of these visualisation techniques could be beneficial for understanding and representing missingness. Therefore, future work will focus on examining the effectiveness of these techniques through a user-based study.

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References

Alsufyani, S., Forshaw, M., & Fernstad, S. J. (2024). Visualization of missing data: a state-of-the-art survey. arXiv preprint arXiv:2410.03712.

Robinson, A. C. (2019). Representing the Presence of Absence in Cartography. Annals of the American Association of Geographers, 109(1), 286–300. https://doi.org/10.1080/24694452.2018.1473754

Song, H., & Szafir, D. A. (2018). Where's my data? evaluating visualizations with missing data. IEEE transactions on visualization and computer graphics, 25(1), 914–924.