Paper Summary

<!--META_START-->

Title: Navigating Uncertainty: Challenges in Visualizing Ensemble Data and Surrogate Models for Decisio

Authors: Kristi Potter, Sam Molnar, J.D. Laurence-Chasen, Yuhan Duan, Julie Bessac, Han-Wei Shen

DOI: 10.1109/MCG.2025.3549665

Year: 2025

Publication Type: Journal

Discipline/Domain: Computer Graphics / Visualization

Subdomain/Topic: Uncertainty visualization, ensemble simulation, surrogate modeling, decision support s

Eligibility: Eligible

Overall Relevance Score: 88

Operationalization Score: 80

Contains Definition of Actionability: Yes (implicit)

Contains Systematic Features/Dimensions: Yes

Contains Explainability: Yes

Contains Interpretability: Yes

Contains Framework/Model: Yes (conceptual)

Operationalization Present: Yes

Primary Methodology: Conceptual + Case Study (Flood Modeling)

Study Context: Visualization design for integrating ensemble data and AI-based surrogate models to supp

Geographic/Institutional Context: National Renewable Energy Laboratory (USA), The Ohio State Universi

Target Users/Stakeholders: Decision-makers, scientists, engineers, emergency planners

Primary Contribution Type: Conceptual framework + applied case study

CL: Yes

CR: Yes

FE: Yes

TI: Partial

EX: Yes

GA: Yes

Reason if Not Eligible: N/A

<!--META_END-->

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Discipline/Domain: Computer Graphics / Visualization

Subdomain/Topic: Uncertainty visualization, ensemble simulation, surrogate modeling, decision suppo

Contextual Background: The paper addresses how uncertainty visualization can transform ensemble

Geographic/Institutional Context: USA – National Renewable Energy Laboratory, The Ohio State Univ

Target Users/Stakeholders: Decision-makers in domains such as disaster response, infrastructure pla

Primary Methodology: Conceptual + applied case study (flood modeling scenario)

Primary Contribution Type: Conceptual framing with practical illustration

General Summary of the Paper

The paper examines how uncertainty visualization can support decision-making when combining ensemb

Eligibility

Eligible for inclusion: **Yes**

How Actionability is Understood

The authors implicitly define actionability as enabling decision-makers to confidently interpret, navigate, a

> “Uncertainty visualization plays a critical role in transforming ensemble simulation data into actionable i

> “…ensuring users can access relevant information, evaluate it accurately, and have confidence in their

What Makes Something Actionable

- Clear communication of uncertainty types (ensemble vs. surrogate)

- Support for both global exploration (ensembles) and localized queries (surrogates)

- Ability to interact flexibly with input and output spaces

- Representation of joint and conditional parameter relationships

- Support for tradeoff analysis when objectives conflict

How Actionability is Achieved / Operationalized

- **Framework/Approach Name(s):** Not named formally, but uses a conceptual integration framework (F

- **Methods/Levers:** Visual parameter space exploration, forward and inverse surrogate modeling, widg

- **Operational Steps / Workflow:** Explore ensemble data → Use forward surrogate for prediction → Us

- **Data & Measures:** Ensemble simulation outputs, surrogate predictions, quantified uncertainty metric

- **Implementation Context:** Flood modeling (dam breach scenario)

> “…present the intricate connections between input parameters and output predictions in an intuitive ma

> “…highlight sets of inputs that satisfy each output individually as well as input configurations that achiev

Dimensions and Attributes of Actionability (Authors’ Perspective)

- **CL (Clarity):** Yes — Clear representation of uncertainty is essential for decision-making.

- **CR (Contextual Relevance):** Yes — Tailoring visualizations to specific decision-makers (engineers v

- **FE (Feasibility):** Yes — Identifying when scenarios are feasible and when constraints are unrealistic.

- **TI (Timeliness):** Partial — Surrogates enable faster exploration but timeliness is not emphasized as a

- **EX (Explainability):** Yes — Differentiating uncertainty sources and mapping input–output dependenc

- **GA (Goal Alignment):** Yes — Linking visualization design to stakeholder objectives.

- **Other Dimensions Named by Authors:** Tradeoff analysis, interpretability, interactivity.

Theoretical or Conceptual Foundations

- Ensemble simulation theory

- Uncertainty visualization literature

- Surrogate modeling (Gaussian Processes, deep learning)

- Visual parameter space analysis frameworks

Indicators or Metrics for Actionability

- Degree to which uncertainty is distinguishable (ensemble vs. surrogate)

- Accuracy and stability of surrogate predictions

- Ability to generate feasible and goal-consistent input–output configurations

Barriers and Enablers to Actionability

- **Barriers:** Surrogate accuracy variability; difficulty reconciling uncertainty types; usability challenges in

- **Enablers:** Integration of ensemble + surrogate strengths; interactive constraint setting; visualization o

Relation to Existing Literature

The paper extends prior work on uncertainty visualization by focusing on the integration of ensemble and

Summary

This paper provides a detailed conceptual and applied exploration of how uncertainty visualization can m

Scores

- **Overall Relevance Score:** 88 — Strong implicit conceptualization of actionability with multiple explicit

- **Operationalization Score:** 80 — Provides a clear applied example (flood modeling) and concrete inte

Supporting Quotes from the Paper

- “Uncertainty visualization plays a critical role in transforming ensemble simulation data into actionable in

- “Communicate diverse uncertainties: Clearly distinguish and convey the different uncertainties associate

- “Clarify input–output relationships: Present the intricate connections between input parameters and outp

- “Highlight sets of inputs that satisfy each output individually as well as input configurations that achieve

Actionability References to Other Papers

- Bonneau et al. (2014) – State-of-the-art in uncertainty visualization
- Sedlmair et al. (2014) – Visual parameter space analysis framework
- Obermaier & Joy (2014) – Challenges in ensemble visualization
- Shen et al. (2025) – Flow-based surrogate models for uncertainty quantification