A User Study to Compare Four Uncertainty Visualization Methods for 1D and 2D Datasets

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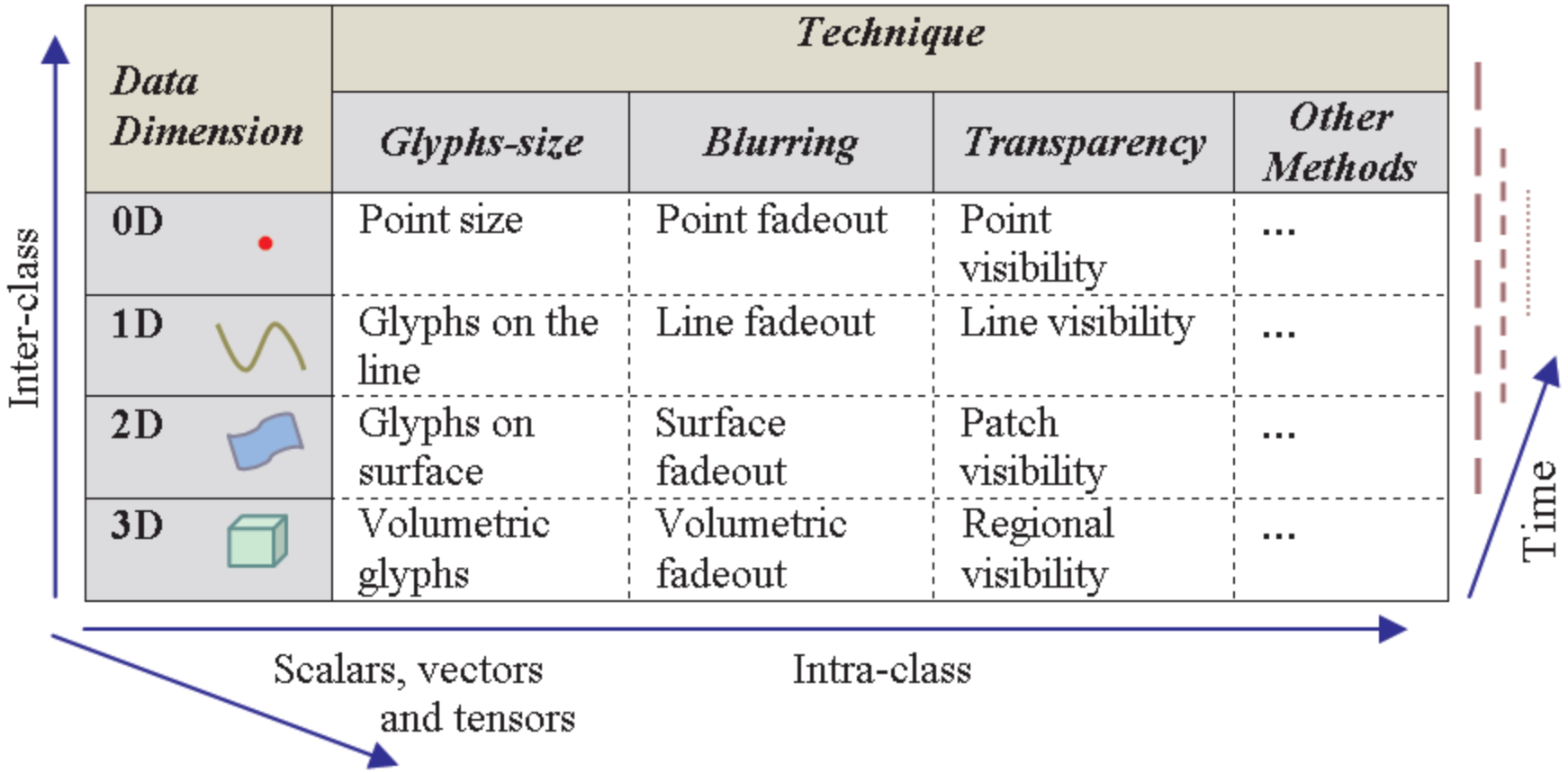
Background

- Define uncertainty
  - *CIPM - Statistical Method
    - Scientific Judgment
  - *NIST - A combined standard uncertainty
- Classify uncertainty visualizations
- Thomas presented a typology to visualize uncertainty information pertinent to geospatially referenced data.
- Olston, Mackinlay: statistical uncertainty & bounded uncertainty.

Background

- Schmidt presented the multivariate nature of bathymetric uncertainty.
- Rheingans visualized the positional uncertainty of molecules.
- Lundstroom presented animation method to illustrate uncertainty in medial volume renderings.
- Some user studies to understand effectiveness of uncertainty visualization but they were specific studies.

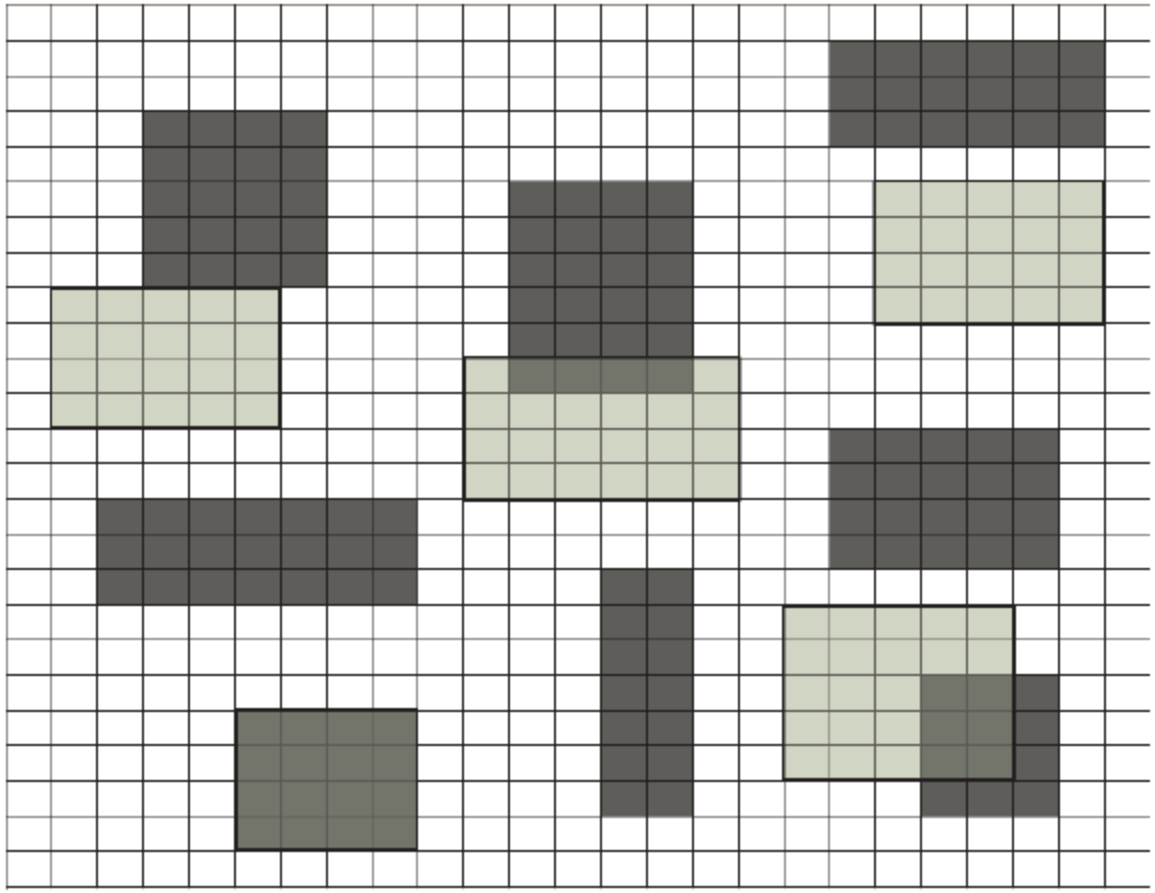
Uncertainty Evaluation Framework



Study Design

- Data Generation
- Visualization Techniques
- Participant Tool
- User-study tasks
- Interface design
- Participant Training
- Identifying tree parameters
- Main study

Data Generation

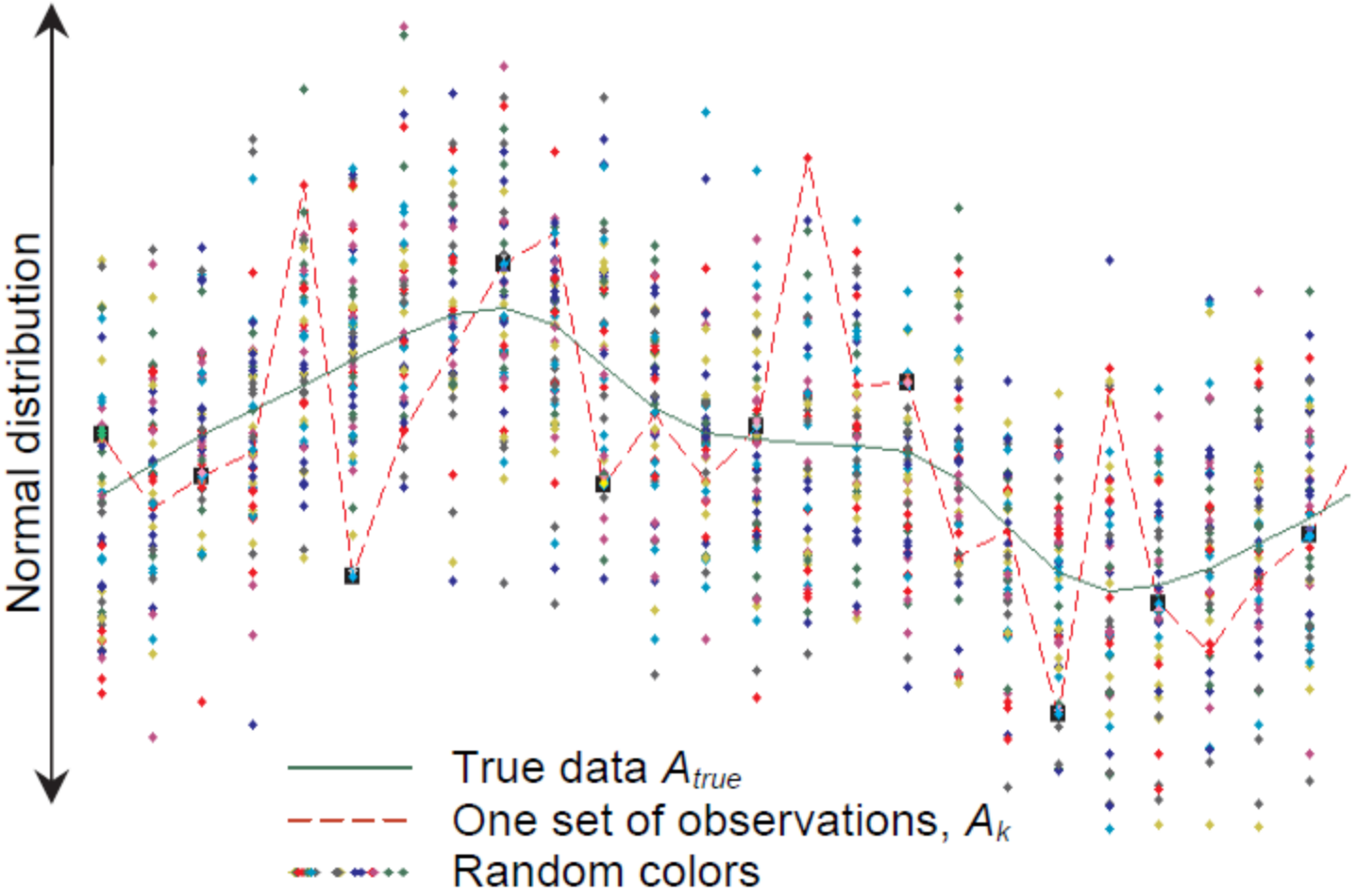


Uncertainty feature

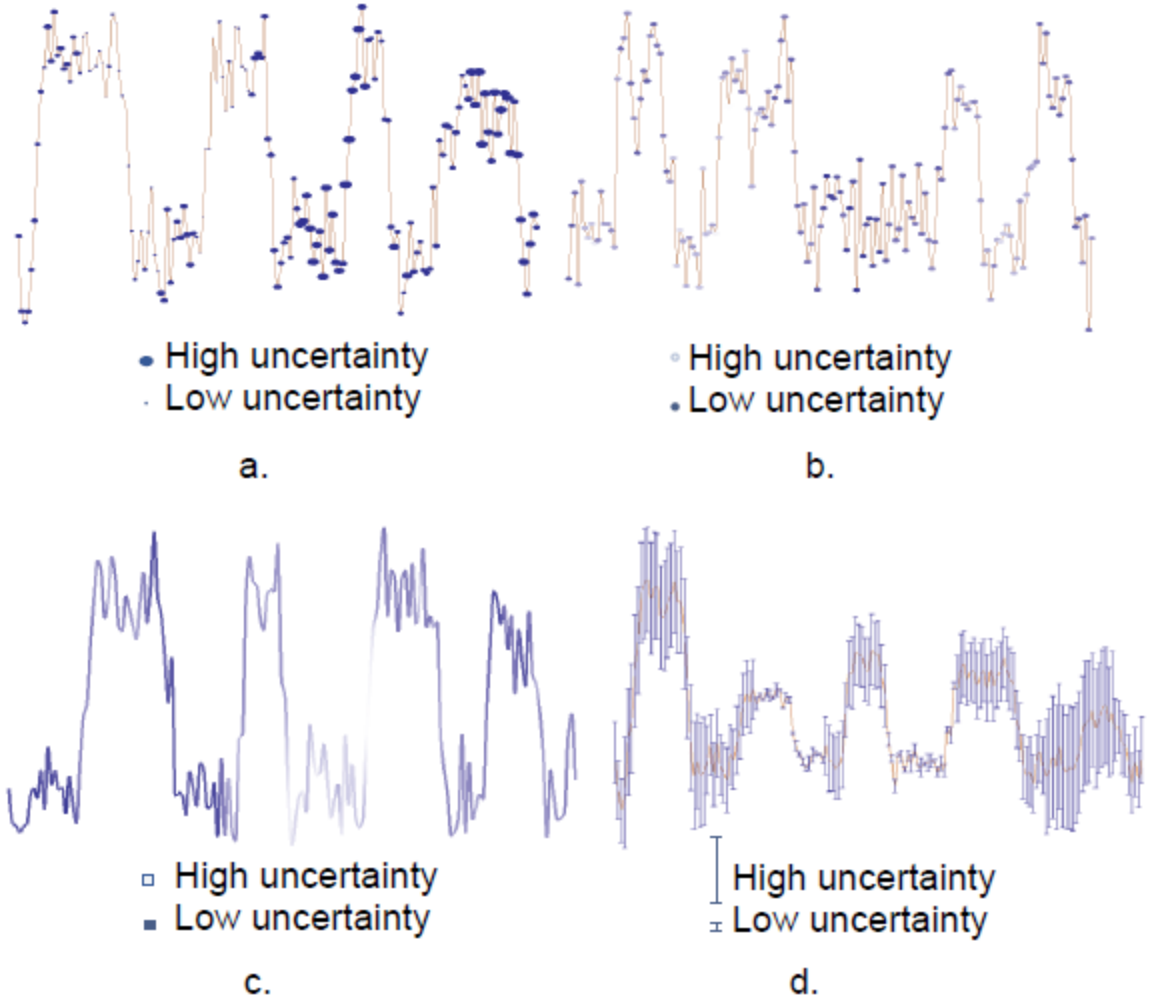
Data feature

Overlap of data and uncertainty feature

Data Generation



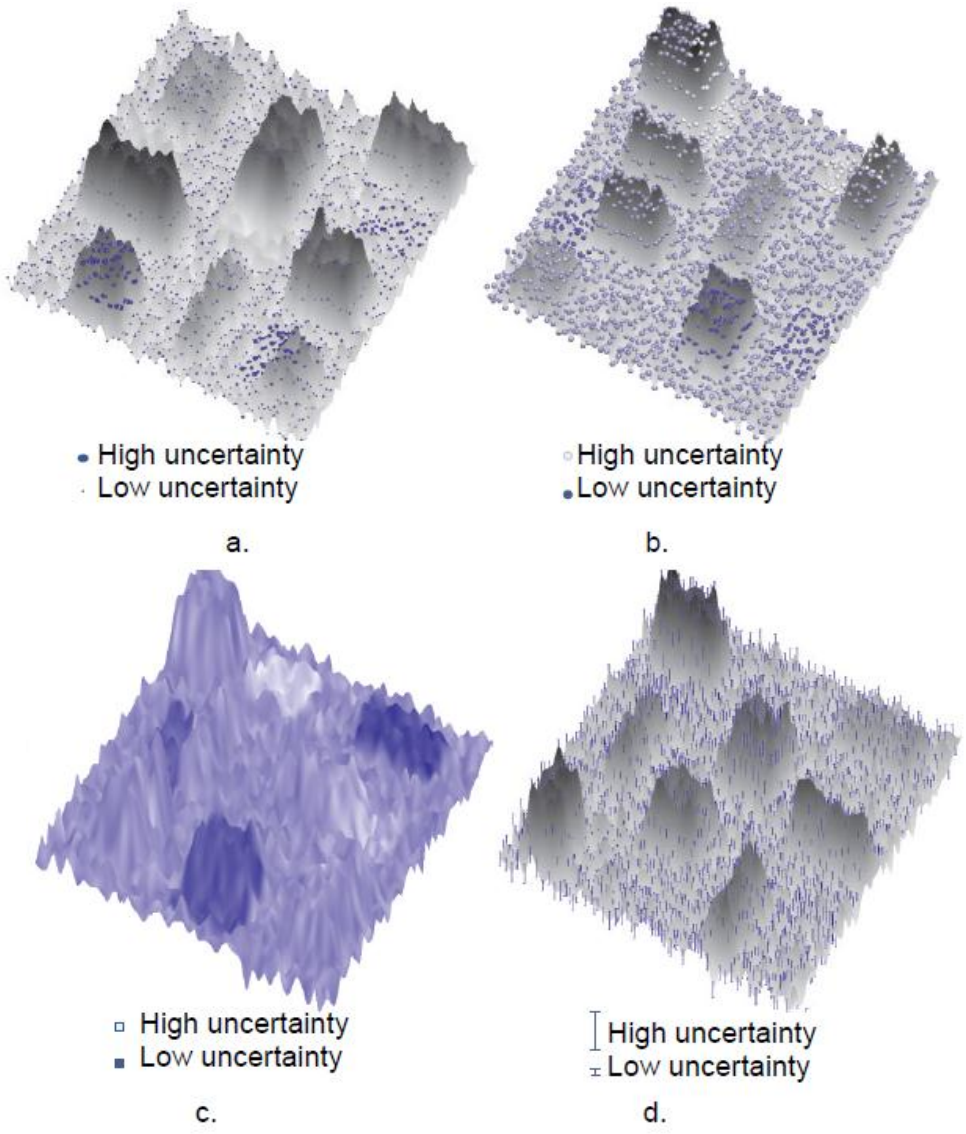
Visualization Techniques



Uncertainty visualization techniques explored for 1D datasets.

a) Scaling the size of glyphs
b) Altering the color attribute of glyphs
c) Color-mapping the surface of data with uncertainty
d) Using the traditional error bars.

Visualization Techniques



Uncertainty visualization techniques explored for 2D datasets.

a) Scaling the size of glyphs
b) Altering the color attribute of glyphs
c) Color-mapping the surface of data with uncertainty
d) Using the traditional error bars.

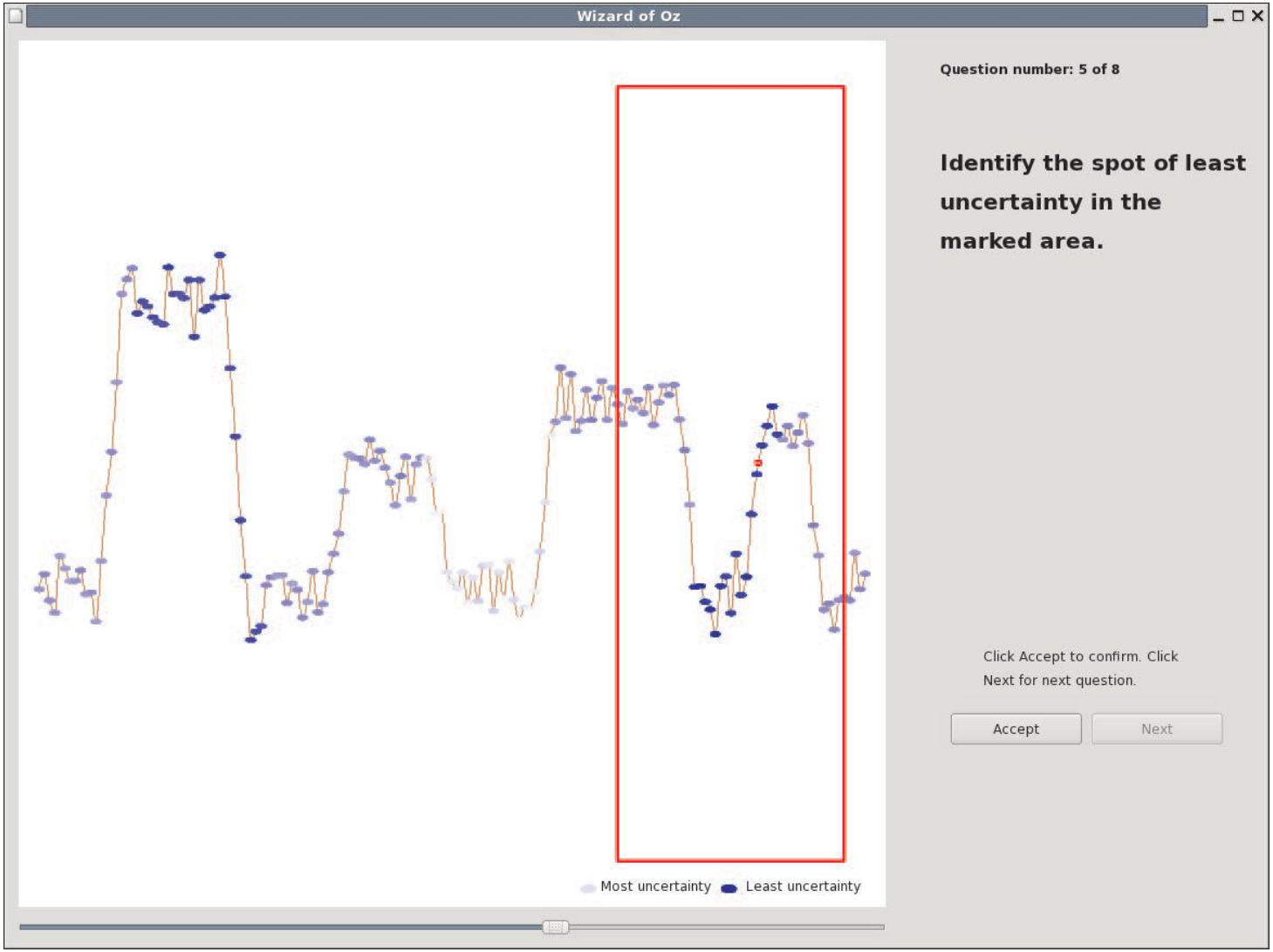
Participant Tool

- 36 participants: 6 participants in a pilot study, 27 in main study (2 researchers, 3 trial run people) (27 male and 19 female).
- Most people understand statistics, charts, graph.
- 15 hours weekly.

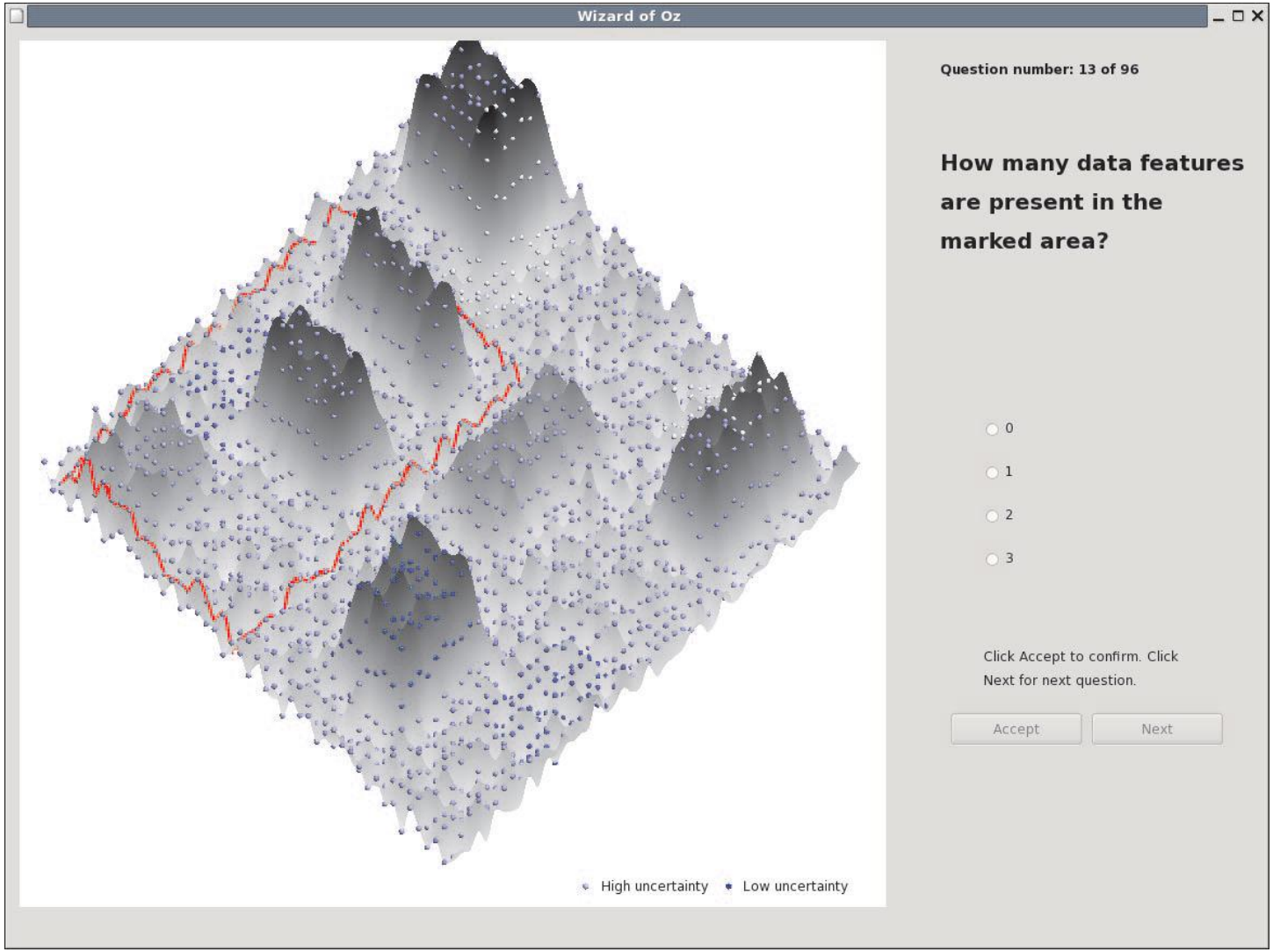
User-study Tasks

- Search Tasks:
  - Searching for locations of high or low uncertainty.
  - Expect users perform similarly with search tasks.
- Counting Tasks:
  - Counting data features (any peak in data) and uncertainty features.

Interface Design – 1D



Interface Design – 2D



Participant Training

- 15 – 20 minutes to brief the participant about user study.
- Users were assigned computer with training module.
- Familiarized users with 8 posed questions.

Identifying Free Parameters

- Pilot study
- 6 participants could use data from 4 of participants.
- Three size of error bars & glyph → compare small, medium and large presentations.
- 1 person – 144 questions.
- 1D data: use glyphs that had the largest size among the three evaluated sizes.
- 2D data: three glyph sizes used for glyph color-mapping.

Main Study

- 27 participants
- 98 questions (48 ques for 1D data, 48 ques for 2D data)
- 4 questions:
  - How many data features are present in the marked area?
  - How many uncertainty features are present in the marked area?
  - Identify the spot of least uncertainty in the marked area.
  - Identify the spot of most uncertainty in the marked area.

Methods of Analysis

Data Dim	Task t- values (df)	Significantly better	Significantly worse
1D	Search for location of low uncertainty (SLU) $F(3, 104) = 16.176,\ p < .0001$	Glyph size**	Glyph color
		Glyph size**	Surface color
		Glyph size*	Error bars
		Error bars*	Surface color
	Search for location of high uncertainty (SHU) $F(3, 104) = 13.874, p < .0001$	Glyph color**	Glyph size
		Glyph color**	Error bars
		Surface color**	Glyph size
		Surface color**	Errorbars
	Count uncertainty features (CUF)	No significant difference	
	Count data features (CDF)	No significant difference	
2D	Search for location of low uncertainty (SLU) $F(3, 104) = 6.775, p < .0001$	Surface color*	Glyph size
		Surface color*	Glyph color
		Surface color*	Error bars
	Search for location of high uncertainty (SHU) $F(3, 104) = 48.144, p < .0001$	Surface color*	Glyph size
		Surface color**	Error bars
		Glyph size**	Error bars
		Glyph color**	Error bars
	Count uncertainty features (CUF) $F(3, 104) = 7.534, p < .0001$	Surface color*	Glyph size
		Surface color*	Glyph color
		Surface color*	Error bars
	Count data features (CDF) $F(3, 104) = 25.910, p < .0001$	Glyph size*	Glyph color
		Glyph size**	Surface color
		Glyph size*	Error bars
		Glyph color**	Surface color
		Error bars**	Surface color

* $p \leq .0083$
** $p \leq .0001$

ANOVA results for pairwise comparison on techniques

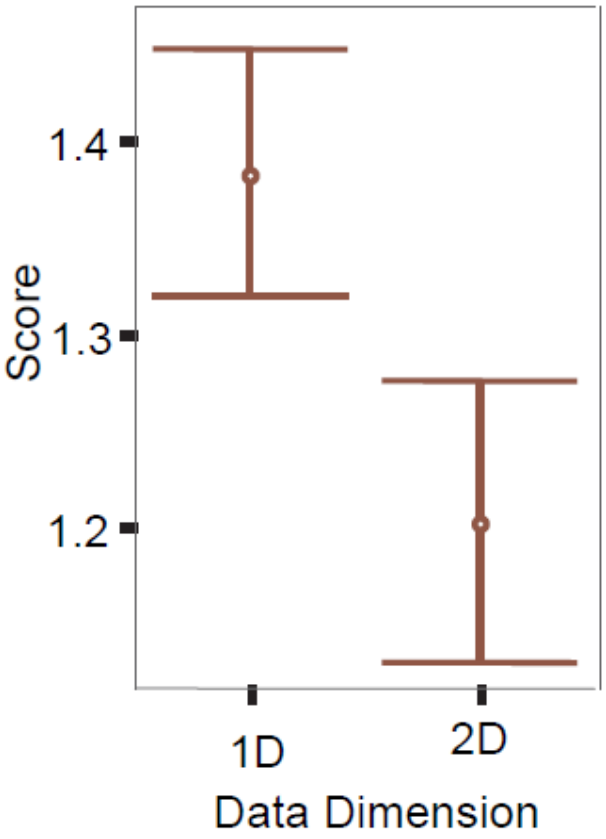
Methods of Analysis

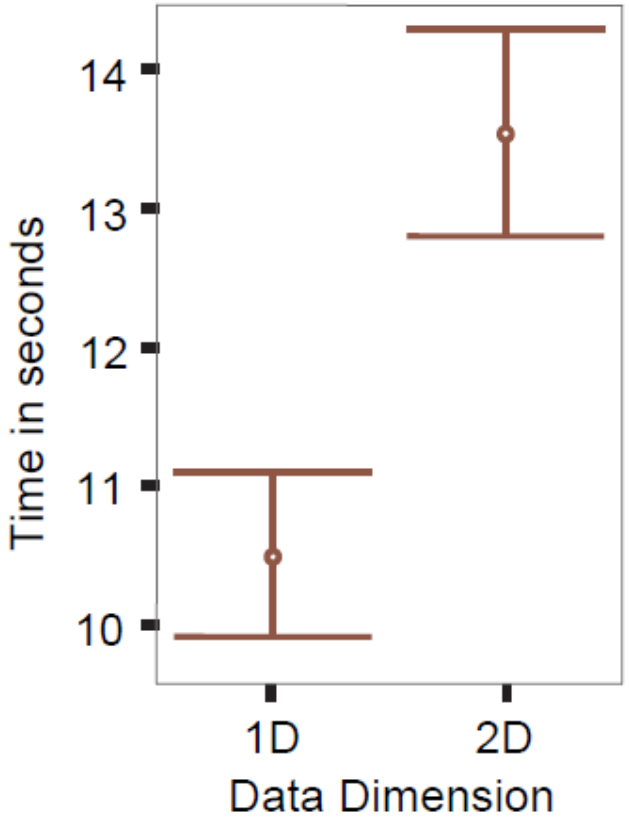
Data Dim	Technique t- values (df)	Significantly better	Significantly worse
1D	Glyph size $F(3, 104) = 13.499, p < .0001$	SLU**	SHU
		SLU**	CUF
		CDF**	SHU
	Glyph color $F(3, 104) = 6.880, p < .0001$	SHU*	SLU
		CDF**	SLU
		CDF*	CUF
	Surface color $F(3, 104) = 17.295, p < .0001$	SHU**	SLU
		CDF**	SLU
		CDF*	CUF
	Error bars $F(3, 104) = 11.587, p < .0001$	CDF**	SHU
		CDF**	CUF
2D	Glyph size $F(3, 104) = 16.721, p<.0001$	SHU**	SLU
		SLU**	CUF
		CDF*	SHU
		CDF**	SLU
		CDF**	CUF
	Glyph color $F(3, 104) = 11.780, p < .0001$	SHU**	SLU
		SLU*	CUF
		CDF**	SLU
	Surface color $F(3, 104) = 36.356, p < .0001$	SHU*	SLU
		SHU**	CDF
		CUF*	CDF
		CUF*	SLU
		SLU**	CDF
	Error bars $F(3, 104) = 14.067, p < .0001$	SLU**	SHU
		CUF**	SHU
		CDF**	SHU

* $p \leq .0083$
** $p \leq .0001$

ANOVA results for pairwise comparison on tasks

Result & Discussion



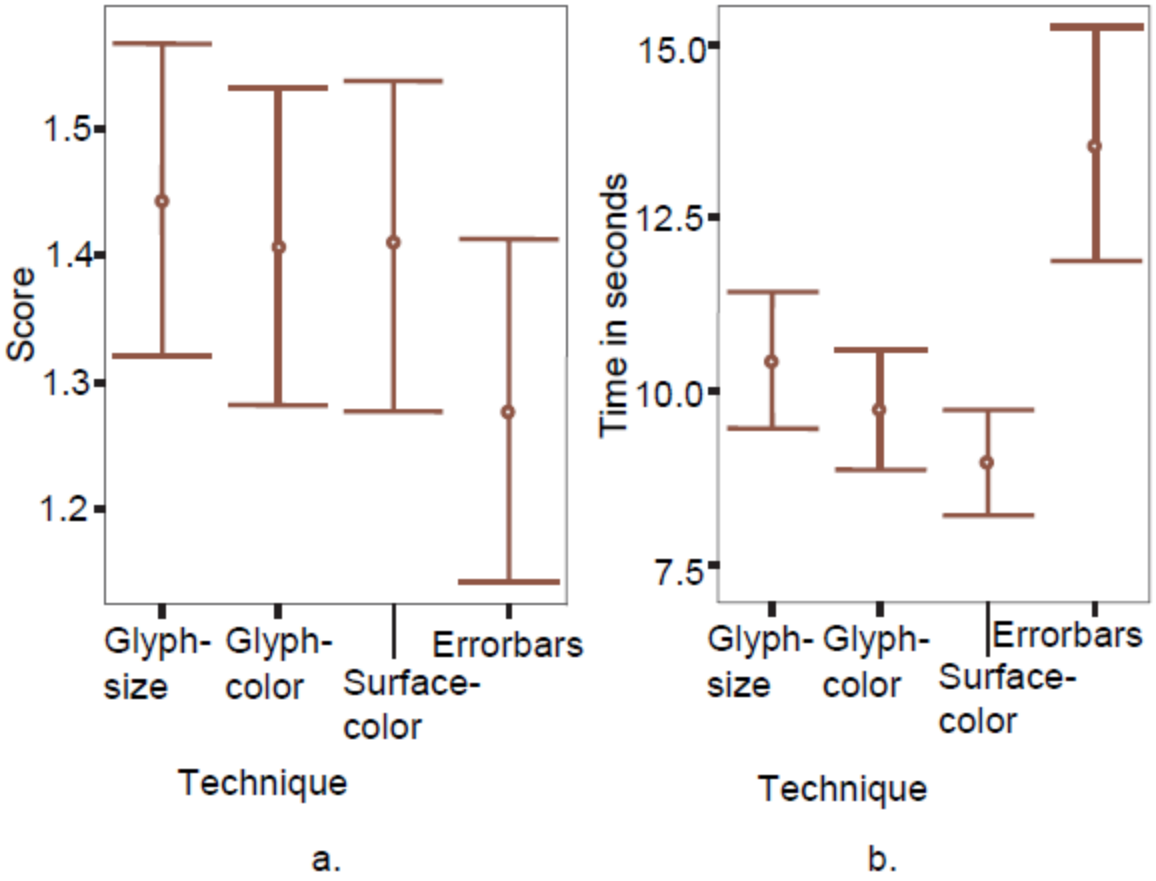


Overall performance of the two datasets.

a) Average scores attained for each dataset

b) Response time recorded for each dataset.

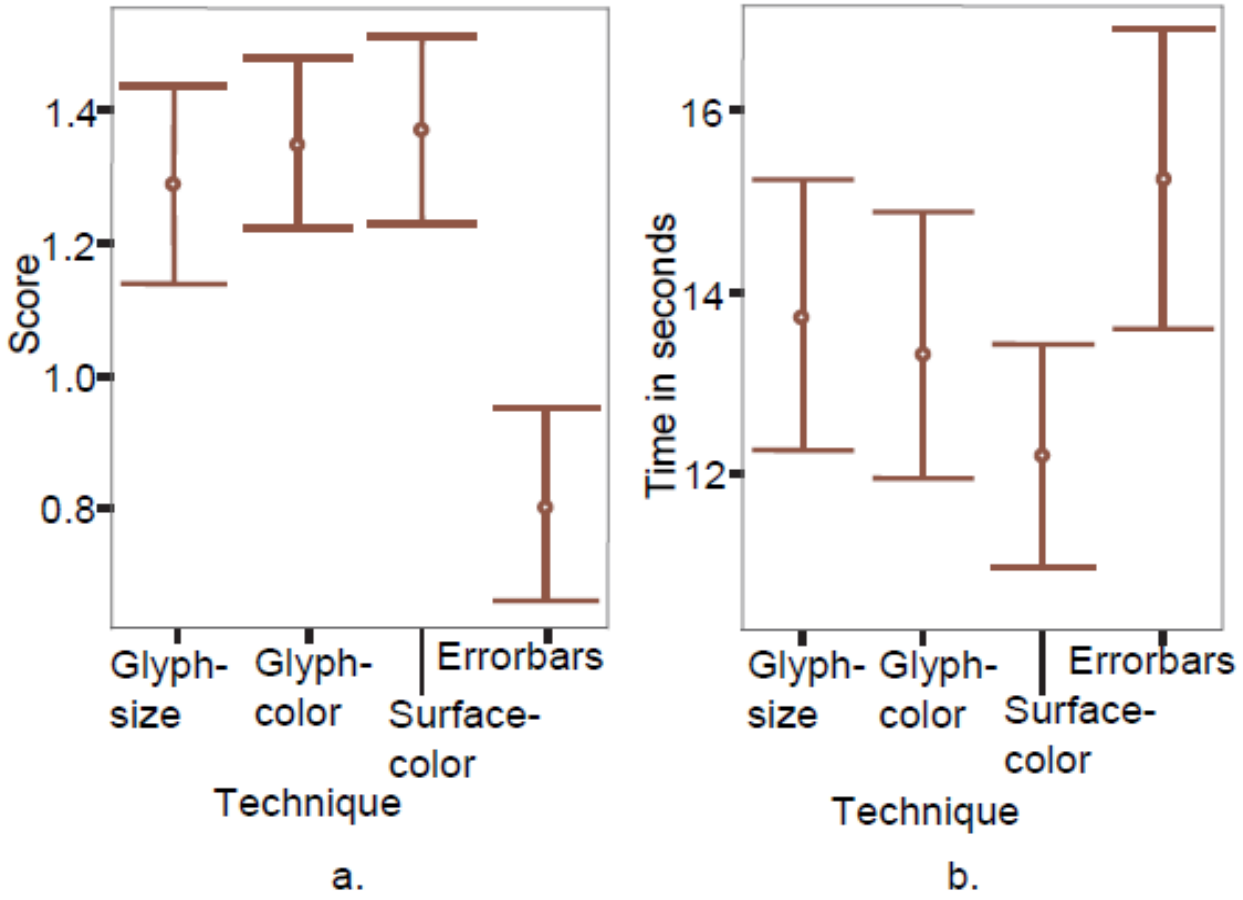
Result & Discussion



Performance plots for the 1D dataset

a) Average scores for each technique
b) Response times recorded for each technique.

Result & Discussion



Performance plots for the 2D dataset

a) Average scores for each technique
b) Response times recorded for each technique.

Conclusion

- User study to compare effectiveness of 4 uncertainty visualization techniques on 1D and 2D datasets.
- Accuracy of responses on 1D tasks was higher than 2D.
- Effectiveness of uncertainty Visualization depend on task at hand.
- Method to create synthetic data with uncertainty.

THANK YOU