Visual Analytical Approaches to Evaluating Uncertainty and Bias in Crowdsourced Crisis Information

Iain Dillingham

May 8, 2012

Overview

- Introduction
- Research questions
- Literature
- Data
- Research process
- Work plan
- Completed work
- Recent and planned publications

Overview

As slide.

The role of social media in humanitarian response

Rewards and risks

- Increasing numbers of people are using social media to exchange information during crisis and conflict events [5]
- Can the humanitarian community trust crisis reports from social media? Are these reports accurate? [22]

Introduction:

- A recent United Nations Foundation report highlighted how increasing numbers of people are using social media to exchange information during crisis and conflict events [5].
- Research suggests that the humanitarian community is reluctant to use reports from social media to respond to these events because it fears the cost of untrustworthy and inaccurate information [22].
- Result: Although there is potentially more information about conditions 'on the ground' during crisis and conflict events, the humanitarian community is reluctant to use this information in the response effort.

The role of social media in humanitarian response

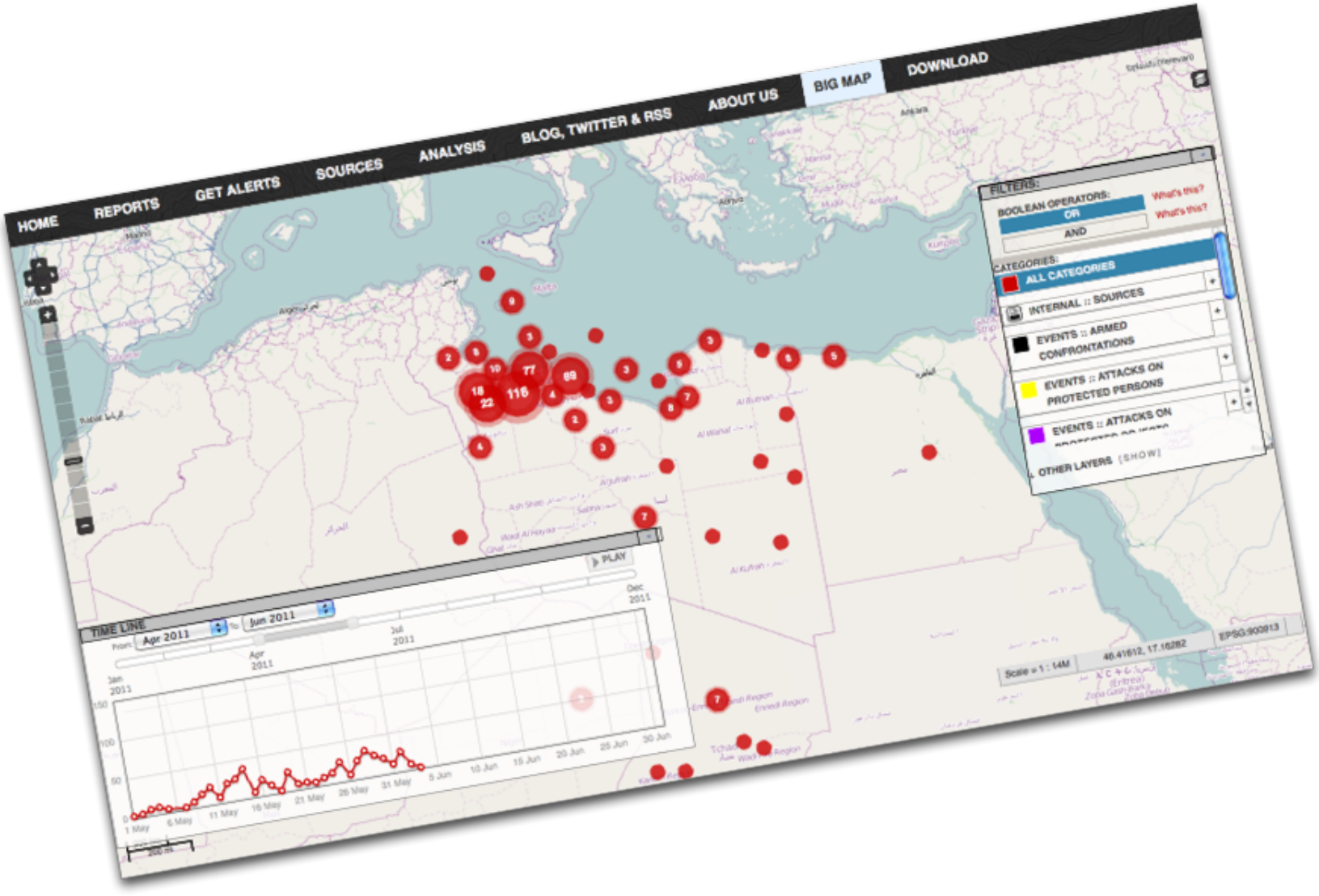
Crowdsourcing

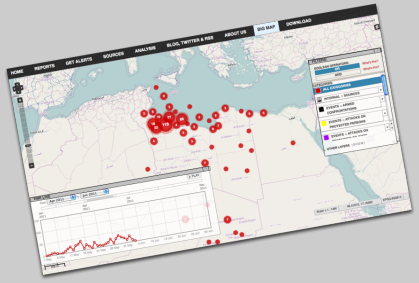
- Ushahidi: Software for crowdsourcing crisis information
- *Crowdsourcing:* The completion of tasks by a heterogeneous group, in response to an open call [9]

- The volunteer and technical communities have attempted to resolve this impasse. For example, Ushahidi is software for crowdsourcing crisis information.
- *Crowdsourcing:* The completion of tasks by a heterogeneous group, in response to an open call [9].

The role of social media in humanitarian response

Crowdsourcing





- An example of an Ushahidi deployment, in this case the Libya Crisis Map [18].

The role of social media in humanitarian response

Crowdsourcing

"The Karibe Hotel and ajoining apartments have collapsed. My brother and his three daughters—aged 2 to 6 are trapped inside one of the apartments in the Karibe compound. His wife, Emily Sanson-Rejouis can hear the baby cry. She urgently needs help. She has been waiting for help for the last 12 hours. The baby is crying." [24]

"The Karibe Hotel and ajoining apartments have collapsed. My brother and his three daughters—aged 2 to 6 are trapped inside one of the apartments in the Karibe compound. His wife, Emily Sanson-Rejouis can hear the baby cry. She urgently needs help. She has been waiting for help for the last 12 hours. The baby is crying." [24]

- In practice, 'crowdsourcing crisis information' means asking volunteers to ascertain whether crisis reports are trustworthy and accurate. However, volunteers also gather, categorise and—importantly—geocode crisis reports.
- A crisis report looks like this. . .

The role of social media in humanitarian response

Crowdsourcing

"We are looking for our cousins in Delmas 3 Guilda, Marie-Gerald and Jimmy (or anyone in the area) please let us know! or have them call us please. we haven't heard a thing since the incident. Email me at ladysica@hotmail.com thank you very much! May God bless you!" [24]

The role of social media in humanitarian response

Crowdsourcing

"...Good evening, I am in a little tent near to SOGED (30 Boulevard Toussaint Louverture), there are two guys Monday who are drinking acid make the food heat with a little sachet food the American people us to give..."

Research context

- Geography characterises crisis information
- Uncertainty = trust + accuracy + ...
- From GISc to VA

Where do we go from here?

- Research suggests that geography characterises crisis information.
- GISc and geovisualization have incorporated trust and accuracy into conceptual models of uncertainty.
- In terms of techniques, GISc has focused on accuracy.
- Because it combines human and computational approaches, VA offers another route into uncertainty.
- VA engages with the wider visualization literature, which includes geovisualization (and by extension GISc and cartography).

Research questions

1. To what degree are uncertainty and bias found in crowdsourced crisis information?
   - 1.1 What characteristics of uncertainty can be identified in crowdsourced crisis information?
   - 1.2 To what degree do these characteristics vary over space/place? over time? with theme?
   - 1.3 Are any of these characteristics subject to bias? (systematic variation)
2. What heuristics help manage uncertainty and bias in crowdsourced crisis information?

Visual Analytical Approaches to Evaluating Uncertainty and Bias in Crowdsourced Crisis Information

Research questions

As slide.

Characterising crisis information

- Geography characterises crisis information...
- ...but the nature and phase of the event may influence the geography

Literature:

- Research suggests that geography characterises crisis information, but the nature and phase of the event may influence the geography.
- Here, *geography* is as much about "socially produced" place as Euclidean space [6, p.6] and geographic phenomena also have temporal and thematic dimensions.

Characterising crisis information

Gelernter and Mushegian [8]:

- 1,500 tweets
- 253 locations appeared 1,207 times

How do we know about geography?

- Gelernter and Mushegian [8] report that in a dataset of roughly 1,500 tweets related to the 2011 earthquake in Christchurch, New Zealand, 253 locations appeared 1,207 times.

Characterising crisis information

Vieweg and colleagues [26]:

- 3,000 tweets
- 40% contained GI
- 19,000 tweets
- 18% contained GI

How do we know about geography?

- Vieweg and colleagues [26] report that:
  - of roughly 3,000 tweets, wildfire, 40% contained GI
  - of roughly 19,000 tweets, flooding, 18% contained GI
- They suggest that the difference in the percentages of GI may relate to the nature and phase of the event:
  - wildfire, unpredictable location, short warning phase
  - flooding, predictable location, long warning phase

Characterising uncertainty

Geographic information

Following MacEachren and colleagues [13]:

- Accuracy/error
- Precision
- Completeness
- Consistency
- Lineage
- Currency
- Credibility
- Subjectivity
- Interrelatedness

What do we know about uncertainty in GI?

- MacEachren and colleagues identify nine characteristics of uncertainty relevant to GISc and geovisualization [13].
- We can think of trust and accuracy as general concepts that embody many of these specific characteristics of uncertainty.

Characterising uncertainty

Geographic information

Following Fisher [7]:

- Accuracy
- Vagueness and ambiguity

What do we know about uncertainty in GI?

- Alternative perspectives: Fisher characterises uncertainty according to the 'definition' of geographic objects or classes of geographic objects [7].
  - well defined, accuracy
  - poorly defined, vagueness and ambiguity
- Fisher's vagueness and ambiguity do not have obvious analogues with MacEachren's nine characteristics of uncertainty. Accuracy is common to both, possibly because it is well researched in GISc.

Characterising uncertainty

Crowdsourced crisis information

- What is the 'target' dataset?
- What if geographic objects in crowdsourced crisis information are vague or ambiguous?

- GISc offers several techniques to evaluate the accuracy of geographic objects.
- These techniques compare 'test' datasets to 'target' datasets, the accuracy of which is known.
- It is much harder to evaluate the accuracy of CCI:
  - What is the 'target' dataset?
  - What if geographic objects in CCI are vague or ambiguous?

Visual analytics

- VA = human judgement + computational techniques
- Analytical reasoning (sensemaking)
- Interactive visual interfaces (visualization)
- Insight: Complex, deep, unexpected and relevant [16]

- VA offers a powerful means of tackling complex socio-technical issues such as uncertainty and bias.
- VA combines human judgement and computational techniques to "detect the expected and discover the unexpected" [23, p.10].
- Human judgement is exercised using "analytical reasoning facilitated by interactive visual interfaces" [23, p.10] to give someone (an analyst) insight into something (a problem).
- Insight is complex, deep, unexpected and relevant [16].

Visual analytics

Analytical reasoning and sensemaking

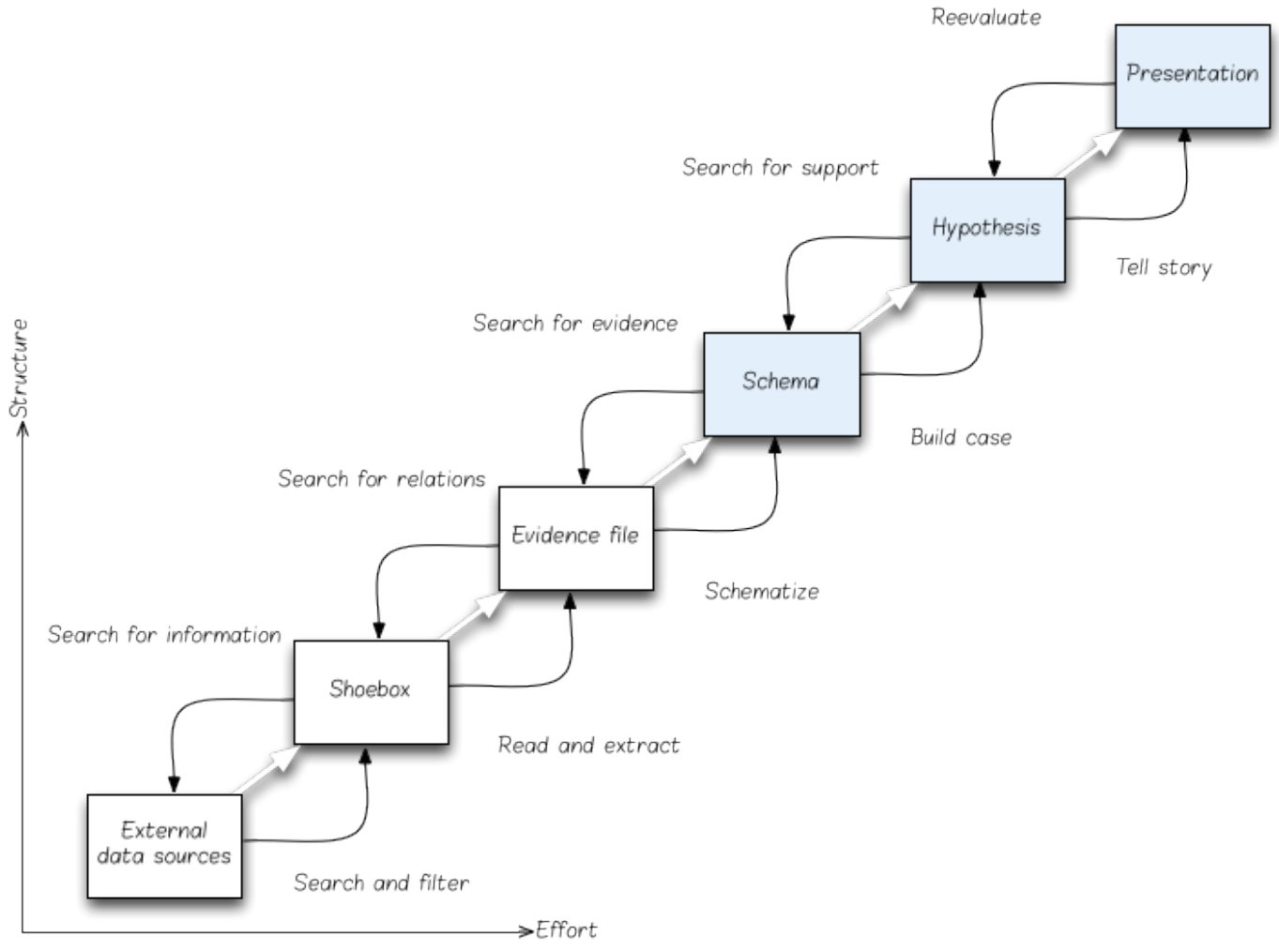


Figure: Sensemaking model [20]

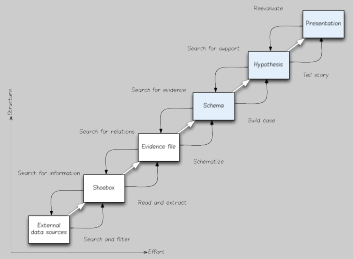


Figure: Sensemaking model [20]

- Analytical reasoning is often described in terms of creating and testing hypotheses, and discovering relationships [23]. Analysts make sense of information; they engage in sensemaking.
- According to Pirolli and Card, an analyst, when sensemaking, represents information in a schema (a task-specific knowledge structure), and manipulates this schema to gain insight into a problem [20].
- Explain the sensemaking model...

Action research

Process model

1. Diagnose the problem situation
2. Plan action
3. Take action
4. Evaluate action
5. Specify learning

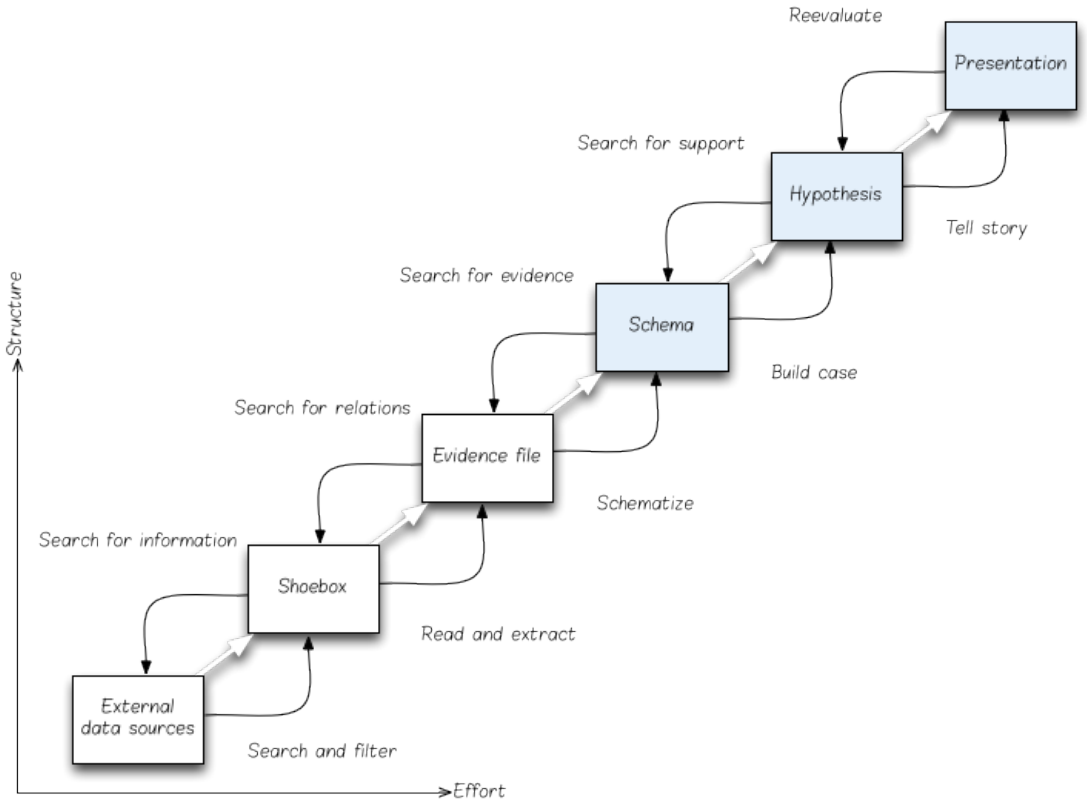


Figure: Sensemaking model [20]

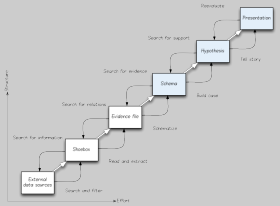


Figure: Sensemaking model [20]

- Analytical reasoning and sensemaking are akin to the process model [21] that underpins AR [17].
- Like analytical reasoning and sensemaking, the process model is iterative; it involves creating hypotheses (*diagnosing the problem situation*); testing hypotheses (*evaluating action*); and presenting findings (*specifying learning*). However, the process model is explicit about *planning action* and *taking action*.
- AR underpins scenario-based design, an approach to software development that attempts to bridge science (research) and technology (practice) [4]. Oates suggests that prototyping is a form of AR [17].
- Summary: AR brings together VA's two strands—analytical reasoning and sensemaking; and the development of interactive visual interfaces—within a clear approach to science.

Action research

Conceptual model

- Framework: Conceptual models of uncertainty
- Methodology: VA
- Application area: Current research questions

- AR also draws on a simple conceptual model.
- Within the context of the current research. . .

Action research

Criticisms

Baskerville and Wood-Harper [1]:

- AR is unscientific
- AR lacks rigour
- AR is hard to generalise

Baskerville and Wood-Harper address three criticisms of AR [1].

- AR is collaborative, interventionist and so is unscientific. This criticism is levelled at social science research more generally (philosophical supremacy). Collaboration and intervention are central to visualization research.
- AR lacks rigour. However, 'rigorous' AR is disciplined: It follows an iterative process; it is clear about the framework, methodology and application area. Similar approaches have been proposed by Munzner (nested model) [14] and adopted by MacEachren and colleagues (scenario-based design) [12].
- AR is hard to generalise. However, whilst AR may not be repeatable, it may still be valid. Validity, rather than repeatability, is recognised by Munzner (nested model) [14] and Isenberg and colleagues ('grounded evaluation') [10].

Visual analytics

- Analytical reasoning (sensemaking)
  - AR, scenario-based deign
- Interactive visual interfaces (visualization)
  - Visual representation of uncertainty
  - Interaction

Summary:

- As slide.

Interactive visual interfaces and visualization

The visual representation of uncertainty

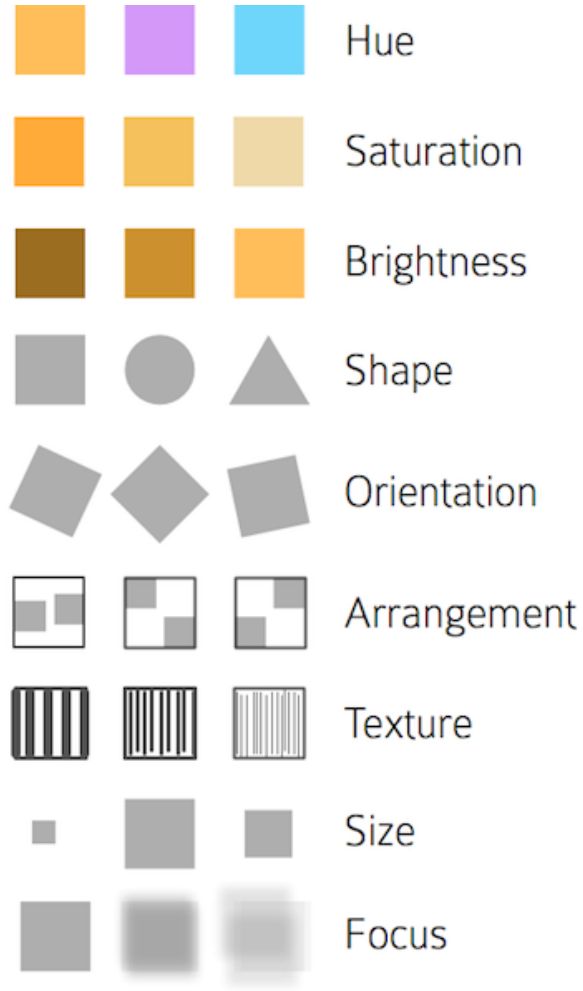


Figure: Visual variables [11] (image courtesy of Jo Wood)

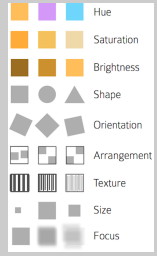


Figure: Visual variables [11] (image courtesy of Jo Wood)

- From the GISc and geovisualization perspectives, MacEachren and colleagues argue that most research into the visual representation of uncertainty has focused on applying Bertin's visual variables [11] according to cartographic good practice [13].
- Beard and Mackaness suggest there is a fundamental conflict between representing the data and representing the uncertainty associated with the data [2].

Interactive visual interfaces and visualization

Interaction

- ‘High level’ (analyst–problem) to
- ‘Low level’ (analyst–visual representation)
- ‘Goals’ (what) to
- ‘Intentions’ (how)

- Pike and colleagues argue that interaction is fundamental to analytical reasoning [19].
  - 'High level' (analyst–problem)
  - 'Low level' (analyst–visual representation)
- Norman distinguishes between *goals*, or what to achieve and *intentions*, or how to achieve it [15].

Interactive visual interfaces and visualization

Interaction

- High level and low level?
- Dichotomy or continuum?
- ‘Interaction’ or ‘task’?
- Specific instances or generic types?
- What matters is that the literature provides guidance

- Pike's high–low level dichotomy is far from clear-cut, as some elements appear to be both high level and low level.
- He would probably argue that it is less of a dichotomy and more of a continuum.
- Terms such as 'interaction' and 'task' are used loosely.
- It's unclear whether elements are specific instances or generic types.
- What matters is that the literature on the visual representation of uncertainty and on interaction provides considerable guidance on how to develop VA applications.

Research context

- Geography characterises crisis information
- Uncertainty = trust + accuracy + ...
- From GISc to VA

Where have we been?

- Research suggests that geography characterises crisis information.
- GISc and geovisualization have incorporated trust and accuracy into conceptual models of uncertainty.
- In terms of techniques, GISc has focused on accuracy.
- Because it combines human and computational approaches, VA offers another route into uncertainty.
- VA engages with the wider visualization literature, which includes geovisualization (and by extension GISc and cartography).

Data

Attribute	Example value
id	15
title	Karibe Hotel Collapsed
date	2010-01-13 10:57:00
location	Karibe Hotel, Juvenat 7 Petion-Ville, ...
description	The Karibe Hotel and ajoining apartments ...
category	5a. Structure effondres — Collapsed structure, ...
latitude	18.51933
longitude	-72.301626
approved	YES
verified	NO

Table: Example crisis report from the Haiti dataset [24]

Data

Attribute	Example value
id	15
title	Karibe Hotel Collapsed
date	2010-01-13 10:57:00
location	Karibe Hotel, Juvenat 7 Petion-Ville, ...
description	The Karibe Hotel and ajoining apartments ...
category	5a. Structure effondres — Collapsed structure, ...
latitude	18.51933
longitude	-72.301626
approved	YES
verified	NO

Table: Example crisis report from the Haiti dataset [24]

Data:

- Two datasets of crowdsourced crisis information have been obtained to address the current research questions. Both are from public Ushahidi deployments.
  - 2010 earthquake in Haiti, 3,606 reports [24]
  - 2011 armed conflict in Libya, 2,283 reports [18]
- Explain the example crisis report...

Research process

*"***validation** *is about whether one has built the right product, and* **verification** *is about whether one has built the product right" [14, p.923]*

"**validation** *is about whether one has built the right product, and* **verification** *is about whether one has built the product right" [14, p.923]*

Research process:

- The research process is informed by the process and conceptual models provided by AR.
- These models allow the development and the analysis to be validated and verified.
- Munzner defines *validation* as... and *verification* as...
- This is especially important here, as there is no partnership between domain experts and VA experts.
- The current research exemplifies van Wijk's 'curiosity-driven' approach to a problem [25].

Research process

Implementing the process model

1. Diagnose the problem situation
2. Plan action

How do we implement the process model?

- The first stage involves *diagnosing the problem situation* and *planning action*. In this stage, working hypotheses, scenarios and claims are generated.
  - The working hypotheses frame the analytical reasoning and sensemaking processes.
  - The scenarios and claims—important features of scenario-based design—frame the development of interactive visual interfaces to address the current research questions.

Research process

Scenarios and claims

"A scenario is a concrete design proposal that a designer can evaluate and develop, but is also rough in that it can be easily altered and allows many details to be deferred." [3, p.59]

"A scenario is a concrete design proposal that a designer can evaluate and develop, but is also rough in that it can be easily altered and allows many details to be deferred." [3, p.59]

- Carroll and Rosson describe scenarios as narratives: The activities a user might engage in when undertaking a 'basic task' [4].
- Carroll emphasises that scenarios are both concrete and flexible [3].

Research process

Scenarios and claims

"[artifact feature or technique] CAUSES [desirable psychological consequence] BUT MAY ALSO CAUSE [undesirable psychological consequence]" [4]

"[artifact feature or technique] CAUSES [desirable psychological consequence] BUT MAY ALSO CAUSE [undesirable psychological consequence]" [4]

- Carroll and Rosson describe claims as 'causal schemas' [4].
- A claim has the form...
- They argue that claims should be linked to scientific principles or argument.

Research process

Scenarios and claims

- Scenarios: Has one developed the correct VA application?
- Claims: Has one developed the VA application correctly?

- Scenarios afford validation.
- Claims, specifically the links between claims and scientific principles or argument, afford verification.
- Like working hypotheses, scenarios and claims will be generated analytically.
- There is a potentially infinite number of scenarios and claims, so guidance will come from the wider visualization literature and from discussions with colleagues (the intellectual framework).

Research process

Implementing the process model

1. Diagnose the problem situation
2. Plan action
3. Take action
4. Evaluate action
5. Specify learning

How do we implement the process model?

- The second stage involves *taking action*, which in the context of the current research means developing interactive visual interfaces around the Haiti and Libya datasets and beginning to analyse the data. The continuous 'internal dialogue' of development and analysis is documented in a 'living' research report.
- The third stage involves *evaluating action*, where insights are assessed and reflected upon and *specifying learning*, where findings are directed 'inwards' to later iterations and 'outwards' to the scientific community. In later iterations this stage results in a design study; a form of principled justification common in the wider visualization literature.

Work plan

- 5
- 10 $(4 + 4 + 2)$
- 12
- 4

Work plan:

- 5 iterations of the process model.
- Each iteration lasts 10 weeks: 4 weeks on stage 1 (diagnosing, planning); 4 weeks on stage 2 (taking action); 2 weeks on stage 3 (evaluating action, specifying learning).
- 12 weeks allocated for 'writing up' (although documentation is central to the research process); 4 weeks allocated for preparing for the viva.

Work plan

National and international conferences

- GISc Research UK
- EuroVis Workshop on Visual Analytics (EuroVA)
- VisWeek: IEEE Information Visualization; IEEE Visual Analytics Science and Technology (VAST Challenge)

- GISc Research UK
- EuroVis Workshop on Visual Analytics (EuroVA)
- VisWeek: IEEE Information Visualization; IEEE Visual Analytics Science and Technology (VAST Challenge)

- The work plan also includes time for submissions to national and international conferences and associated activities.
- Targeted conferences. . .

Completed work

John, an analyst, wants to explore how the distribution of incidents in the Haiti dataset changes in space and time. John launches IncidentExplorer and is presented with a map of Haiti, a histogram and a bar chart. Initially, each view shows all incidents in the dataset...

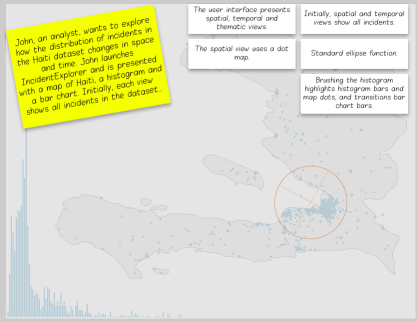
The user interface presents spatial, temporal and thematic views.

Initially, spatial and temporal views show all incidents.

The spatial view uses a dot map.

Standard ellipse function.

Brushing the histogram highlights histogram bars and map dots, and transitions bar chart bars.



Completed work:

- The first iteration of the process model will be completed by mid-May.
- Its first stage (diagnosing, planning) resulted in:
  - a scenario, from which features and claims were generated
  - a plan that prioritises the development of these features
  - a 'living' research report (problems and solutions)
- Its second stage (taking action) resulted in a prototype VA application that incorporates these features.
- Its third stage (evaluating action, specifying learning) resulted in the acceptance of a peer-reviewed poster and extended abstract at the EuroVis Workshop on Visual Analytics (EuroVA).

Recent publications

- Dillingham, I., Dykes, J., Wood, J., 2011. Visual Analytical Approaches to Evaluating Uncertainty and Bias in Crowdsourced Crisis Information. Poster presented at the IEEE Conference on Visual Analytics Science and Technology, 23–28 October 2011, Providence, RI, USA.
- Dillingham, I., Dykes, J., Wood, J., 2012. Exploring Patterns of Uncertainty in Crowdsourced Crisis Information. Poster presented at the EuroVis Workshop on Visual Analytics (EuroVA), 4–5 June 2012, Vienna, Austria.

Recent publications:

- Two are peer-reviewed posters and extended abstracts that discuss the development of interactive visual interfaces to the Libya and Haiti datasets.
- The first reports the development of a prototype VA application prior to the work plan and outlines the nature of the current research.
- The second introduces the ‘analytics’ aspect of the current research; spatial statistical functions such as standard ellipses.

Recent publications

- Dillingham, I., Dykes, J., Wood, J., 2012. Characterising Locality Descriptions in Crowdsourced Crisis Information, in: Proceedings of the GIS Research UK 20th Annual Conference (GISRUK 2012). 11–13 April 2012, Lancaster University, Lancaster, UK.

- Dillingham, I., Dykes, J., Wood, J., 2012. Characterising Locality Descriptions in Crowdsourced Crisis Information, in: Proceedings of the GIS Research UK 20th Annual Conference (GISRUK 2012). 11–13 April 2012, Lancaster University, Lancaster, UK.

Recent publications:

- One is a peer-reviewed paper that reports the findings from a preliminary investigation into how people describe location in the Haiti dataset.

Recent publications

Characterising Locality Descriptions in Crowdsourced Crisis Information

- What types of locality descriptions are present in crowdsourced crisis information?
- Are the proportions of these types different to those present in related datasets?
- Unlike related datasets, location is seldom described using offsets and headings in the Haiti dataset; it is often described in terms of features (such as named places) and paths (such as roads).

- What types of locality descriptions are present in crowdsourced crisis information?
- Are the proportions of these types different to those present in related datasets?
- Unlike related datasets, location is seldom described using offsets and headings in the Haiti dataset; it is often described in terms of features (such as named places) and paths (such as roads).

As slide.

Recent publications

- Dillingham, I., Mills, B., Dykes, J., 2011. Exploring Road Incident Data with Heat Maps. Poster Presented at the GIS Research UK 19th Annual Conference (GISRUK 2011). 27–29 April 2011, University of Portsmouth, Portsmouth, UK.

- Dillingham, I., Mills, B., Dykes, J., 2011. Exploring Road Incident Data with Heat Maps. Poster Presented at the GIS Research UK 19th Annual Conference (GISRUK 2011). 27–29 April 2011, University of Portsmouth, Portsmouth, UK.

Recent publications:

- The final recent publication is a peer-reviewed poster and extended abstract that relates to an earlier research project. This project served as an introduction to many aspects of the current research.
- All publications are available from City Research Online.

Planned publications

- VisWeek 2012: Research process
- GISc Research UK 2013: Preliminary findings
- VisWeek 2013: Design study

Planned publications:

- Poster at VisWeek 2012: This will present the research process.
- Paper at GISc Research UK 2013: This will present preliminary findings.
- Paper at VisWeek 2013: This will present a design study that summarises the current research.

Summary

- Introduction
- Research questions
- Literature
- Data

- Introduction: The role of social media in humanitarian response
- Research questions
- Literature: Crisis information; Uncertainty; Visual analytics; Action research
- Data

Summary

- Research process
- Work plan
- Completed work
- Recent and planned publications

Summary

- Research process: Implementing the process model; Scenarios and claims
- Work plan
- Completed work: First iteration of the process model
- Four recent publications
- Three planned publications

Progress to PhD

- Initial phase of PhD
  - Formulate...
  - Select...
  - Undertake...
  - Interpret...
  - Communicate...
- Progress to PhD

- I believe I have demonstrated my ability to:
  - formulate research questions;
  - select appropriate research methods;
  - undertake research;
  - interpret the results of and findings from this research;
  - communicate these results and findings to an informed audience, both 'internally' and 'externally'.
- I believe that my completed work and work plan demonstrate my ability to progress to PhD within the agreed time-period.

Contact

iain.dillingham.1@city.ac.uk
dillingham.me.uk

giCentre
School of Informatics
City University London
Northampton Square
London
EC1V 0HB

Contact

iain.dillingham.1@city.ac.uk
dillingham.me.uk

giCentre
School of Informatics
City University London
Northampton Square
London
EC1V 0HB

- Any questions?

Bibliography I

Richard L. Baskerville and A. Trevor Wood-Harper.

A critical perspective on action research as a method for information systems research.
Journal of Information Technology, 11(3):235–246, 1996.

Kate Beard and William Mackaness.

Visual access to data quality in geographic information systems.
Cartographica, 30(2–3):37–45, 1993.

J.M. Carroll.

Five reasons for scenario-based design.
Interacting with Computers, 13(1):43–60, 2000.

John M. Carroll and Mary Beth Rosson.

Getting around the task-artifact cycle: how to make claims and design by scenario.
ACM Transactions on Information Systems, 10(2):181–212, 1992.

Diane Coyle and Patrick Meier.

New technologies in emergencies and conflicts: The role of information and social networks.
Technical report, UN Foundation–Vodafone Foundation Partnership, Washington DC, USA and London, UK, 2009.
[Accessed 2 June 2011].

Peter Fisher and David J. Unwin.

Re-presenting geographical information systems.
In Peter Fisher and David J. Unwin, editors, *Re-Presenting GIS*, pages 1–14. John Wiley and Sons, Chichester, UK, 2005.

Bibliography II

P.F. Fisher.

Models of uncertainty in spatial data.
In Paul A. Longley, Michael F. Goodchild, David J. Maguire, and David W. Rhind, editors, *Geographical Information Systems, Principles and Technical Issues*, volume 1, pages 191–205. John Wiley and Sons, Chichester, UK, 2nd edition, 1999.

Judith Gelernter and Nikolai Mushegian.

Geo-parsing messages from microtext.
Transactions in GIS, 15(6):753–773, 2011.

Jeff Howe.

Crowdsourcing: How the Power of the Crowd is Driving the Future of Business.
Random House, London, UK, 2009.

Petra Isenberg, Torre Zuk, Christopher Collins, and Sheelagh Carpendale.

Grounded evaluation of information visualizations.
In *Proceedings of the CHI Workshop Beyond Time and Errors: Novel Evaluation Methods for Information Visualization*, pages 56–63, 2008.
Florence, Italy, 5–10 April 2008.

Alan M. MacEachren.

Some Truth with Maps: A Primer on Symbolization and Design.
Association of American Geographers, Washington DC, USA, 1994.

Alan M. MacEachren, Anuj Jaiswal, Anthony C. Robinson, Scott Pezanowski, Alexander Savelyev, Prasenjit Mitra, Xiao Zhang, and Justine Blanford.

SensePlace2: GeoTwitter analytics support for situational awareness.
In *Proceedings of the IEEE Conference on Visual Analytics Science and Technology*, pages 181–190, 2011.
Providence, RI, USA, 23–28 October 2011.

Bibliography III

Alan M. MacEachren, Anthony Robinson, Susan Hopper, Steven Gardner, Robert Murray, Mark Gahegan, and Elisabeth Hetzler.
Visualizing geospatial information uncertainty: What we know and what we need to know.
Cartography and Geographic Information Science, 32(3):139–160, 2005.

Tamara Munzner.
A nested model for visualization design and validation.
IEEE Transactions on Visualization and Computer Graphics, 15(6):921–928, 2009.

Donald A. Norman.
The Design of Everyday Things.
MIT Press, Cambridge, MA, USA, 1998.

Chris North.
Toward measuring visualization insight.
IEEE Computer Graphics and Applications, 26(3):6–9, 2006.

Briony J. Oates.
Researching Information Systems and Computing.
Sage, London, UK, 2006.

OCHA.
Libya crisis map, 2011.
[Accessed 19 October 2011].

William A. Pike, John Stasko, Remco Chang, and Theresa A. O'Connell.
The science of interaction.
Information Visualization, 8(4):263–274, 2009.

Bibliography IV

Peter Pirolli and Stuart Card.

The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis.
In *Proceedings of the 2005 International Conference on Intelligence Analysis*, 2005.

Gerald I. Susman and Roger D. Evered.

An assessment of the scientific merits of action research.
Administrative Science Quarterly, 23(4):582–603, 1978.

Andrea H. Tapia, Kartikeya Bajpai, Jim Jansen, John Yen, and Lee Giles.

Seeking the trustworthy tweet: Can microblogged data fit the information needs of disaster response and humanitarian relief organizations.
In *Proceedings of the 8th International Conference on ISCRAM*, 2011.

James J. Thomas and Kristin A. Cook.

A visual analytics agenda.
IEEE Computer Graphics and Applications, 26(1):10–13, 2006.

Ushahidi.

Haiti crisis map, 2009.
[Accessed 19 October 2011].

Jarke J. van Wijk.

Bridging the gaps.
IEEE Computer Graphics and Applications, 26(6):6–9, 2006.

Sarah Vieweg, Amanda L. Hughes, Kate Starbird, and Leysia Palen.

Microblogging during two natural hazards events: what Twitter may contribute to situational awareness.
In *Proceedings of the 28th international conference on human factors in computing systems*, pages 1079–1088, 2010.
Atlanta, GA, USA, 10–15 April 2010.