

# Certainly Uncertain: Reintroducing Uncertainty in Visualizations

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## Abstract

*Information Diffusion (ID) is shaped by uncertainty, yet most visualizations overlook it, leading to oversimplified or misleading interpretations. This work enhances two existing ID visualizations by integrating uncertainty through visual encodings within the original research goals. We are exploring how visualizing uncertainty might influence interpretation, including the potential for signal suppression or amplification. We discuss design alternatives and insights that apply to visualizing uncertainty in two existing visualization techniques. Future work directions are focusing on evaluating the designs and eliciting user feedback and comments on the interpretability and intuitiveness of the proposed uncertainty visualization encodings.*

## CCS Concepts

• **Human-centered computing** → **Visualization**;

## 1. Introduction

Uncertainty is inherent in data analysis, especially in dynamic networks, where it influences how information is interpreted and propagated. While uncertainty visualizations are intended to enhance decision-making, research suggests that effectively incorporating uncertainty remains a challenge. Concerns about misinterpretation, added complexity, and lack of standard methods often lead to excluding uncertainty, despite its crucial role in interpretation [Hu19, PPKH21, KDJ\*21, CGH\*24, MSH\*23]. However, omitting uncertainty distorts analysis and leads users to draw misleading conclusions [MCG\*24, BJSM22, DK23]. ID refers to how information spreads over communication networks. It is stochastic in nature, influenced by behavior, external events, and network topology [GHFZ13]. Research [CLY17, GHFZ13] focused on structural and temporal patterns but overlooked the relevance of visualizing uncertainty. Most ID visualizations emphasize clear diffusion paths while suppressing weaker signals, leading to misperception of how and why information spreads. Excluding uncertainty in visualizations risks reinforcing an illusion of certainty in inherently unpredictable processes. Furthermore, uncertainty visualization is “noisy” [MCG\*24], with results varying significantly between task framing, user perception, and specific design choices. When users are made aware of a visualization’s confidence levels, missing data, or probabilistic aspects, they are better equipped to interpret the information critically rather than taking it at face value. Transparency is particularly valuable in ID, where the stochastic nature of diffusion processes means that absolute certainty is rarely attainable.

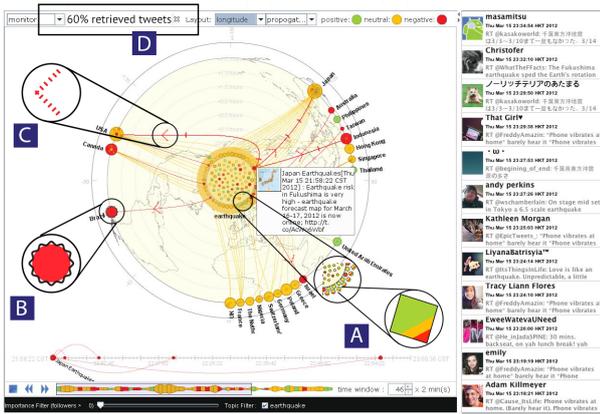
**Contribution:** This poster revisits two influential ID visualizations and explores how uncertainty can be meaningfully reintroduced while preserving the original research objectives. By modifying these visualizations to include uncertainty through visual encod-

ings, we assess whether this additional layer influences interpretation, including effects like signal suppression or misinterpretation.

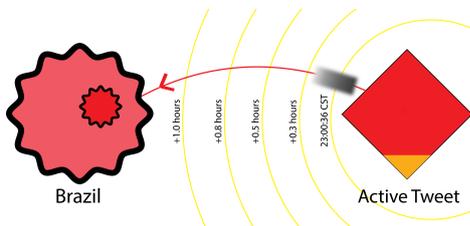
## 2. Case Studies

We adapt ID visualizations from two domains, social media and epidemics with the goal of introducing uncertainty while preserving the research objectives, refining visual channels from the paper to suit the visualization. Through the interactive poster session, we invite feedback and discussion on the intuitiveness of these uncertainty representations and explore alternative design possibilities.

**I. Social Media** has been a significant research focus due to its critical role in the rapid diffusion of information. One of the widely cited works in this domain is Whisper [CLS\*12]. Whisper encodes retweets relationships using sunflower glyphs, incorporating both temporal (*when*) and spatial (*where*) aspects of the diffusion process. Whisper enables researchers to track viral trends, identify popular topics, and understand the influence of key players dynamically. With use cases like politics and earthquakes, Whisper highlights critical moments and locations in information spread. By incorporating uncertainty, we aim to reflect the stochastic nature of ID and offer a more nuanced and reliable view of how, when, and where information spreads. In Whisper, colors were used to represent sentiments both in individual tweets and across user groups during the ID processes. We aim to enhance this approach by using textured patterns, where each pattern includes a combination of three sentiment colors (see Figure 1-A), encoding how probable a sentiment category is at any given moment. As noted in the expert evaluation of Whisper [CLS\*12, 9], one user commented, “*I can have a sense of what sentiment is from what place*”. By adding uncertainty, we not only preserve the sentiment visualization but



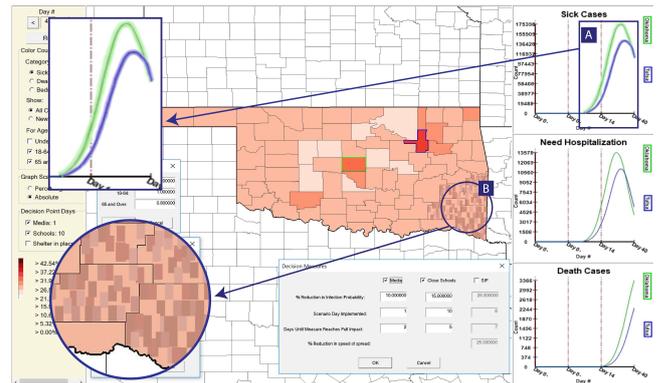
**Figure 1:** Whisper [CLS\* 12] modified with (A) sentiment, (B) spatial, (C) temporal, and (D) data completeness uncertainties.



**Figure 2:** Retweet glyph showing temporal uncertainty. Upon interaction, grayscale shading encodes the likelihood of the retweeting.

also offer a deeper understanding of the variability and confidence in sentiment categorization, enriching users’ interpretation of the diffusion process. For geocoded user groups, missing geoinformation in user profiles introduces spatial uncertainty, even though it is tackled by using tweet locations. We will use wiggly lines around the circular location markers (see Figure 1-B) to encode this uncertainty. This enhancement aligns with the original goals of Whisper, as another user remarked [CLS\* 12, 9], “A journalist would like to report a topic [...] becoming popular elsewhere; your tool has the potential to do this.”. Making location confidence explicit supports this kind of investigative use case. Whisper also captures “bursts of activity” through proximity of the retweet (i.e., arrow) glyphs within a time frame. However, real-time systems introduce uncertainties like delays in processing, data transfer, or API limitations, leading to partial or delayed visibility of events. To represent this temporal uncertainty, we use a grayscale gradient that appears when users interact with (i.e., click on) a retweet glyph. This visual cue helps users explore possible variations in the retweet timing, rather than assuming a fixed moment in time (see Figure 1-C and Figure 2). Additionally, since Twitter API’s may return only a subset of all relevant tweets, especially during high-traffic periods, we propose visualizing the tweet coverage uncertainty (see Figure 1-D) as well to help users interpret trends more accurately and avoid overconfidence in incomplete signals.

**II. Epidemics, particularly COVID-19, generated significant re-**



**Figure 3:** COVID-19 dashboard [AGJS\* 20] modified with (A) confidence bounds and (B) pixel tessellated choropleth map

search interest in ID. The paper by Afzal et al. [AGJS\* 20] focuses on providing a comprehensive decision-making environment that aids in understanding and mitigating the spread of COVID-19. The primary goals are to help public health officials estimate critical metrics like the number of sicknesses, hospitalizations, and the duration of the pandemic, as well as evaluate different scenarios based on various interventions, such as shelter-in-place measures. The paper uses predictive models to analyze spatiotemporal contagion dynamics via a geospatial map, enabling comparisons across counties under various circumstances. One of the future goals of this paper is to incorporate model uncertainty into the visualization, highlighting a clear need for uncertainty-aware design. To expand on this, we suggest using pixel tessellations over the choropleth map, as recommended by [LW17, KMB08] to encode parameter uncertainty, as this visualization relies on the input parameters (see Figure 3-B). This supports reducing the risk of misinterpretation [MCG\* 24] where conclusions may be less certain. Since users are particularly focused on numerical metrics like case counts and hospitalizations, incorporating confidence bands around baseline projections can communicate the likelihood of alternative outcomes and helps in reliable decision-making (see Figure 3-A).

**3. Discussion & Future Work**

We augment existing visualizations by reintroducing uncertainty, making them more transparent and reliable. By embedding uncertainty into visual channels, we sought to modify visual representations to be uncertainty-aware without deviating from the original research goals. Future work aims to develop uncertainty-aware visualizations that specifically address propagation uncertainty taking the lessons learned from this poster. We believe that animation is particularly well-suited for this purpose, as it can effectively convey temporal dynamics and variability over time [PABP20].

**Acknowledgements.** This work was funded by the Austrian Science Fund (FWF) projects SANE [10.55776/I6635] and ArtVis [10.55776/P35767]. The authors acknowledge TU Wien Bibliothek for financial support through its Open Access Funding Programme.

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