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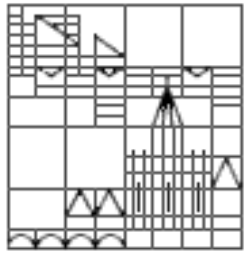

LingVis: Motivation and Use Cases

Miriam Butt & Dominik Sacha

LingVis: Visual Analytics for Linguistics
DGfS 2016 | 24.-26.2.2016

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Tutorial Overview

- Part I: Motivation and Use Cases
- Part II: Background Theory
- Part III: Hands-on
  - Presentation of Possibilities
  - More background on some of the systems
  - Chance to work/explore yourselves

Before we start….

Personal Questions

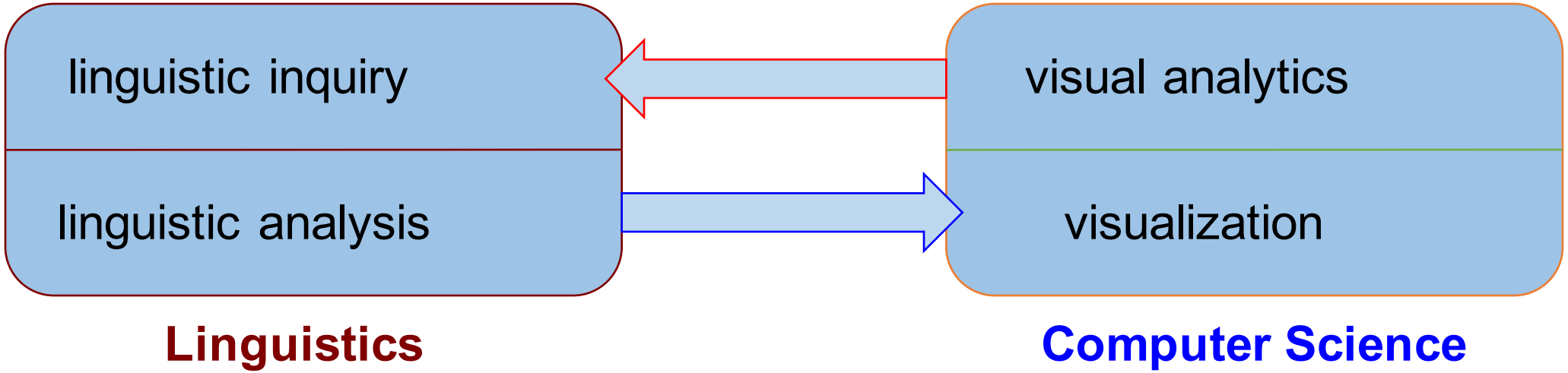
- Who are we?
- Who are you?
  - Programming Background
  - What types of linguistic questions interest you?
  - What is the interest in LingVis?

Motivation and Background

LingVis

Overall Goals:

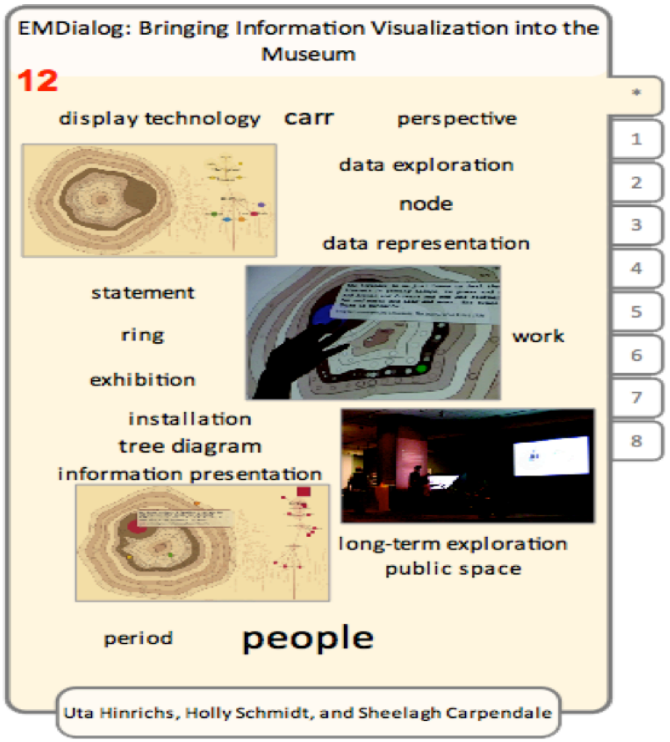
- Integrate methods from **visual analytics** into domains of **linguistic inquiry**.
- Explore challenges based on the needs of **linguistic analysis** for **visualization methods**.

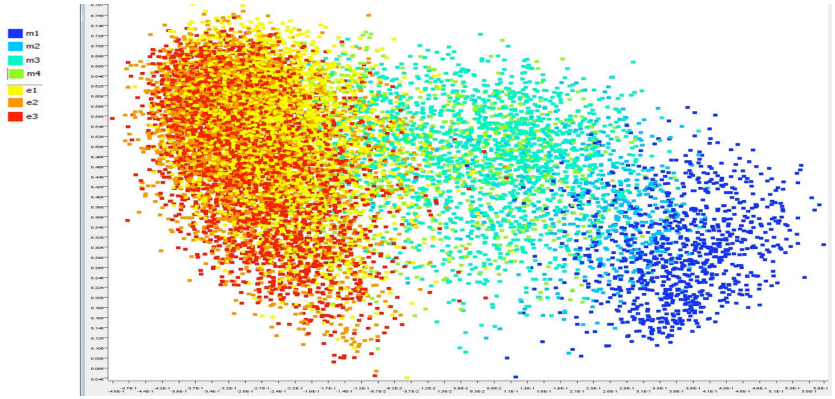


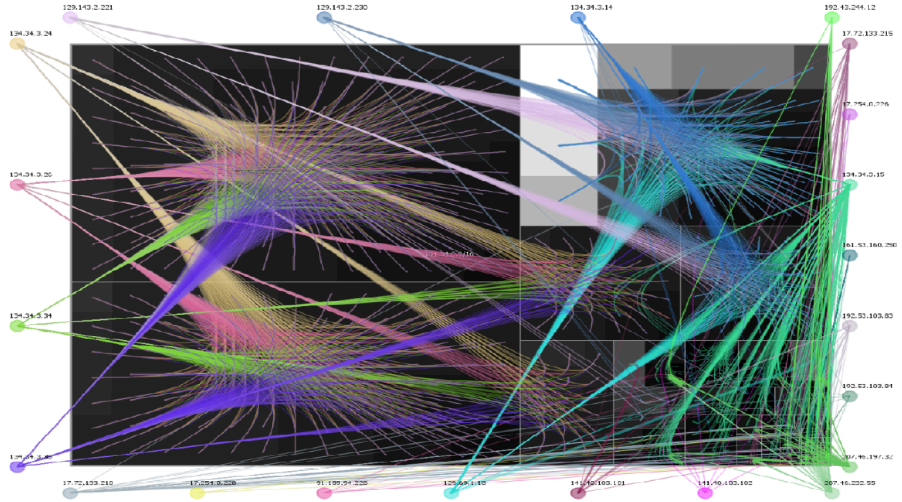
Visual Analytics

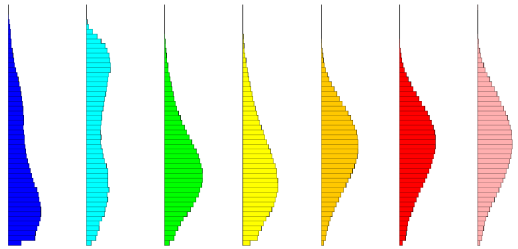
- Interactive, exploratory access to data
- Iterations of hypothesis formation and hypothesis testing
- Overview first – details on demand
  - Holistic picture
  - But can drill down to individual data points
  - Abstract representation of multifactorial, multidimensional data.
  - Good for understanding complex interactions in the data.

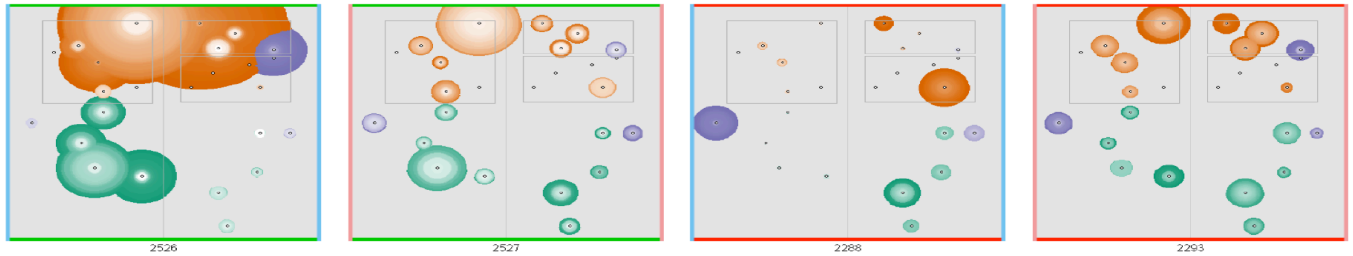
Sample Visualizations

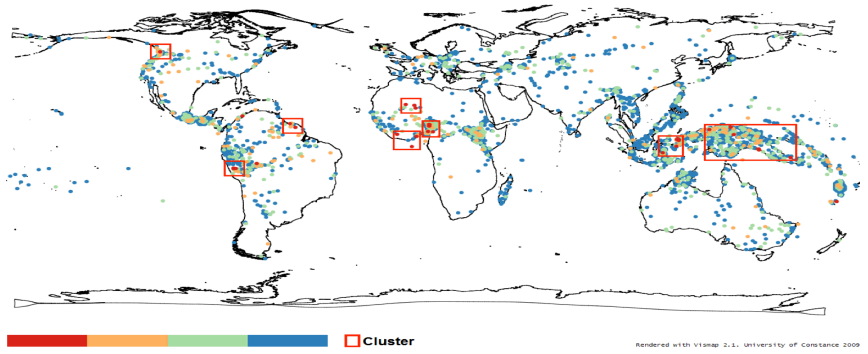












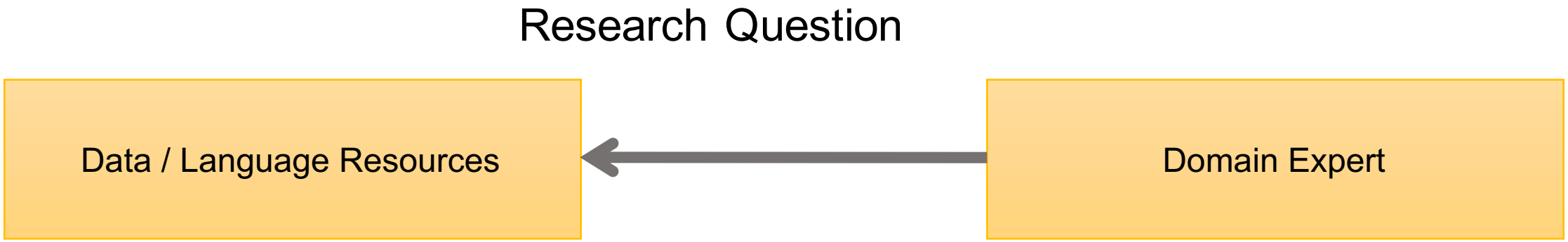
LingVis – Motivation

- Linguists are making more and more use of newly available technology to detect **distributional patterns** in language data.
- Ever increasing availability of **digital corpora** (synchronic and diachronic).
- Increasing interest in language output produced in **social media**.
- Ever better **query** and **search tools** (CQP, COSMAS, DWDS, ANNIS).
- **Programming languages** suitable for text processing, statistical analysis and visualization (e.g., Python, R).
- But: as yet only comparatively little/good use of novel **visualization methods**.

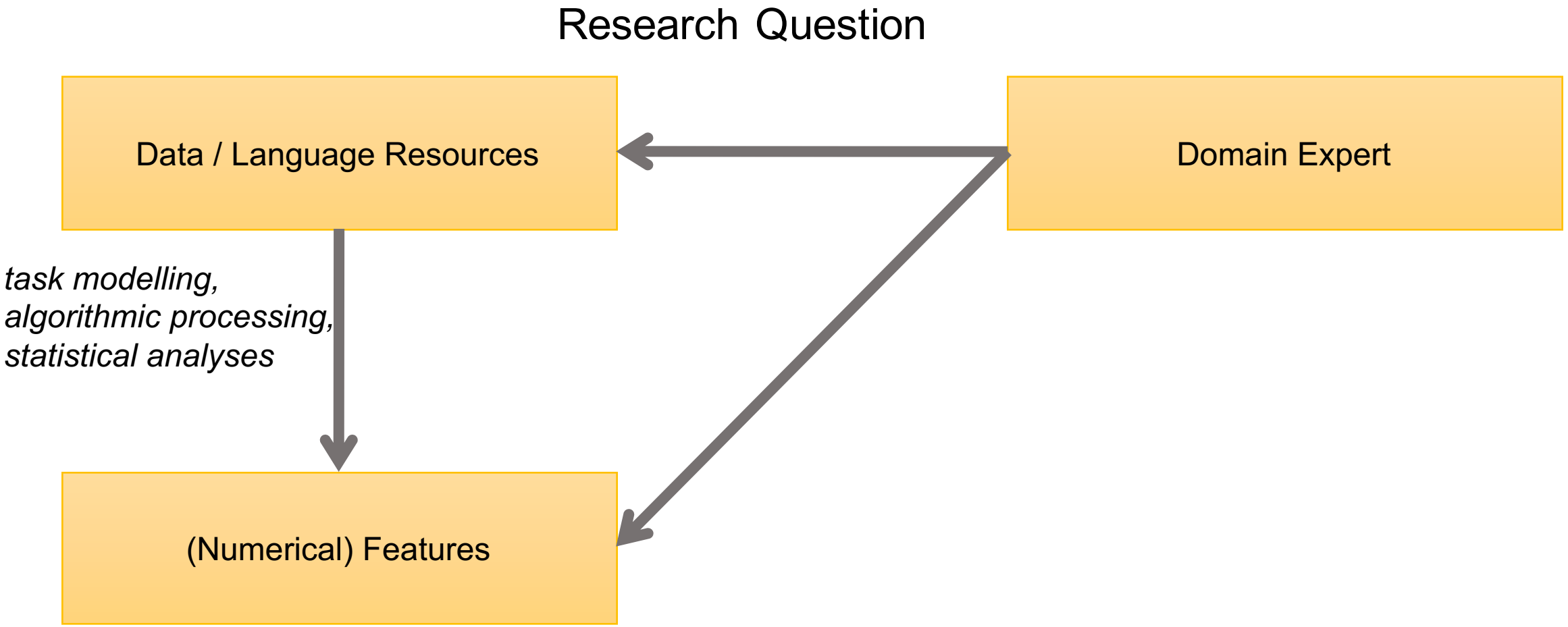
Making Sense of Numbers

- Current linguistics often includes **corpus work**.
- Linguists try to determine patterns, interactions and usage preferences within a language but also across different languages.
- This work generates a lot of numbers (statistics).
- Numbers are difficult for humans to process.
- Solution: translate **numbers** into **visual properties.**
- Human visual apparatus can process this easily.

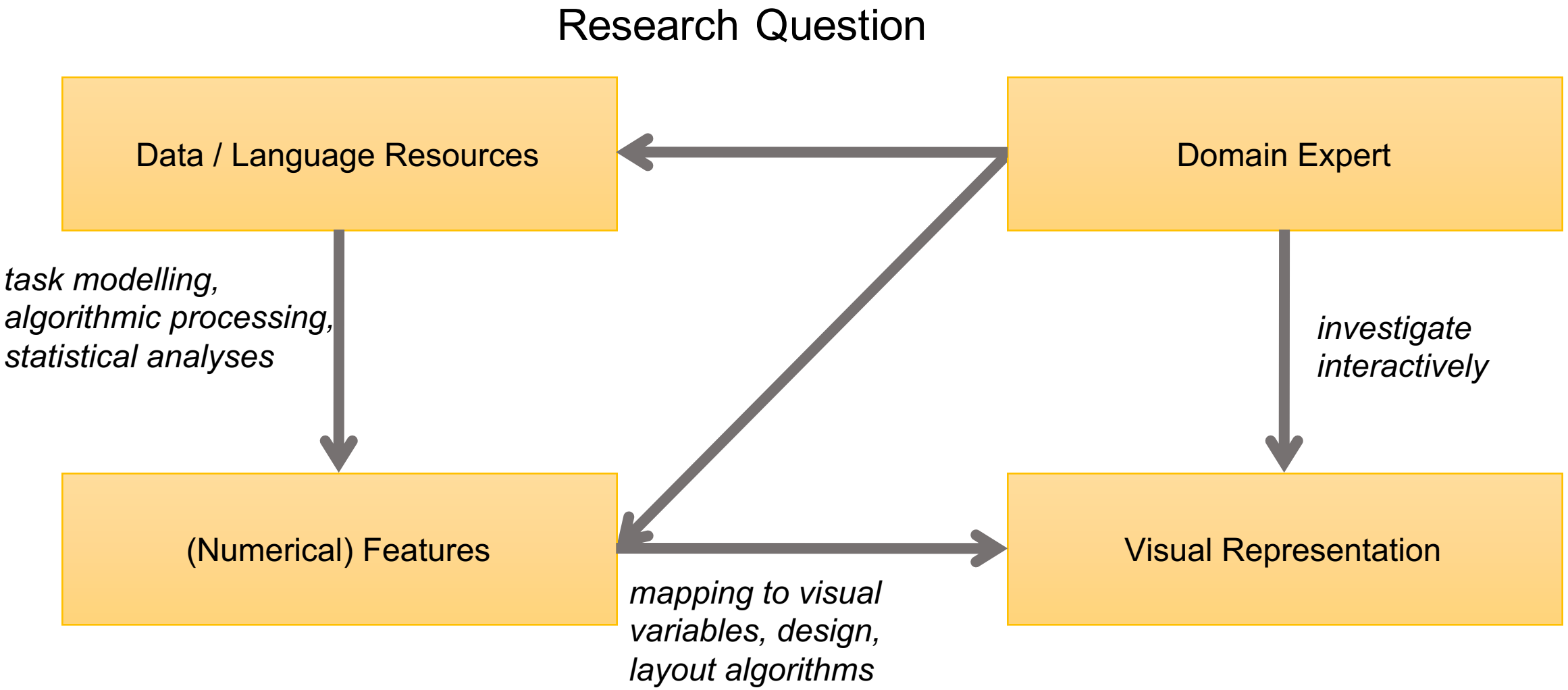
Interdisciplinary Collaboration: LingVis



Interdisciplinary Collaboration: LingVis



Interdisciplinary Collaboration: LingVis



Example: Pixel-Based Visualizations

Two Use Cases

- N-V Complex Predicates
- Vowel Harmony

N-V Complex Predicates

- **N-V complex predicates** occur very frequently in Urdu.
- **Examples:** phone-do, memory-do, memory-become, resolution-do, resolution-be, ...
- **Problem:** would be nice if one knew which nouns were likely to cooccur with which verbs.

Example: N-V Complex Predicates in Urdu

- **Goal:** identify sequences of Noun+Verb for understanding complex predicate patterns
  - *phone-do, use-do, memory-come, begin-do/come*
- **Data:** 7.9 million word raw (unannotated) corpus of Urdu (BBC Urdu)

```
#this file lists X in X+kar, X+ho, X+hu, X+rakh sequences with corr...
esponding occurrences in the (candidate) CP sequences
#X = word occurring directly to the left of LV (LV: kar, ho, hu, rakh)
#kar: # of occurrences of X with kar
#ho: # of occurrences of X with ho
#hu: # of occurrences of X with hu
#rakh: # of occurrences of X with rakh
X          #hu  #kar #ho  #rakh
اضافہ      674  466  524       0
غورش       378  2336 1691      0
جولعم      366  254  609       0
دھمکہ      359  135  44        0
حملہ       227  1232 100       0
متاثر      183  178  765       0
ناصرقن     173  0    114       0
کیا        172  373  7027      0
ثابت       147  394  588       0
تقو        142  105  235       9
پیدا       103  754  956       0
کالہ       102  1501 3609      0
آرمدم      80   210  96        0
اھکر       74   0    263       0
یمخز       62   59   1161      0
آغاز       59   315  75        0
ہی         56   0    2267      0
قدعنم      54   197  262       0
انکشافا    51   165  13        0
```

Butt, Miriam, Tina Bögel, Annette Hautli, Sebastian Sulger & Tafseer Ahmed. 2012. **Identifying Urdu Complex Predication via Bigram Extraction**. In *Proceedings of the 24th International Conference on Computational Linguistics* (COLING), 409–424. Mumbai, India.

Example: Pixel Visualization

Statistical Data:

ID	Noun	Rel. freq. with *kar*	Rel. freq. with *ho*	Rel. freq. with *hu*	Rel. freq. with *rakh*
1	حاصل	0.771	0.222	0.007	0.000
2	اعلان	0.982	0.011	0.007	0.000
3	بات	0.853	0.147	0.000	0.000
4	شروع	0.530	0.384	0.086	0.000

Table 2: Relative frequencies of co-occurrence of nouns with light verbs

do, be, become, put

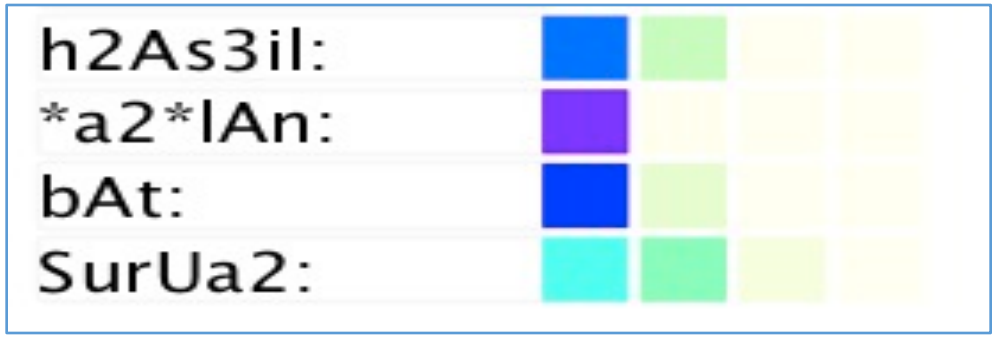
kar, ho, hu, rakh

'achievement'

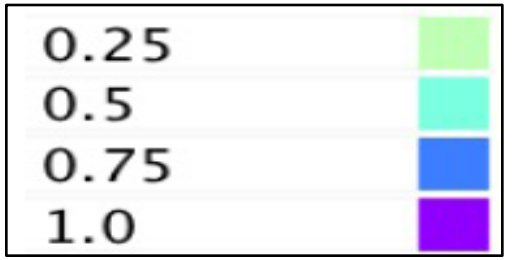
'announcement'

'talk'

'beginning'

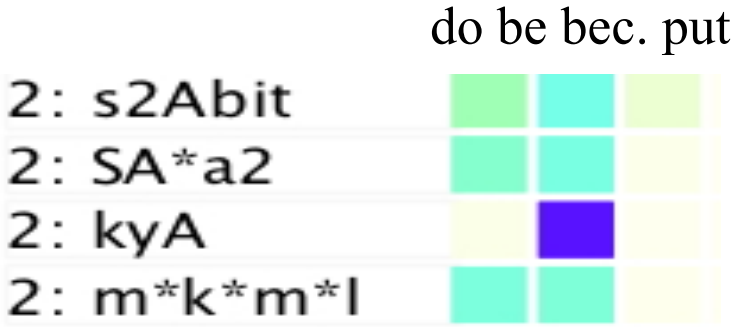


Color Scale



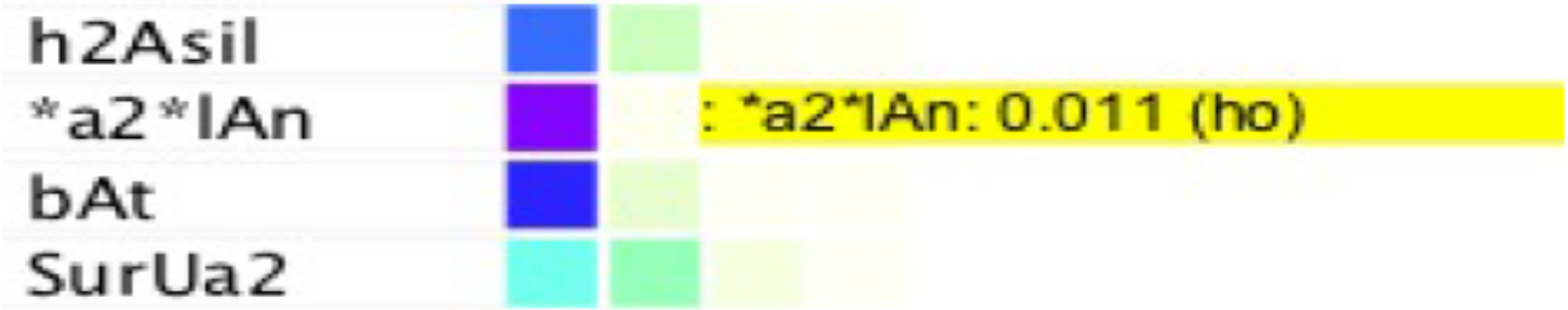
Pixel plus Cluster Visualization

- Performed k-means clustering combined with a pixel visualization.
- Advantages:
  - can inspect clusters visually and detect patterns
  - Outliers spotted easily (mostly errors – “kyA” is not a noun, it is a *wh*-word and was included by mistake).



Example: Identifying N-V complex predicates in Hindi/IUrdu

Tool facilitates zooming and mousing over to see the underlying data set



Outliers/Errors are easily identified (Clustering Algorithm has applied)

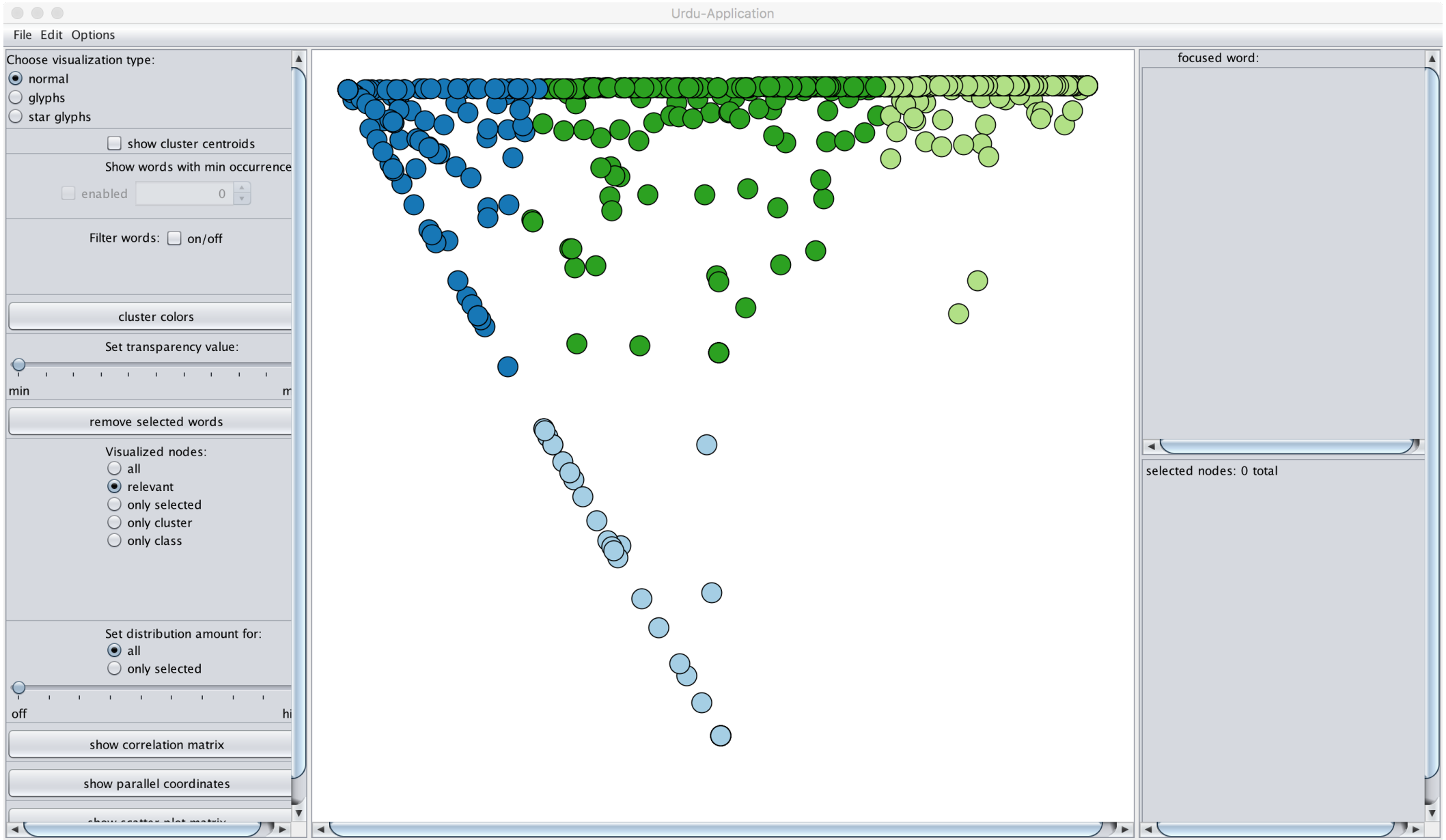
N-V Complex Predicates

Cluster Visualization Demo

More sophisticated version now available –
will look at that in hands-on part

Andreas Lamprecht, Annette Hautli, Christian Rohrdantz, Tina Bögel. 2013. A Visual Analytics System for Cluster Exploration. *In Proceedings of the 51st Annual Meeting of the Association for Computational Linguistics, System Demo,* 109–114, Sofia, Bulgaria.

Improved Cluster Visualization (Lamprecht et al.)



Vowel Harmony (VH)

- **Phenomenon (simplified):** Vowels in affixes change according to vowels found in stems.
- **(Famous) Example:**

Turkish

Genitive suffix
deniz-in, ev-in
tütün-**ün**, çöl-**ün**
kadın-**ın**, adam-**ın**
sabun-**un**, top-**un**

Genitive suffix with plural suffix
deniz-ler-in, ev-ler-in
tütün-ler-**in**, çöl-ler-**in**
kadın-lar-**ın**, adam-lar-**ın**
sabun-lar-**ın**, top-lar-**ın**

Vowel Harmony

Goal: Try to determine automatically whether a given language contains patterns indicative of vowel harmony.

Basic Computational Approach:

- Use written corpus (caveat: only approximates actual phonology).
- **Count** which vowels succeed which other vowels in $VC^{+}V$ sequences (within words — again an approximation)
- Through **statistical analysis** find out the association strength between vowels: normalized association strength value ϕ.
- **Results** show that Turkish and Hungarian, for example, pattern similarly. Languages like Spanish or German pattern differently.

Results — Standard Methods: Can you detect a pattern?

	a	ı	u	o	ö	ü	i	e
a	0.266	0.427	-0.141	-0.060	0.019	-0.125	-0.261	-0.275
ı	0.162	0.292	-0.107	0.077	-0.010	-0.075	-0.190	-0.191
u	0.129	-0.143	0.464	0.017	-0.003	-0.051	-0.138	-0.140
o	0.066	-0.112	0.434	-0.015	0.006	-0.045	-0.104	-0.111
ö	-0.107	-0.092	-0.052	-0.026	0.006	0.366	-0.091	0.164
ü	-0.120	-0.114	-0.059	0.014	-0.006	0.507	-0.112	0.134
i	-0.201	-0.224	-0.118	0.071	-0.004	-0.087	0.319	0.211
e	-0.256	-0.251	-0.132	-0.062	-0.010	-0.097	0.400	0.276

Turkish

	a	i	o	e	u
a	-0.003	-0.075	0.094	-0.025	-0.018
i	-0.025	-0.004	0.064	-0.036	0.005
o	-0.028	-0.006	-0.075	0.098	0.026
e	-0,001	0.063	-0.073	0.016	0.021
u	0.077	0.038	-0.036	-0.057	-0.043

Spanish

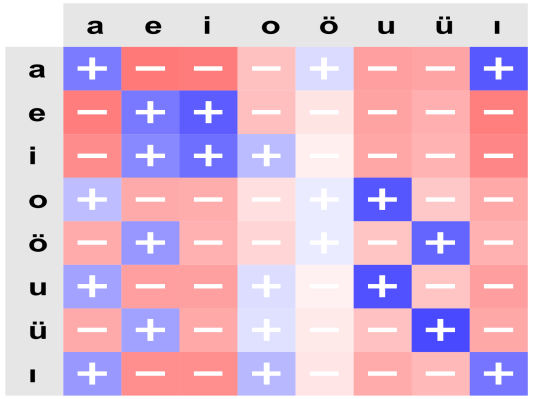
	a	o	i	ü	ö	ä	u	e
a	0.019	0.009	-0.061	-0.034	-0.008	-0.025	0.018	0.035
o	-0.023	-0.004	-0.052	-0.013	-0.020	-0.013	-0.013	0.068
i	-0.069	-0.054	-0.050	-0.039	-0.036	-0.044	-0.003	0.133
ü	-0.067	-0.045	0.070	-0.028	-0.021	-0.033	-0.021	0.050
ö	-0.049	-0.032	0.049	-0.024	-0.013	-0.021	-0.013	0.036
ä	-0.067	-0.037	0.124	-0.033	-0.018	-0.028	-0.038	0.020
u	0.012	-0.018	-0.019	0.046	-0.002	-0.013	0.004	-0.001
e	0.108	0.084	0.026	0.069	0.063	0.096	0.021	-0.195

German

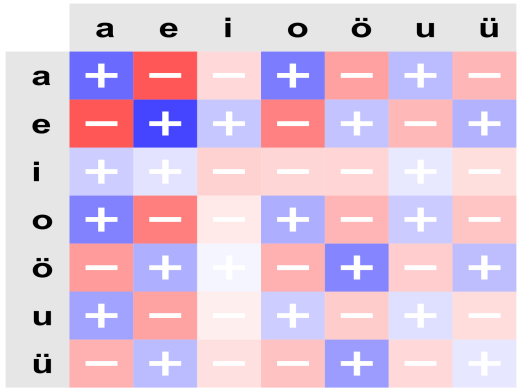
	a	o	u	i	ü	ö	e
a	0.339	0.263	0.070	-0.022	-0.081	-0.136	-0.431
o	0.239	0.099	0.041	-0.007	-0.052	-0.083	-0.253
u	0.132	0.038	0.015	-0.004	-0.017	-0.040	-0.131
i	0.037	-0.026	0.008	-0.030	-0.017	-0.027	0.011
ü	-0.093	-0.056	-0.022	-0.014	0.008	0.148	0.071
ö	-0.152	-0.093	-0.037	0.001	0.065	0.229	0.097
e	-0.435	-0.241	-0.076	0.048	0.091	0.054	0.531

Hungarian

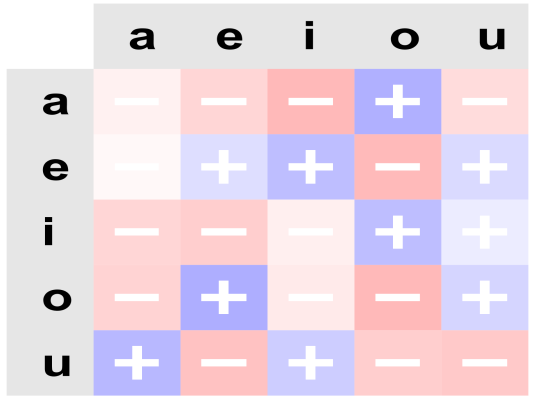
First Simplistic Visualization: Can you detect a pattern?



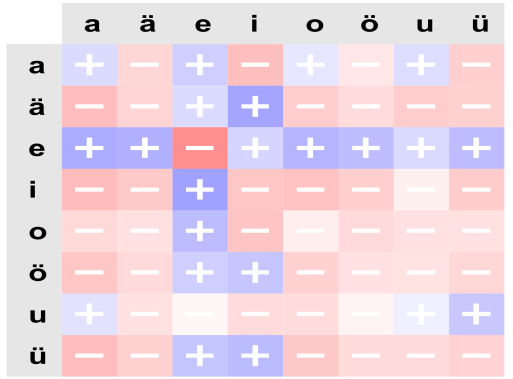
Turkish



Hungarian



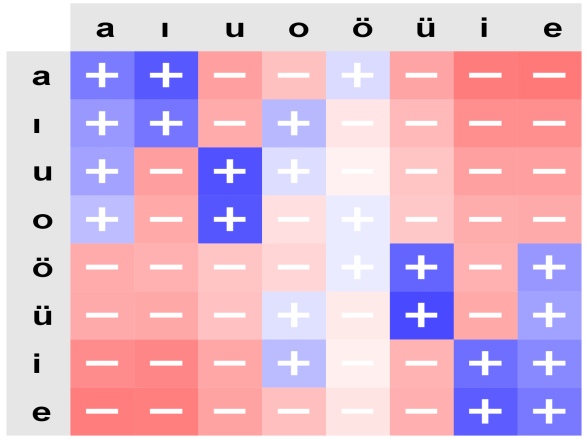
Spanish



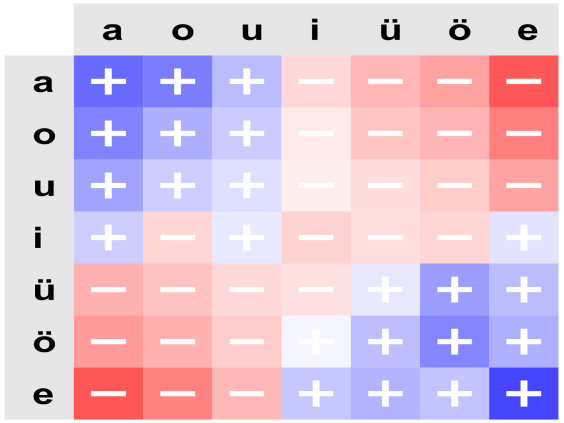
German

- Matrix visualization of association strengths between vowels (deviation from statistical expectation).
- Vowels are sorted alphabetically.
- More saturated colors show greater association strength.
- Blue is for more frequently than expected, red for less.
- The +/– are redundant encodings.

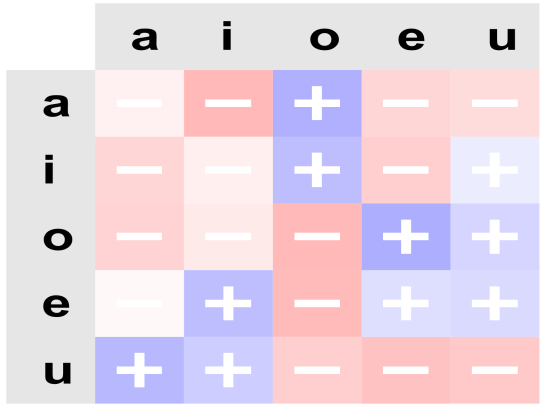
Sorted Visualization: Can you detect a pattern now?



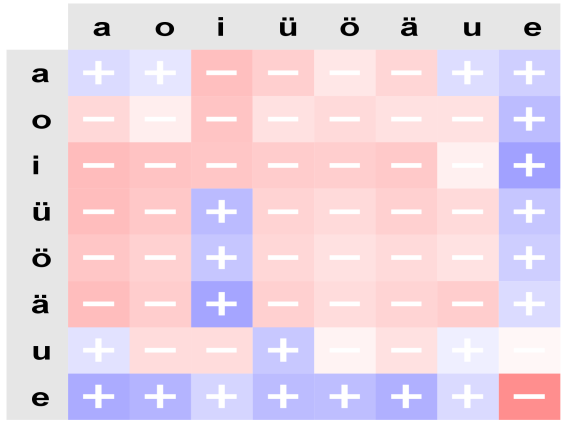
Turkish



Hungarian



Spanish



German

Vowels **sorted** according to similarity (note: not a trivial process)
Can even see the **type** of Vowel Harmony involved.

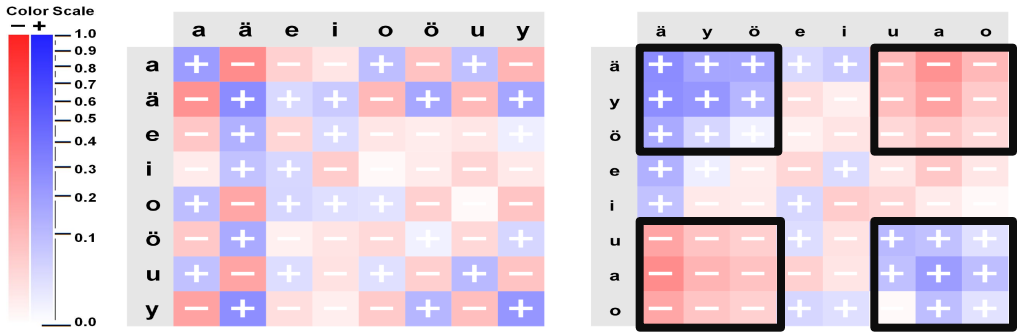
T. Mayer, C. Rohrdantz, M. Butt, F. Plank and D. A. Keim. **Visualizing Vowel Harmony**. *Linguistic Issues in Language Technology*, 4(Issue 2):1-33, 2010.

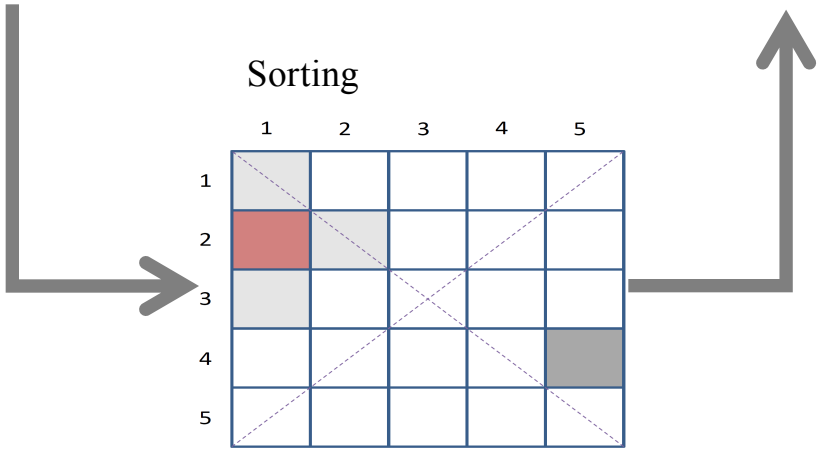
Visualizing Vowel Harmony

Counting Vowel Successions in all Bible Types
Example: Finnish

	a	ä	e	i	o	ö	u	y
a	3548	20	1940	1893	831	0	944	24
ä	35	944	806	820	10	138	33	266
e	1623	1144	1495	1608	419	56	497	187
i	1580	854	1514	1044	376	46	355	135
o	1384	7	1032	902	284	0	294	8
ö	7	125	54	39	0	3	1	18
u	1464	6	1085	850	315	1	547	8
y	39	656	368	368	35	75	4	251

Statistics & Visualization

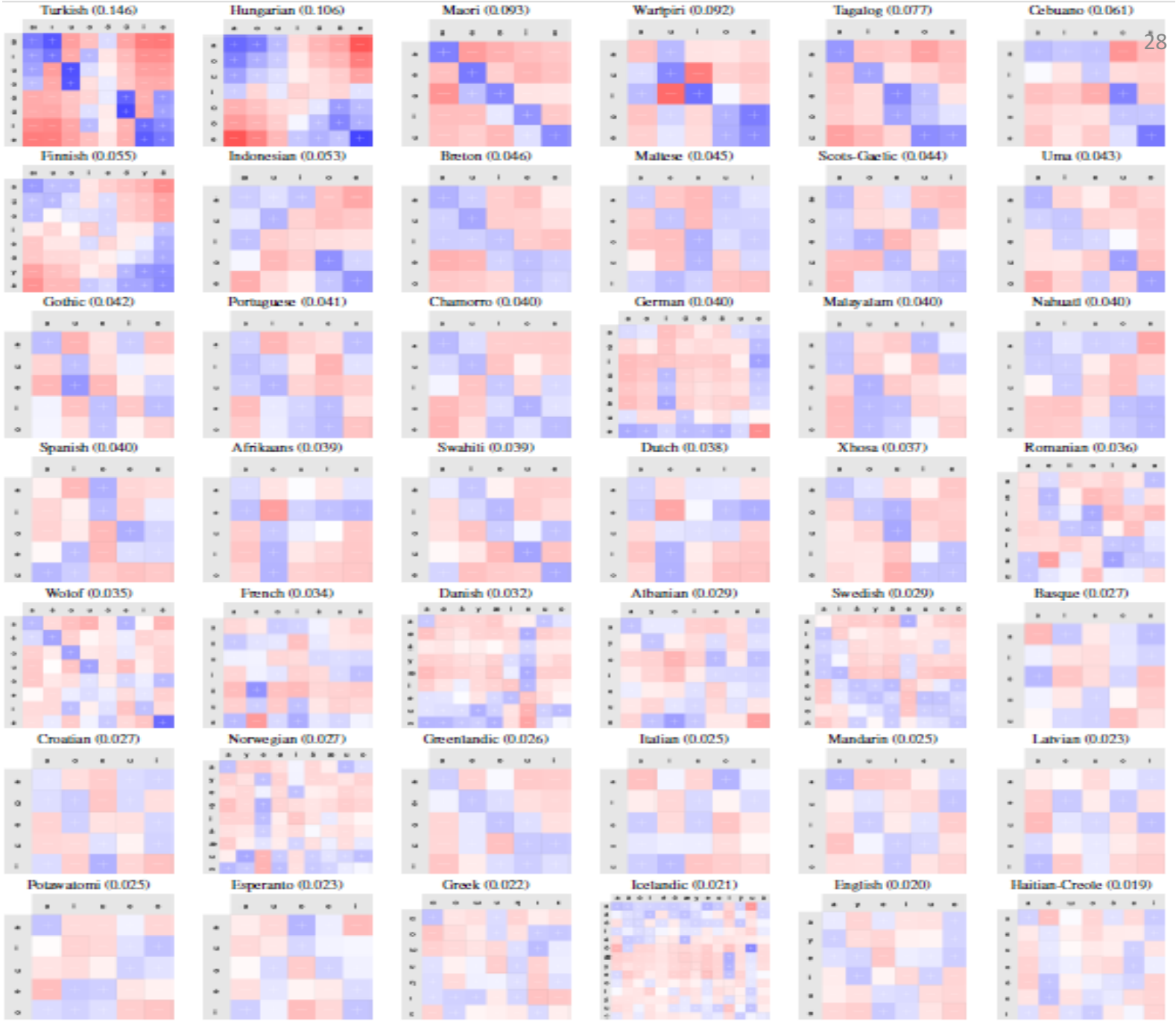




Sorting done according to feature vectors of each of the rows.

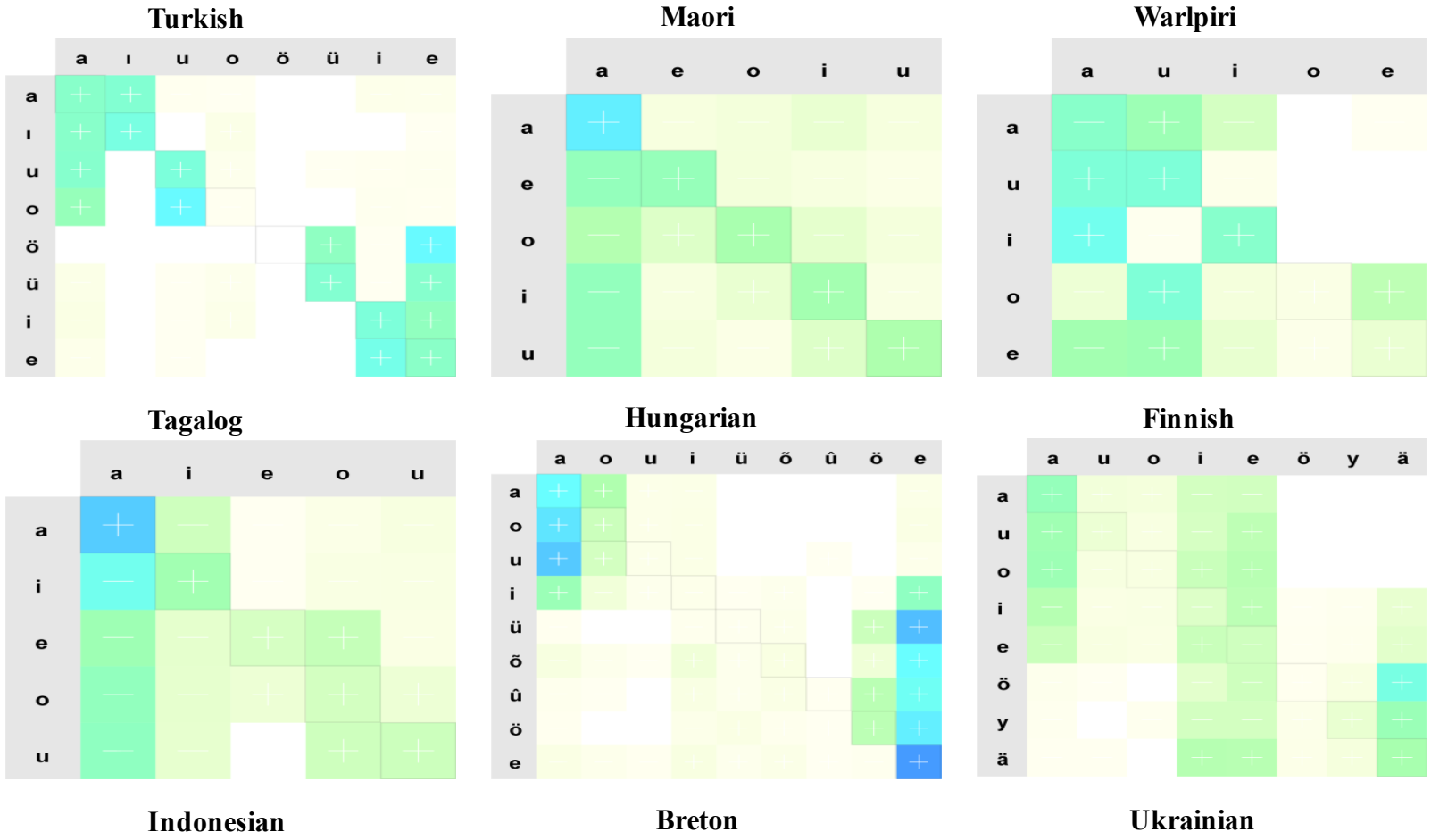
Results –
Sorted Visualization:

- Automatic Visual Analysis of vowel successions for 42 languages – sorted for effect strength.



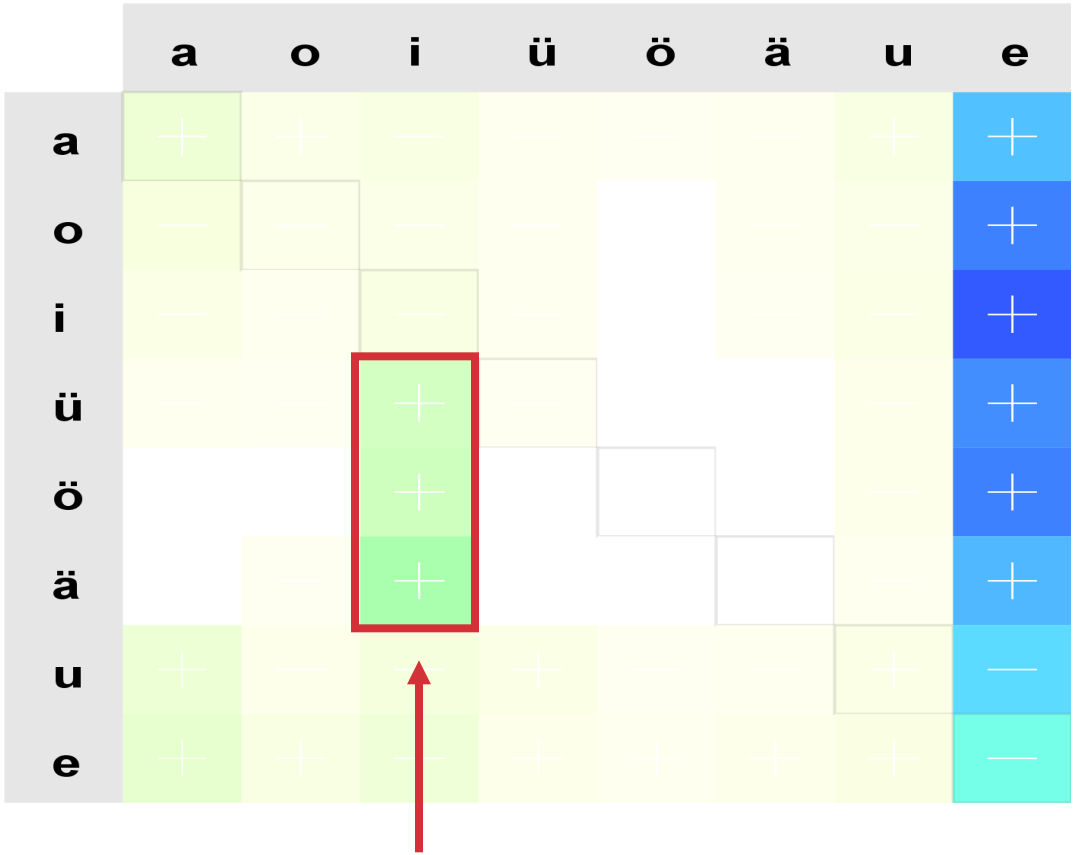
Vowel Harmony vs. Reduplication

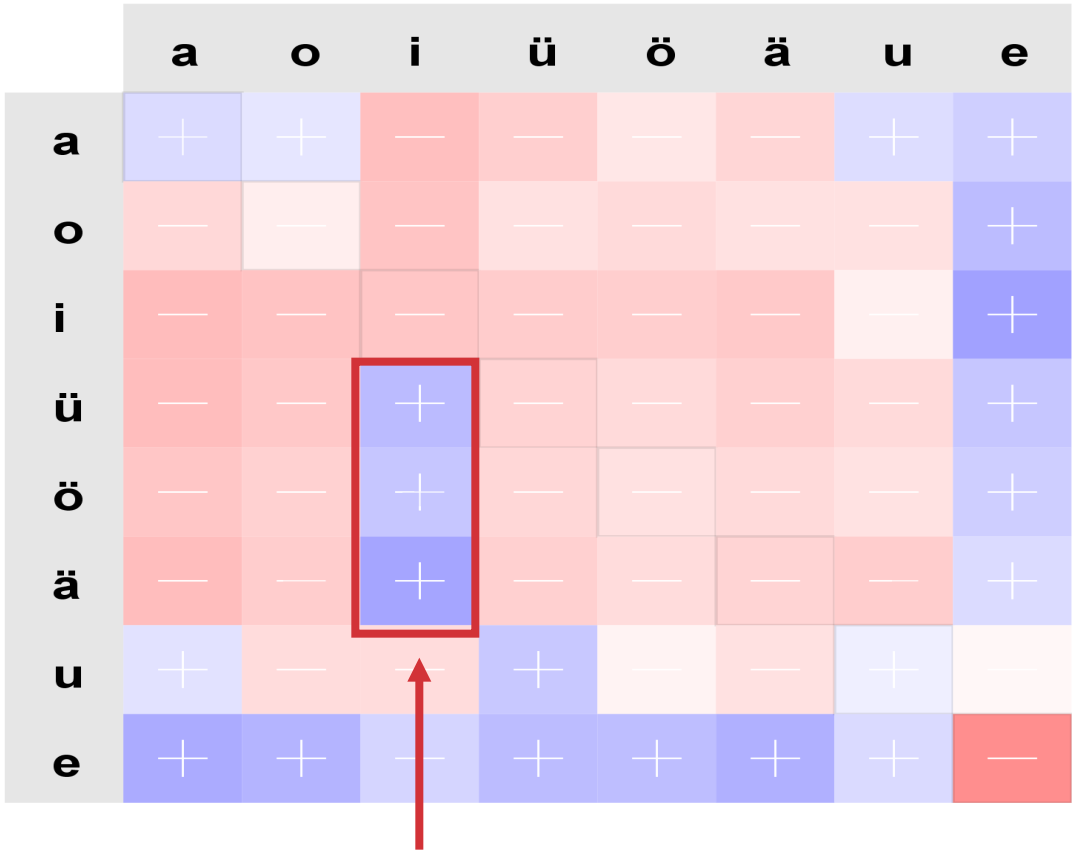
- In VH languages, crucially there are some vowels which never co-occur.
- This can be seen via a calculation of succession probabilities.
- Maori is not a VH language.



Historical Fingerprint: German Umlaut

Even though Umlaut (raising of vowel in stem before high vowel in affix) is no longer a productive process in German, the Umlaut harmony pattern is still visible in the matrices.





On-line Availability

You can use the visualization in a new and improved form yourself on-line.

http://paralleltext.info/phonmatrix/

Main Contact Person: Thomas Mayer

Mayer, Thomas and Christian Rohrdantz. 2013. PhonMatrix: Visualizing co-occurrence constraints in sounds. In *Proceedings of the ACL 2013 System Demonstration*.

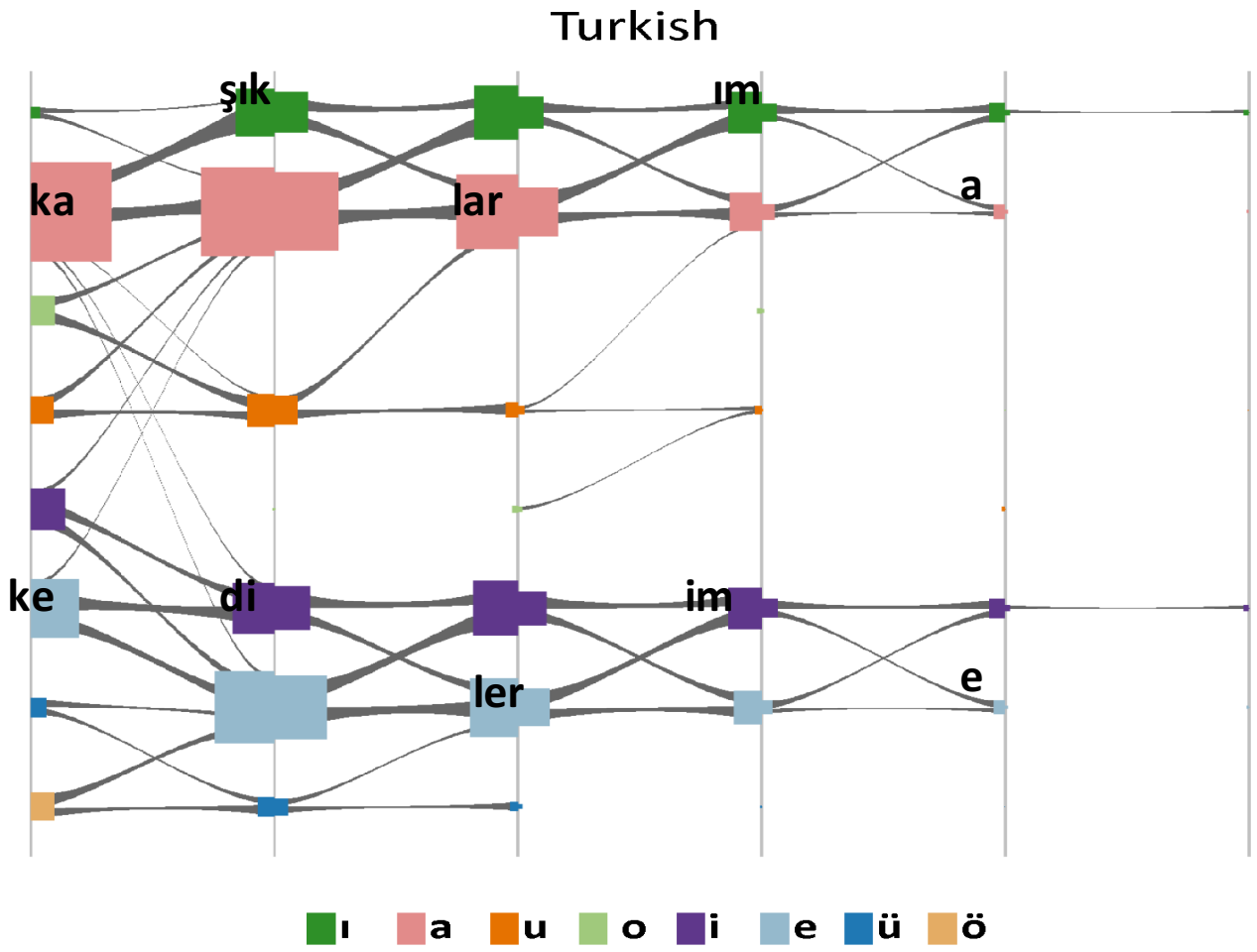
Example: Droplet Visualizations

- Different Types of Visualizations can be used to look at the same data.
- Example: Droplets for Vowel Harmony
- This droplet technique was originally used for rendering geospatial information (an item moving from one place to the next).

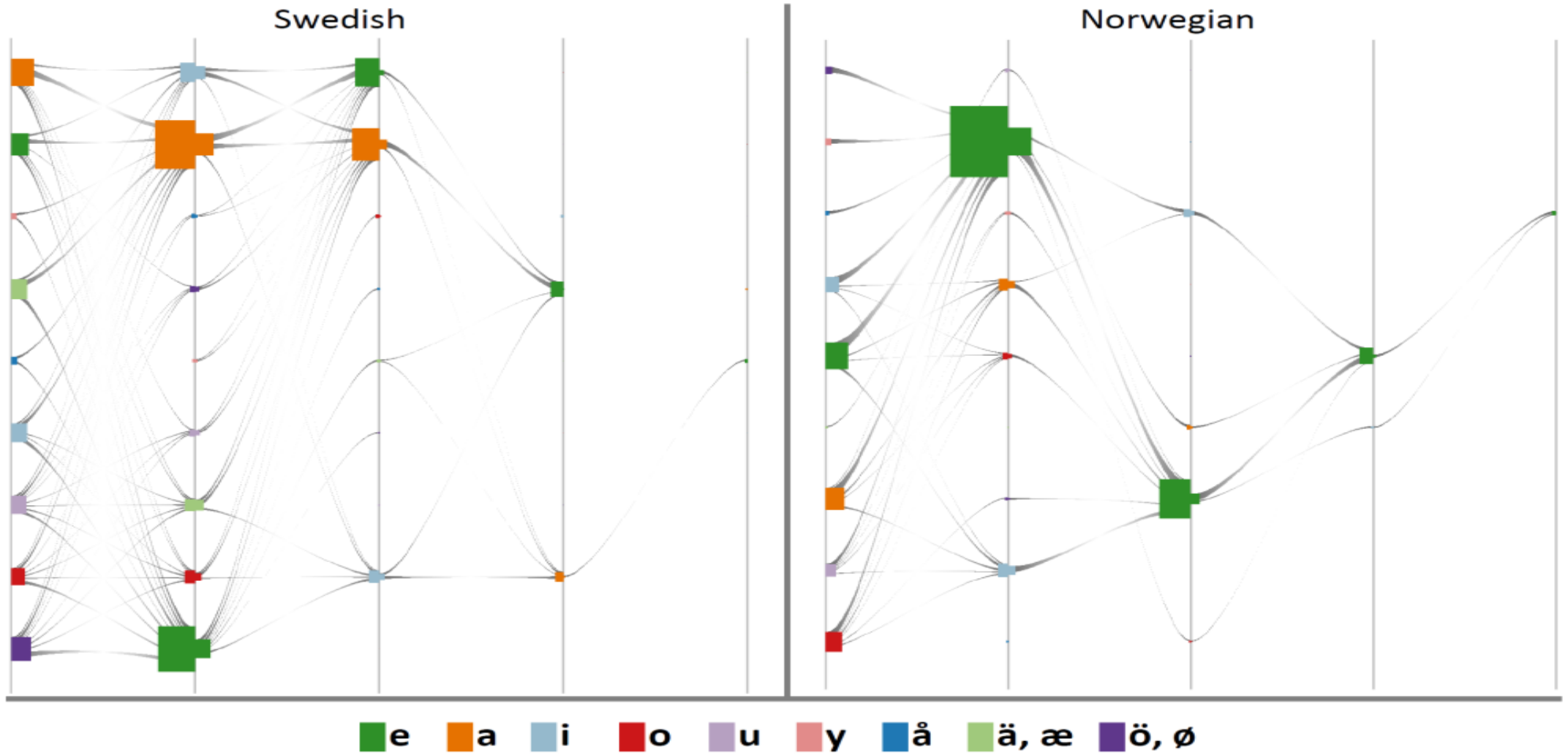
Vowel Harmony via Droplets

kaşık-lar-ım-a
spoon-Pl-1SgPoss-Dat
‘my spoons’

kedi-ler-im-e
cat-Pl-1SgPoss-Dat
‘my cat’



Language Comparison via Droplets



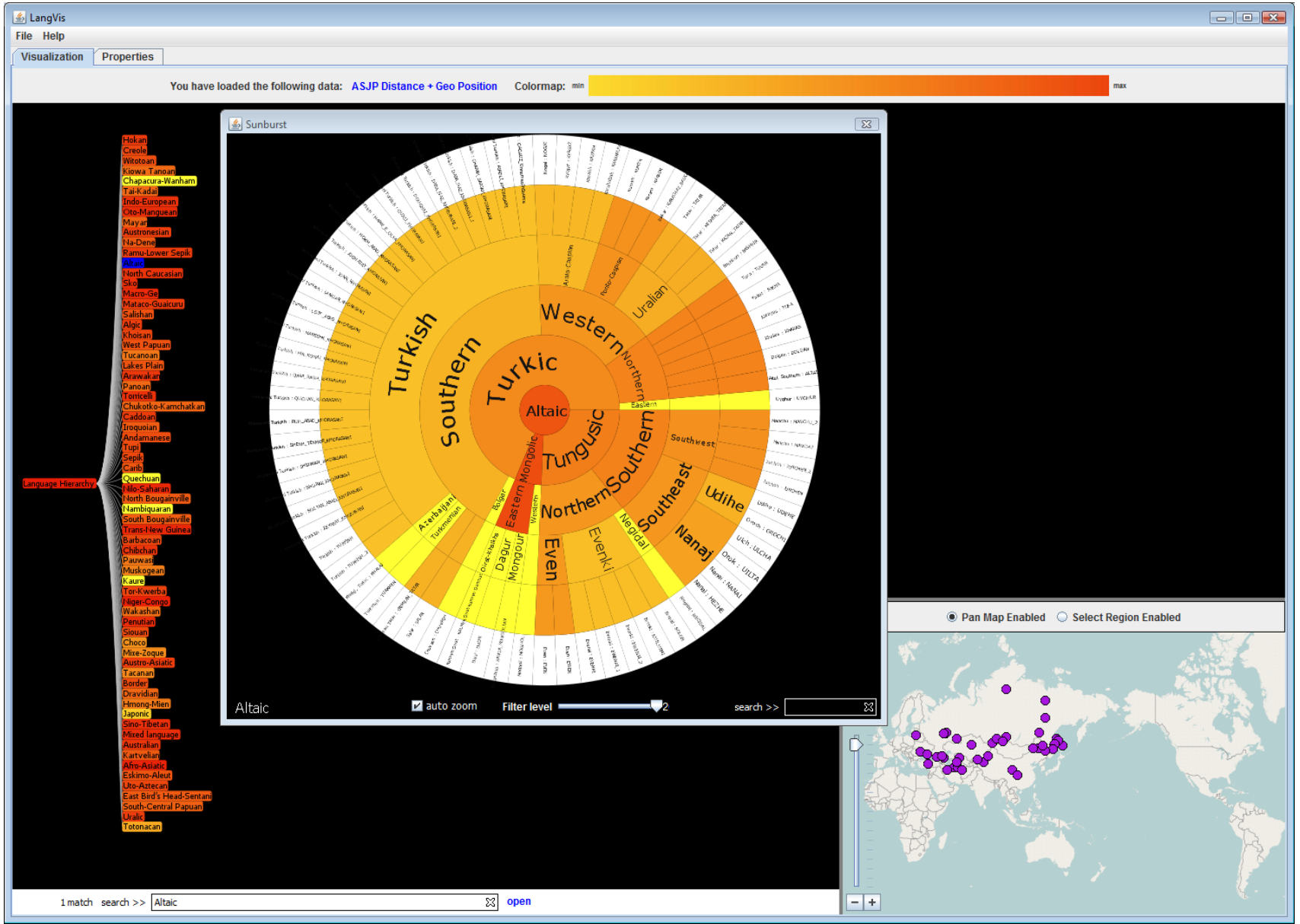
Norwegian shows language change a ➔ e in comparison to Swedish.

Example: Sunburst and Maps

- Another way to compare features across languages is via a sunburst visualization.
- The following visualization combines sunburst with a link to the geographical location of the language.
- The visual analysis is heavily interactive.
  - One can feed in one's own data.
  - One can also use the WALS (World Atlas of Language Structures; http://wals.info).

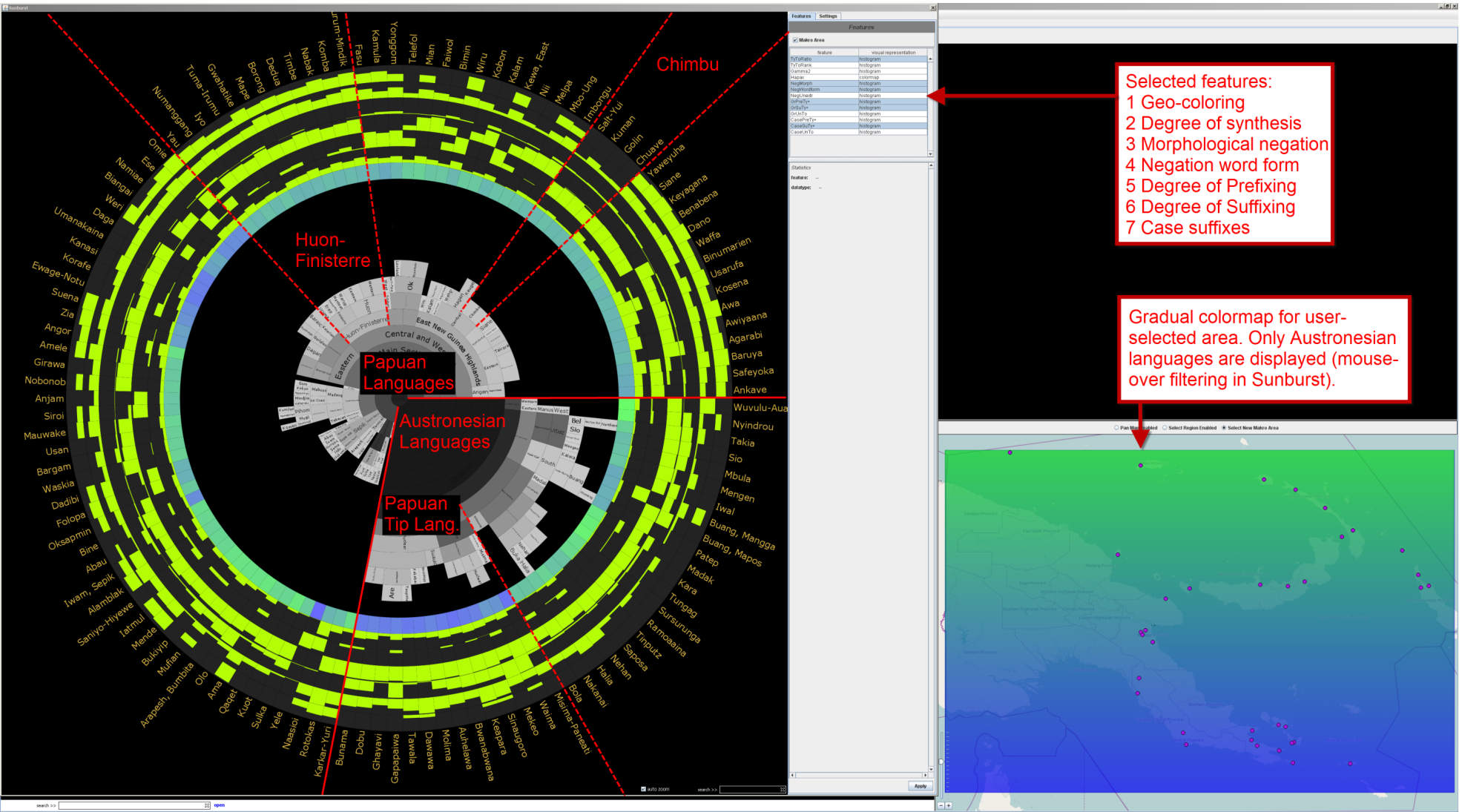
Christian Rohrdantz, Michael Hund, Thomas Mayer, Bernhard Wälchli and Daniel A. Keim. 2012. The World's Languages Explorer: Visual Analysis of Language Features in Geneaologica and Areal contexts. Computer Graphics Forum 31(3), 935-944.

Sunburst and Maps for Language Families



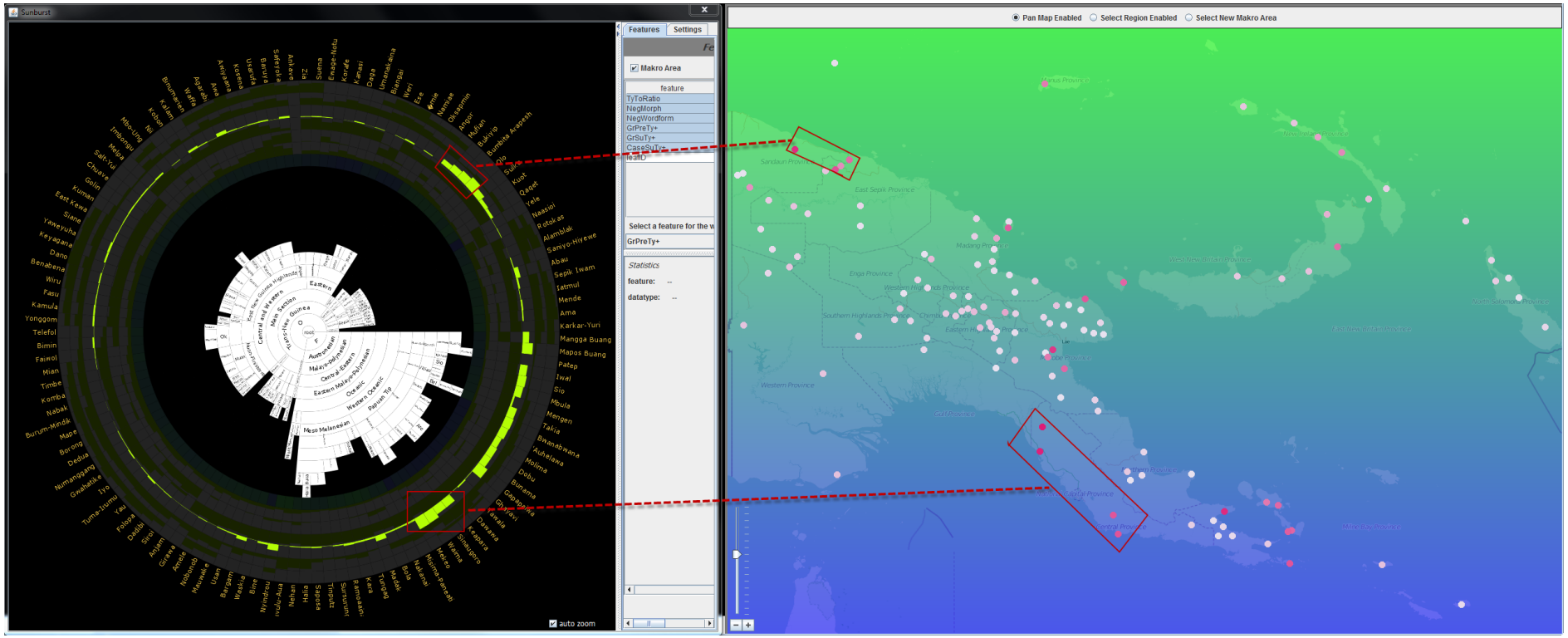
World's Language Explorer

Comparing 126 Languages of Papua New-Guinea based on the New Testament.



Each circle segment represents one language, each ring the values of one feature across all languages.

World's Language Explorer



Bringing genealogy (left) and areal distributions (right) interactively into context: The values of a selected feature ring are color-coded on a map for exploration.

Sorting and Pattern Discovery

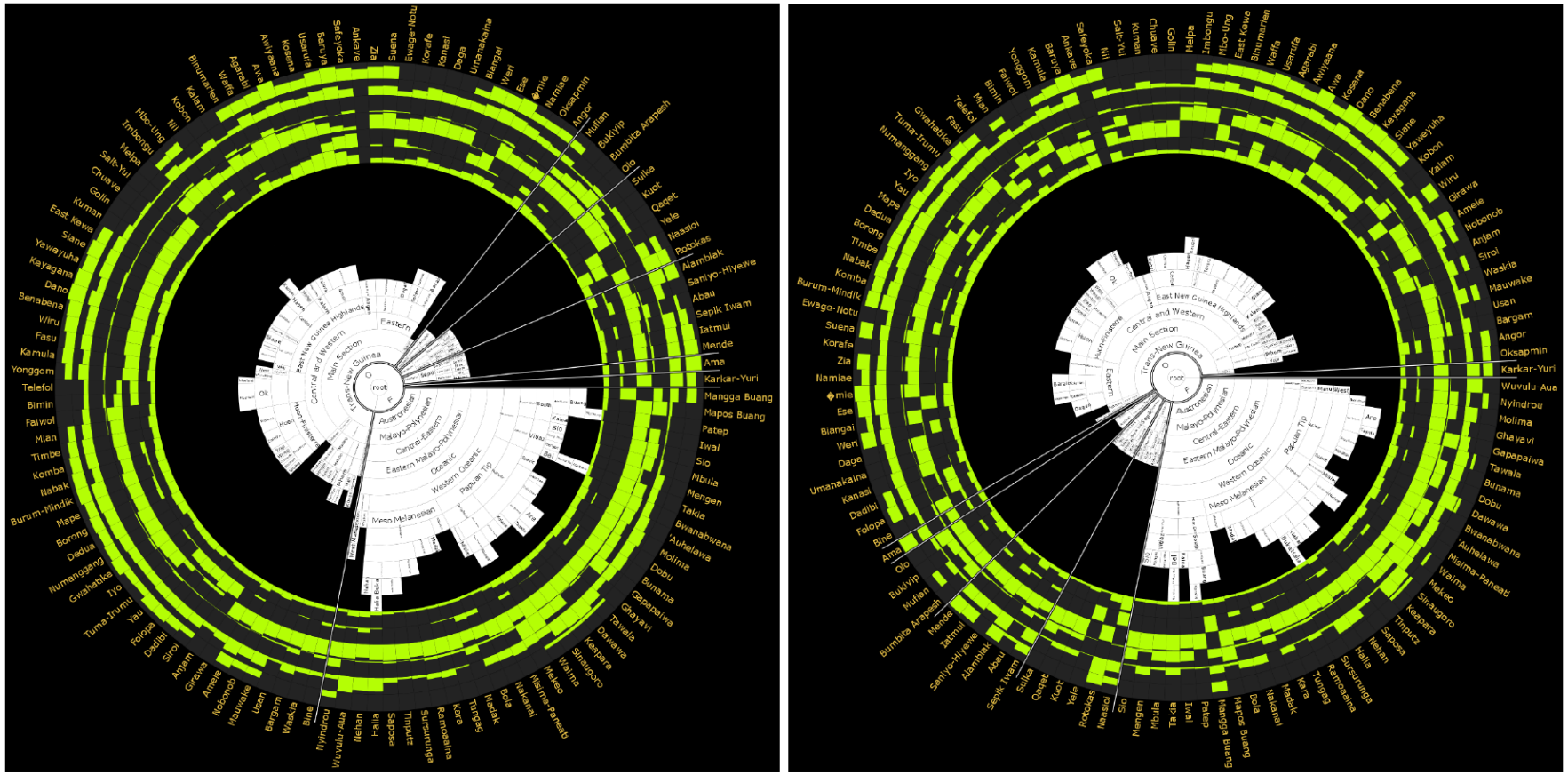
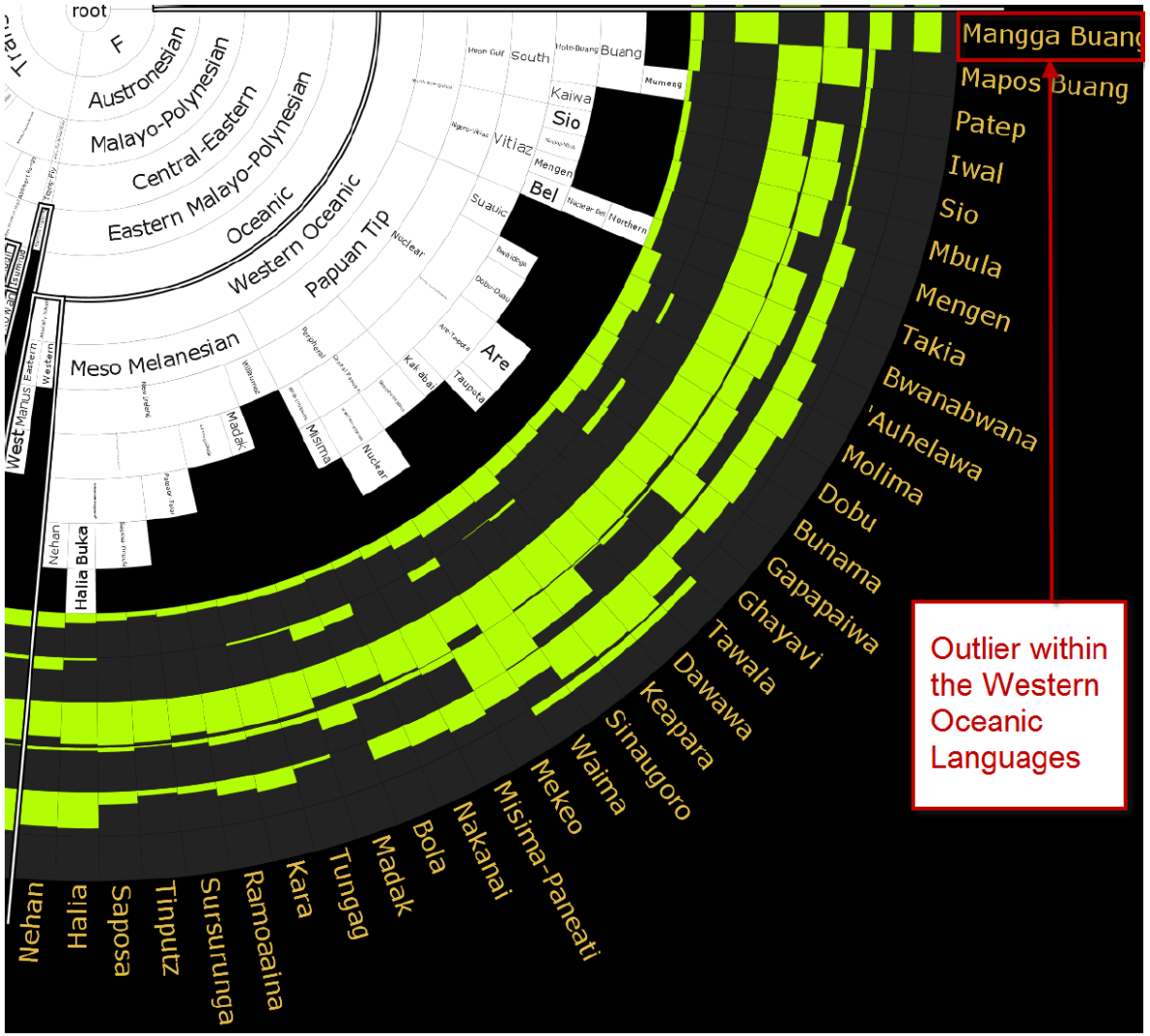


Figure 2.5: High-resolution screenshot showing automatically extracted features for languages from Papua New Guinea with leaves ordered to *maximize* (left) and *minimize* (right) the pairwise leaf similarity for neighbors.

Sorting and Pattern Discovery



WALS Explorer

- A version that is tailored to interact with WALS is available on-line
- http://www.th-mayer.de/wals/

Thomas Mayer, Bernhard Wälchli, Christian Rohrdantz and Michael Hund. 2014. From the extraction of continuous features in parallel texts to visual analytics of heterogeneous areal-typological datasets. In B. Nolan and C. Periñán-Pascual (eds.), Language Processing and Grammars: The role of functionally oriented computational models, 13–38. John Benjamins.

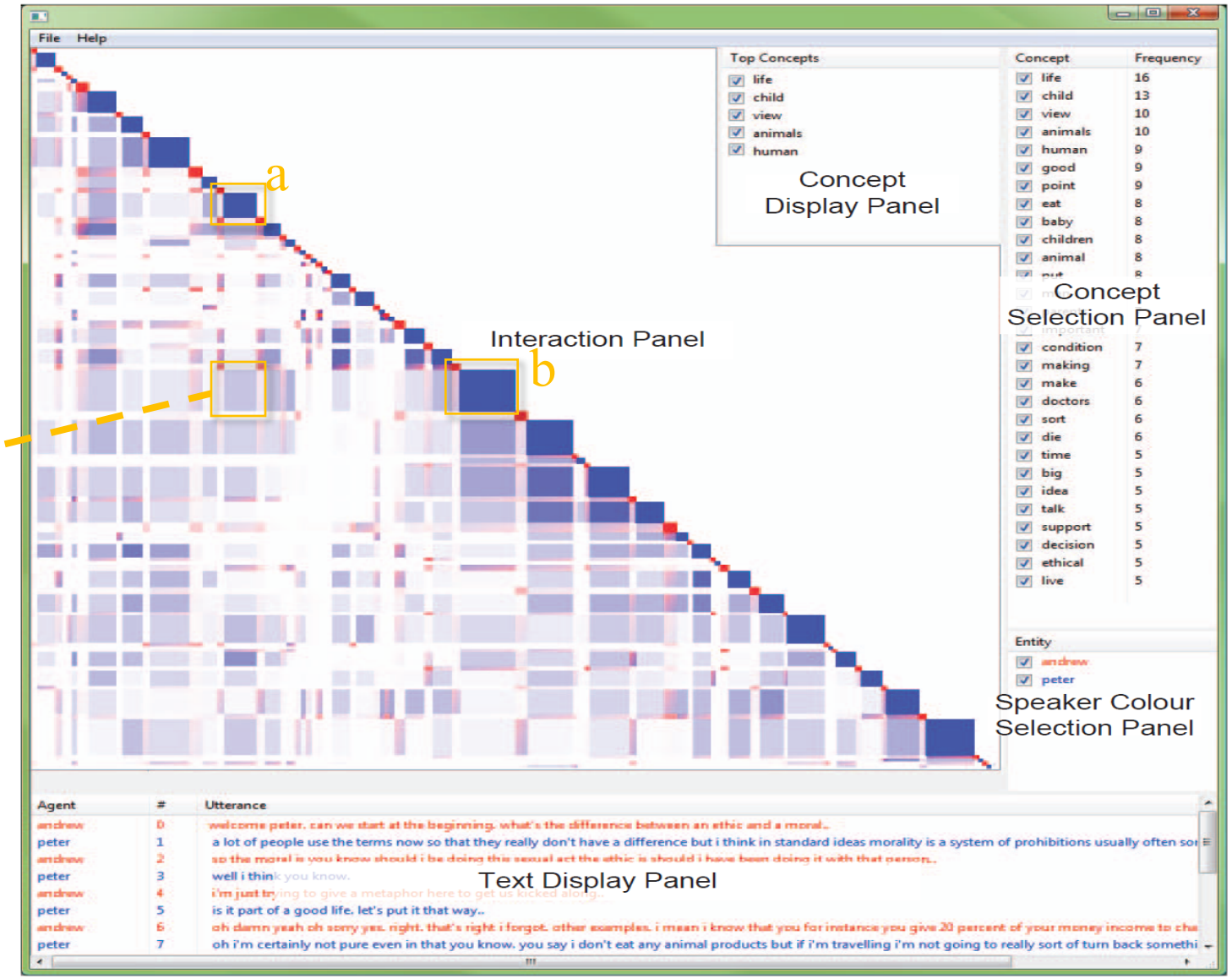
Conceptual Recurrence Plots

- Another type of much studied language data: discourses.
- The context of social media (Twitter, Facebook, etc.) presents us with new opportunities but also with new challenges.
- Next up: visual analysis of a (conventional) dialog – an interview.

Daniel Angus, Andrew E. Smith, Janet Wiles: **Conceptual Recurrence Plots: Revealing Patterns in Human Discourse**. *IEEE Trans. Vis. Comput. Graph.* 18(6): 988-997 (2012)

Discursis

Saturation shows how much b relates to a (content-wise)



Discursis

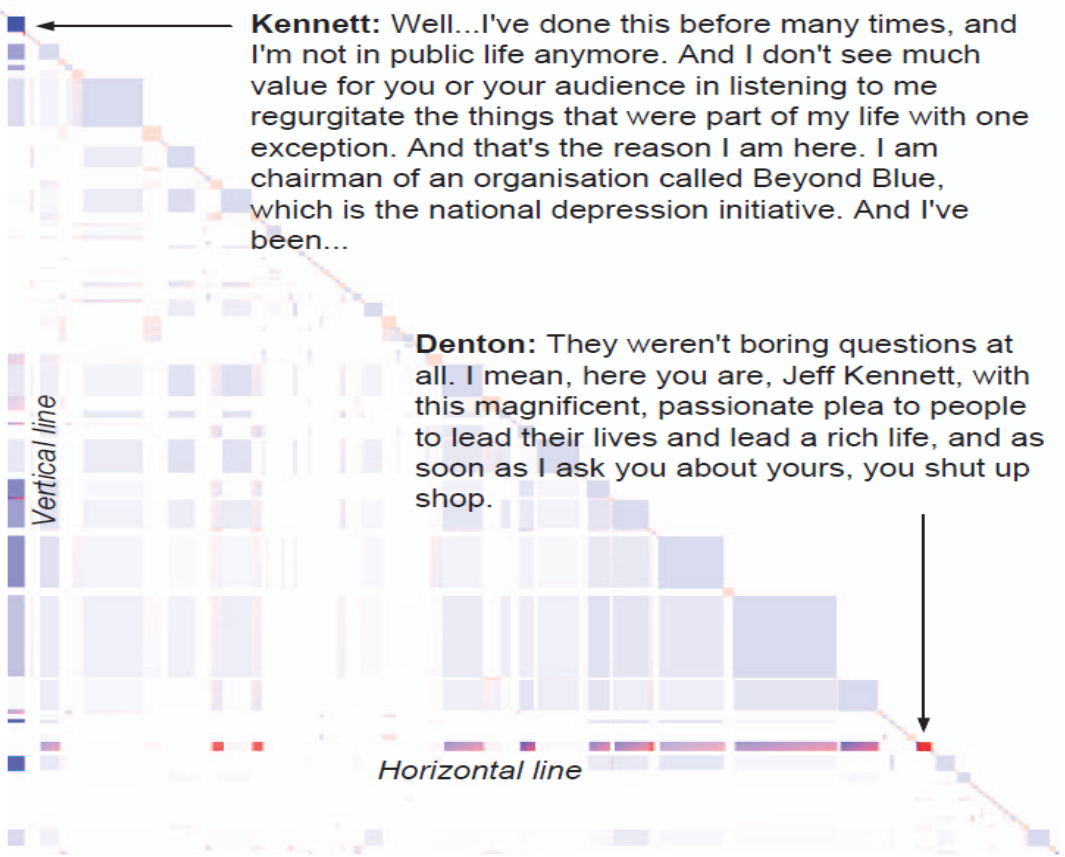


Fig. 7: Recurrence Lines (*Denton/Kennett*)

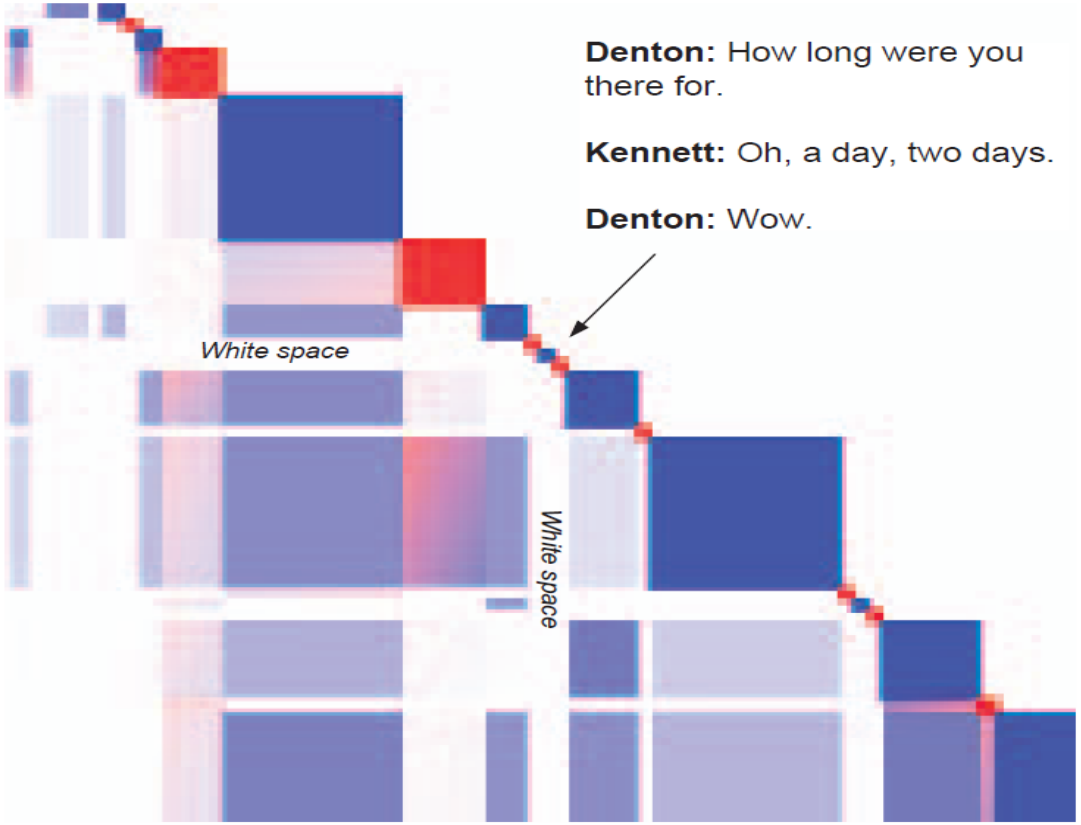


Fig. 8: White space (*Denton/Kennett*)

Discursis

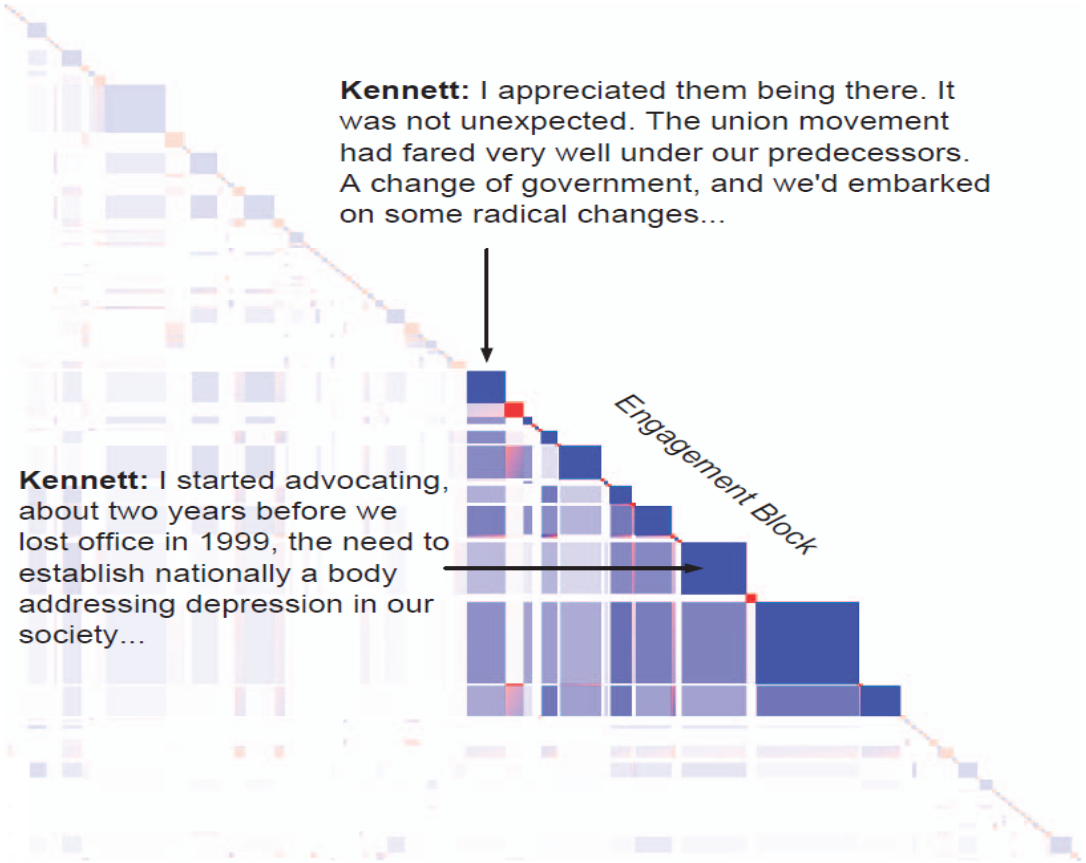


Fig. 9: Engagement Block (*Denton/Kennett*)

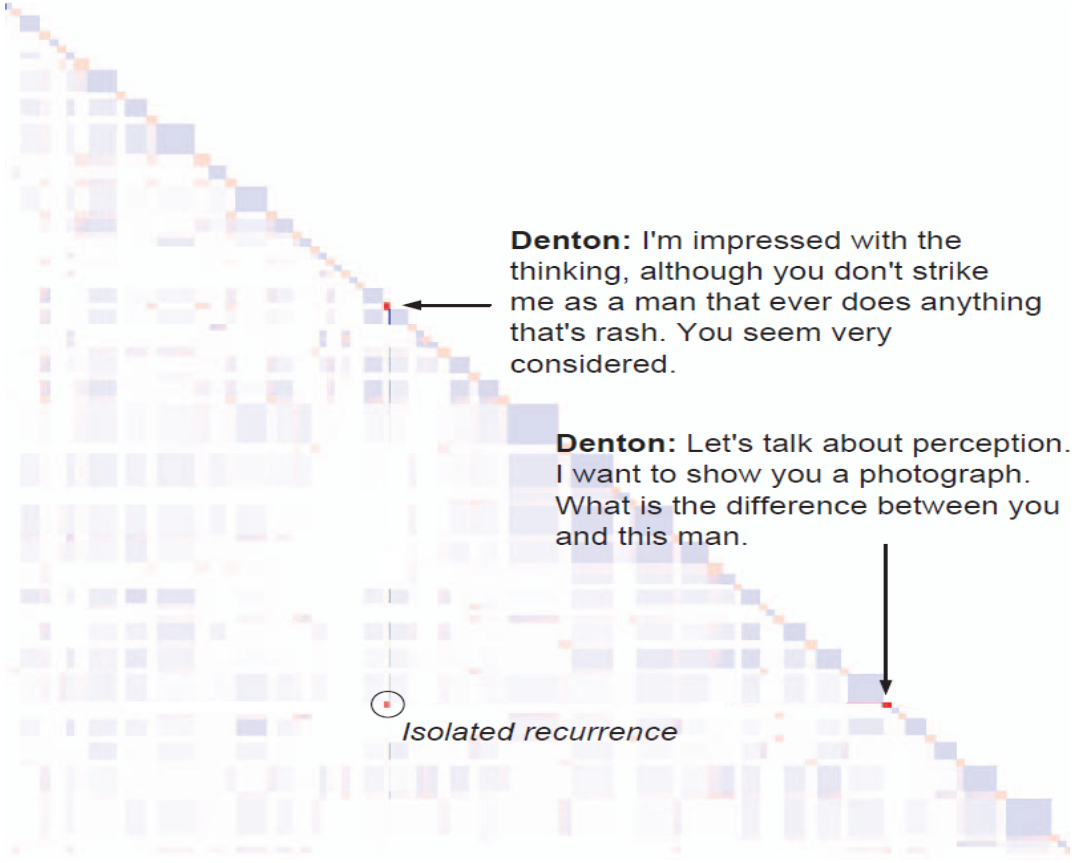
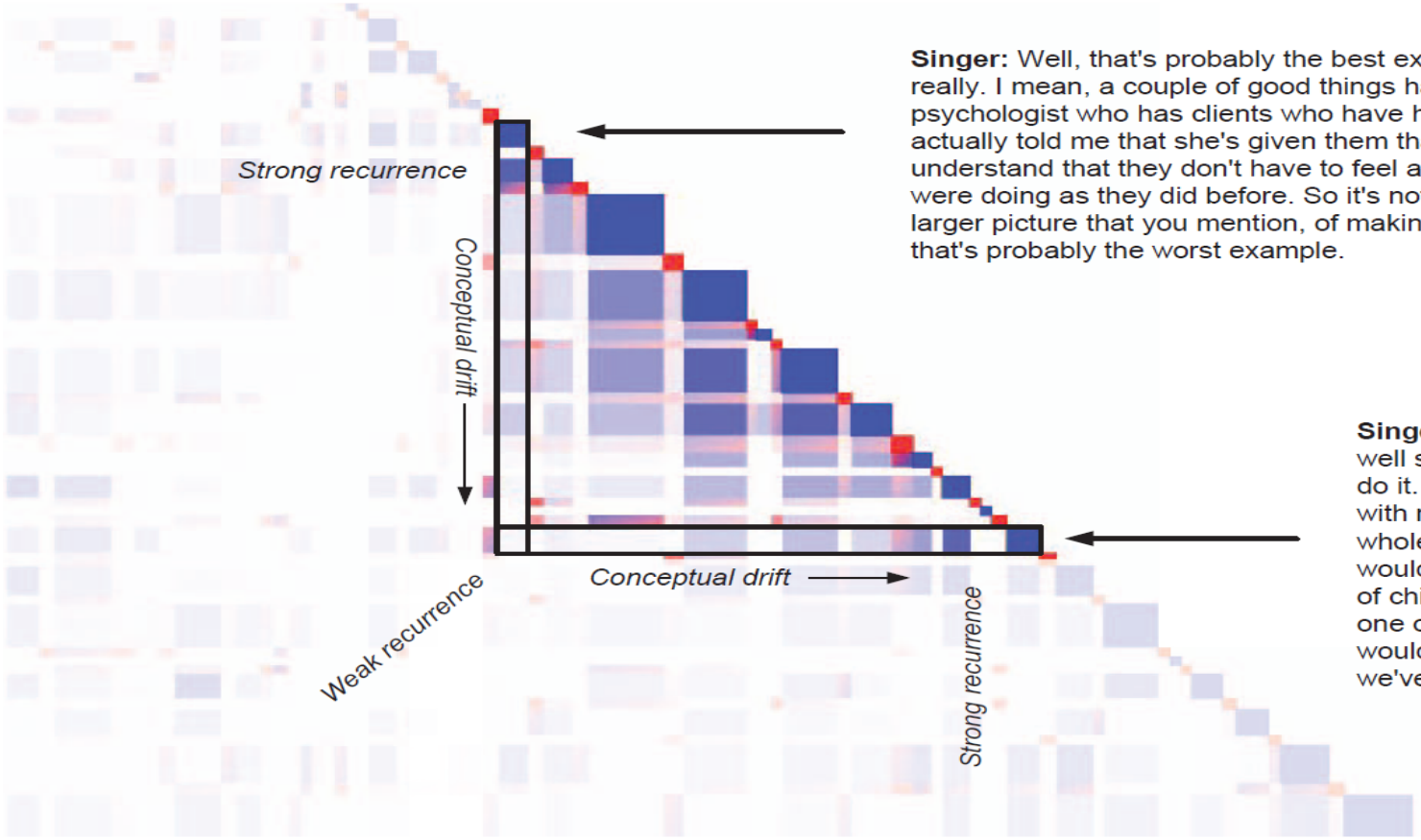


Fig. 10: Random Scattering (*Denton/Singer*)

Discursis



Singer: Well, that's probably the best example because it's not a major issue, really. I mean, a couple of good things have come out of that. I mean, a psychologist who has clients who have had sexual contact with animals has actually told me that she's given them that review and it's helped them to understand that they don't have to feel as guilty and tortured about what they were doing as they did before. So it's not totally a bad thing, but in terms of this larger picture that you mention, of making it easier for people to sideline me, that's probably the worst example.

Singer: Well, no, I think that I'm not the sort of person who's well suited for that kind of child rearing and I would rather no do it. I mean, I think there's many other things that I could do with my time that would be more beneficial for the world as a whole than trying to be the father of a child like that, and I would. You know, as I said, I think there's a limited number of children that my wife and I were planning to have and had one of them been a child with Down's, then I think that we would have felt that we would have missed something which we've fortunately been able to have from our other children.

Fig. 11: Concept Drift (*Denton/Singer*)

Glyph Visualization for Diachronic Corpora

- Visualization of IcePaHC – Diachronic Corpus of Icelandic
  - Syntactically annotated in Penn Treebank style
  - 60 texts
  - 12th century CE to 21st century CE

- Two case studies so far (on-going)
  - V1 in Icelandic
  - Dative Subjects in Icelandic

Glyph Visualization for Diachronic Corpora

V1 (Verb Initial or Verb First)

- Verb initial structures were common in matrix declaratives in Germanic.
- In German (and English) they mostly survive in narrative/joke contexts

  Walked a man into a pub...

Questions

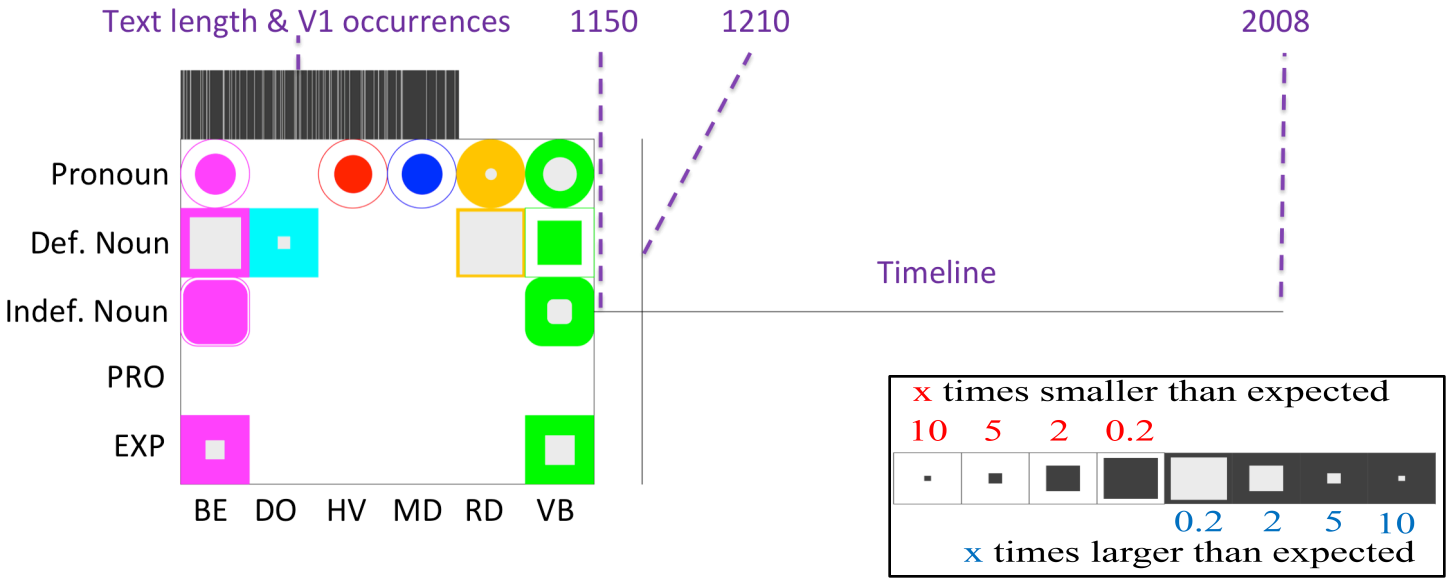
- What determines the appearance of V1?
- How did this change over the history of Germanic?

Butt, Miriam, Tina Bögel, Kristina Kotcheva, Christin Schätzle, Christian Rohrdantz, Dominik Sacha, Nicole Dehé & Daniel Keim. 2014. V1 in Icelandic: A Multifactorical Visualization of Historical Data. Proceedings of the LREC 2014 Workshop on Visualization as added value in the development, use and evaluation of LRs (VisLR). Reykjavil Iceland.

Example: V1 in Icelandic

Visual Analytic Access to Data

- Glyph Visualization of likely factors
- Overview of all 60 texts at once
- Can drill down to individual data points interactively
- **Keim's Mantra**: Overview First, Show the Important – Details on Demand



Icelandic Visualization Demo

Visualization of Pitch Contours

- So far we have been working with textual data.
- However, one can also work with spoken data.
- For Visual Analytics, all one needs is to have features (or vectors) that can be computed with.

Data

- Japanese vs. German ‘sorry’
- Japanese pitch contour always has a fall
- Germans can vary according to pragmatic intent
- Recorded German and Japanese natives vs. learners of German and Japanese (beginners/advanced)

Dominik Sacha, Yuki Asano, Christian Rohrdantz, Felix Hamborg, Daniel A. Keim, Bettina Braun & Miriam Butt. 2015**. Self Organizing Maps for the Visual Analysis of Pitch Contours**. *Proceedings of the 20th Nordic Conference of Computational Linguistics* (NoDaLiDa-2015), Vilnius, Lithuana, 2015.

Example: Speech Data via SOMs

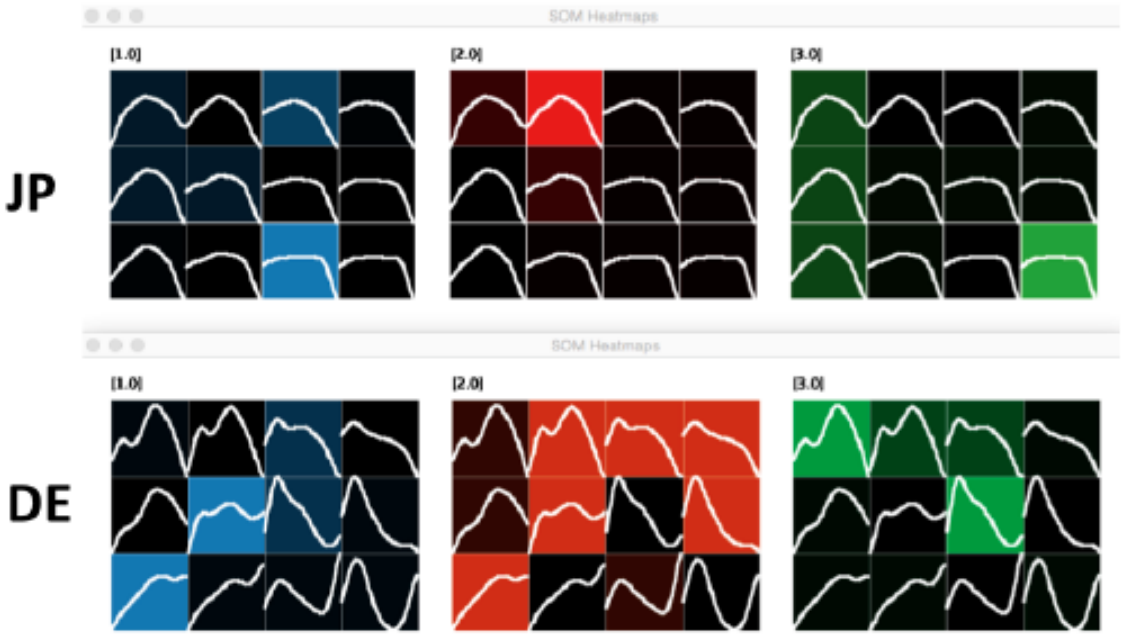
- Japanese Native and German L2 Learner data (pitch contours and meta data)
- F0 contours are smoothed and normalized into pitch vectors
- The pitch vectors are visualized via self-organizing maps (SOM)

Speakers pronounced "*sorry/excuse me*" in ever more exasperating circumstances

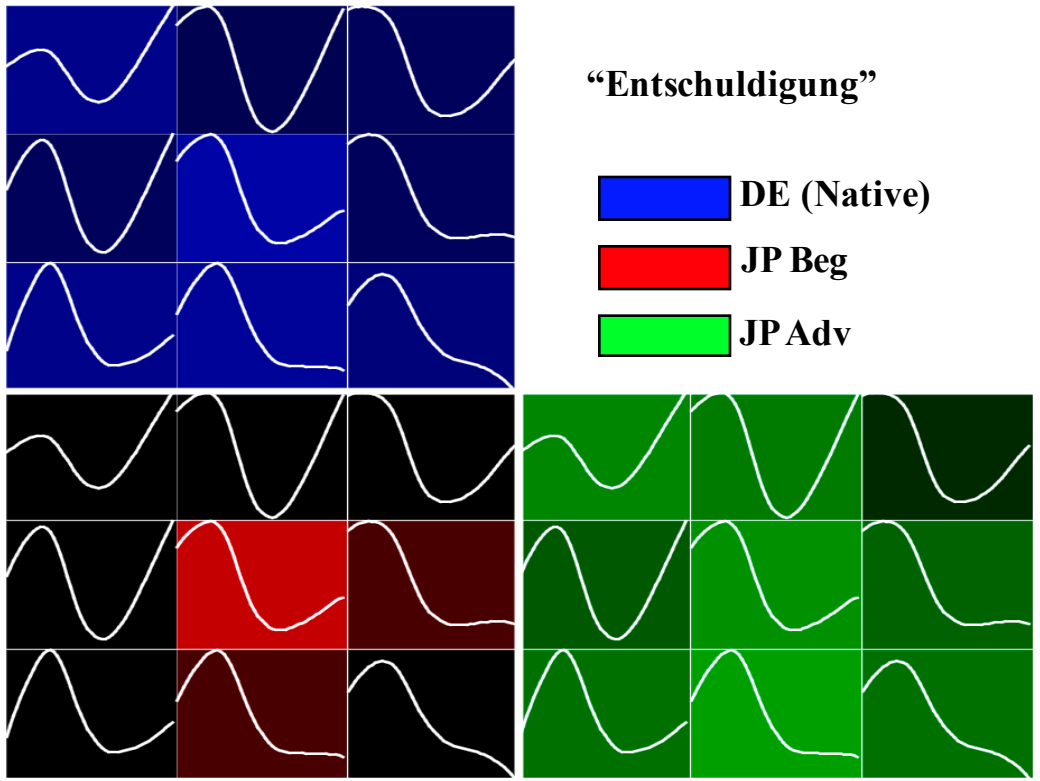
- Japanese natives do not vary the pitch contour
- German learners do vary the pitch
- German beginner learners do so more

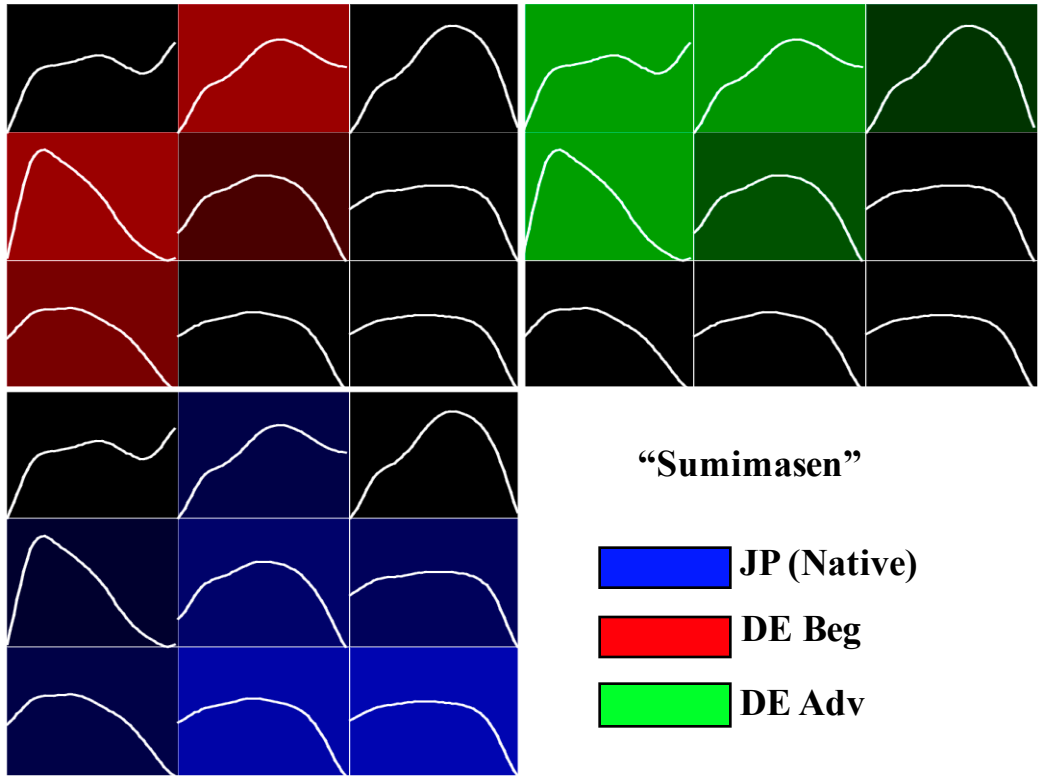
Interactive Exploration:

- individual cells can be merged
- meta data can be inspected
- individual pitch tracks can be examined in context



German Entschuldigung ‘sorry’ vs. Japanese Sumimasen ‘sorry’





Example: Speech Data via SOMs

- Different views on the data and meta data can be explored interactively

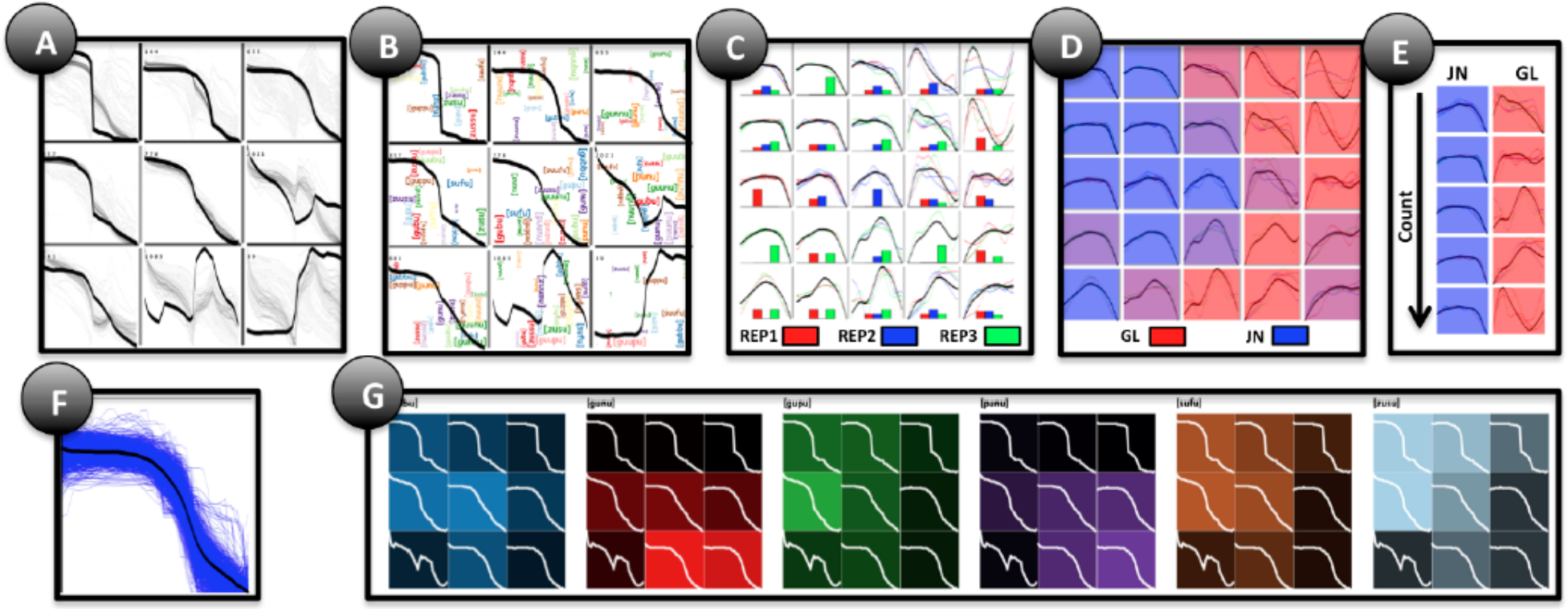
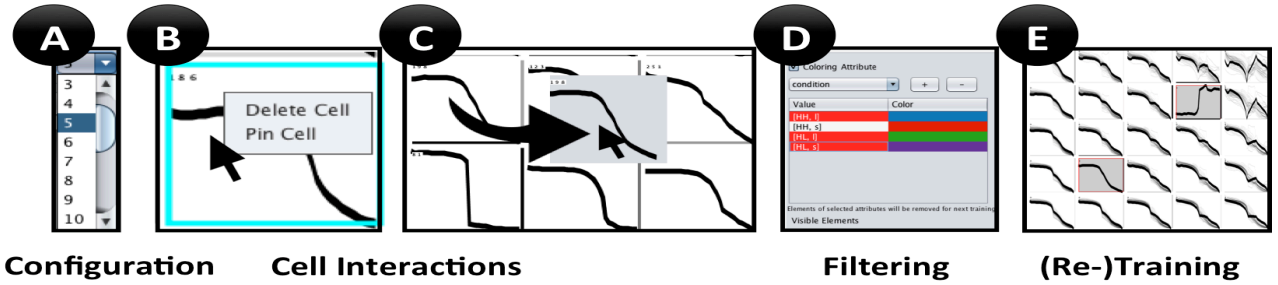
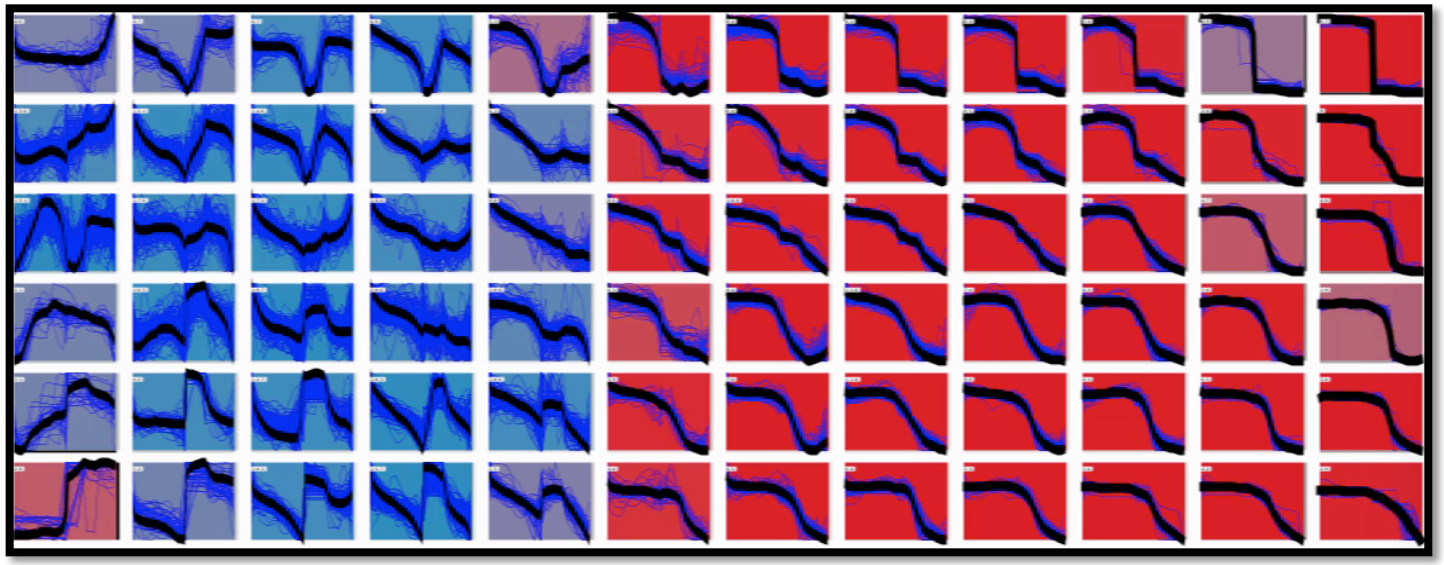


Figure 3: Different approaches to visualize SOM-results according to available meta-data. (A) Grid visualization, (B) word cloud, (C) bar charts, (D) mixed color cells, (E) ranked group clusters, (F) one single cell that visualizes contained vectors and the cluster prototype, (G) separated heatmaps for all values of a categorical attribute.

Interactive Data Exploration: SOMs in Action





Data Exploration

- SOM learning is fast
- user can switch among different perspectives on the data
- user can interactively delete or pin cells
- and retrain and re-explore

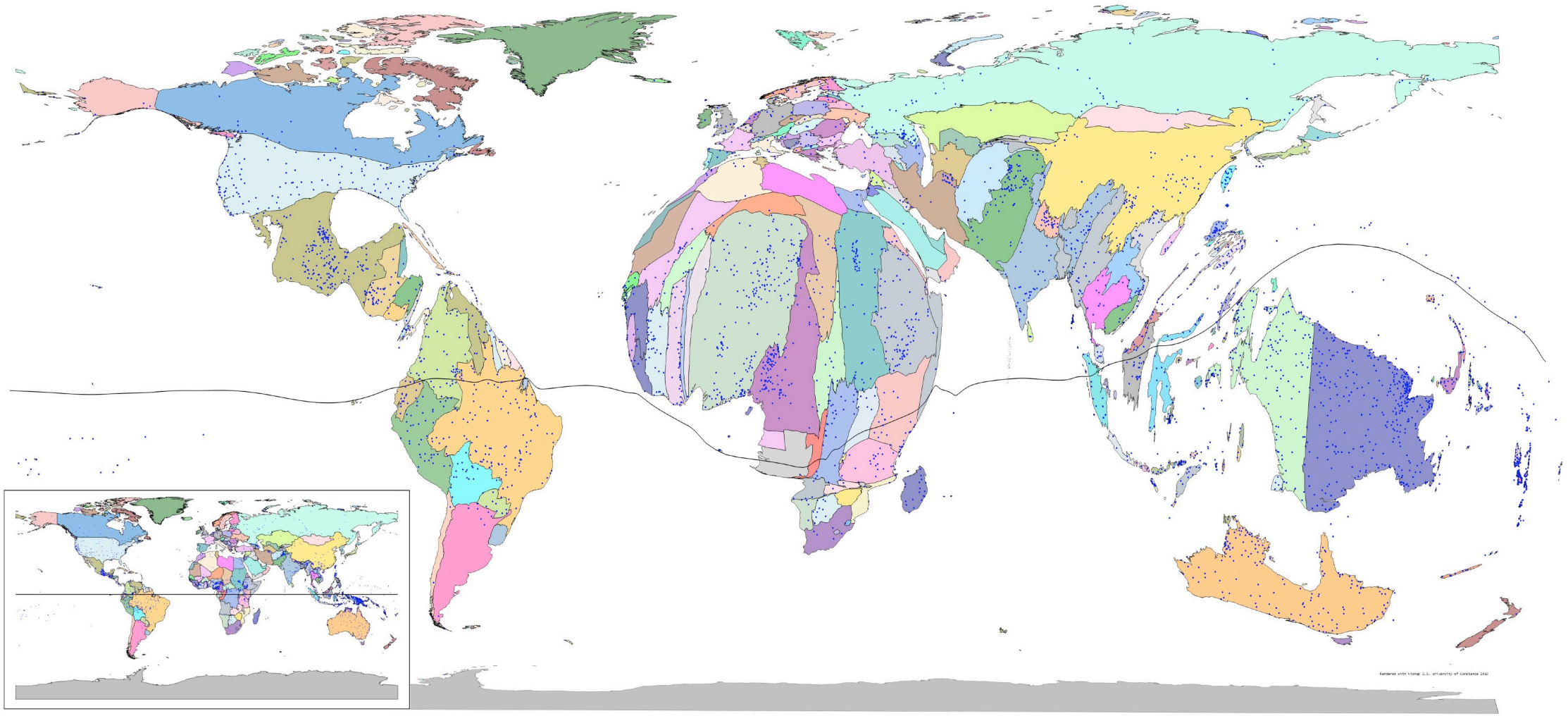
Identifying Optimal Visualizations

- Understanding which visualizations are optimal is not trivial.
- Are the individual dimensions (color, shape, direction, size, etc.) usefully meaningful?
- Does the visualization allow for at-a-glance understanding, or does it confuse the user?

- This also depends on the user's background
  - What is the user used to looking at?
  - How is the user used to understanding the data?
  - How is the user used to interacting with systems?

- Currently evaluations are mainly performed via user studies in Visual Analytics.
- New Project (SFB/TRR 161): Establish evaluation metrics.

Distorted Map according to number of languages spoken in area.



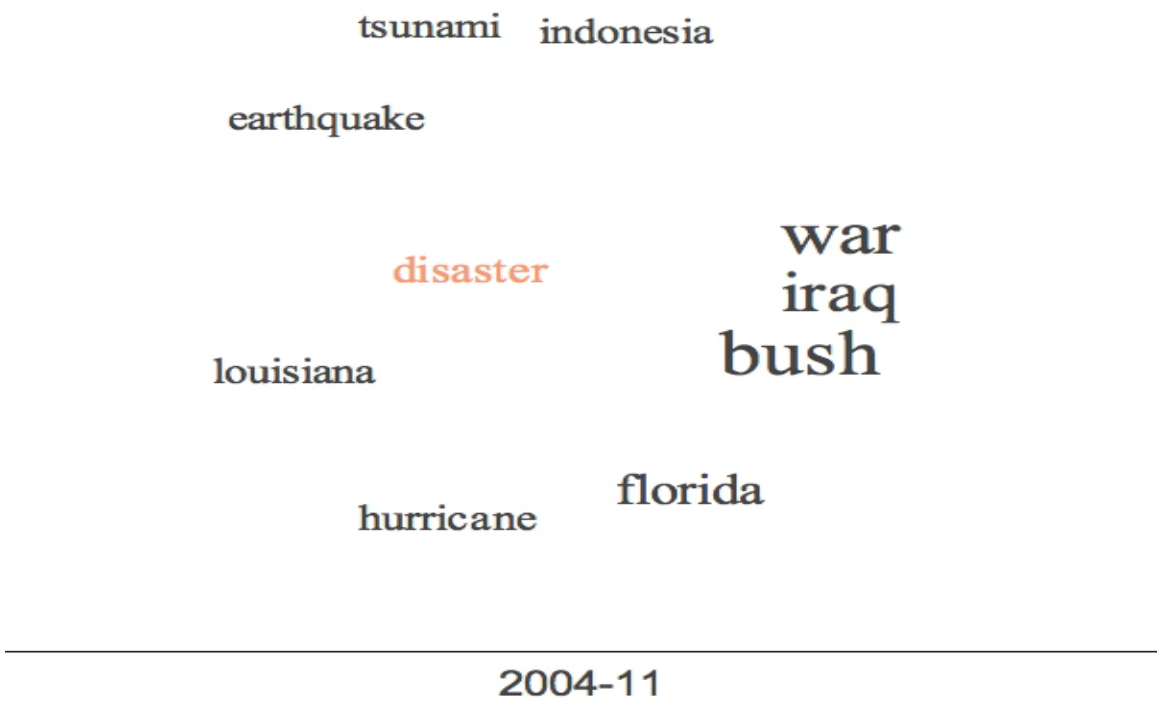
Visualization only as good as your data – India massively underrepresented

Using Motion

- highly frequent words in New York Times articles 2004-2005 and their relation to one another
- show trends/change

Challenges for Visualization:

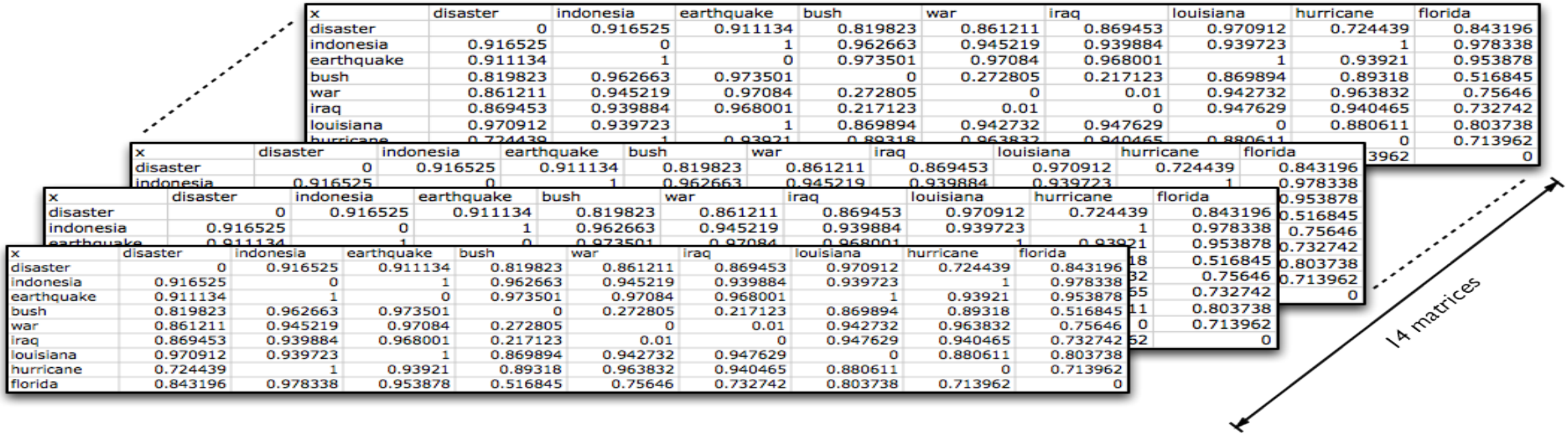
- **dimensionality reduction**:
  high dimensional distance matrices are shown in 2D
- **precision vs. stability**:
  a precise visualization for each time step would induce too much confusing movement



(Work Group: Oliver Deussen, University of Konstanz)

Example: Animated Visualization

- the raw data without visualization:
  - 9x9 distance matrices for each of the 14 time steps



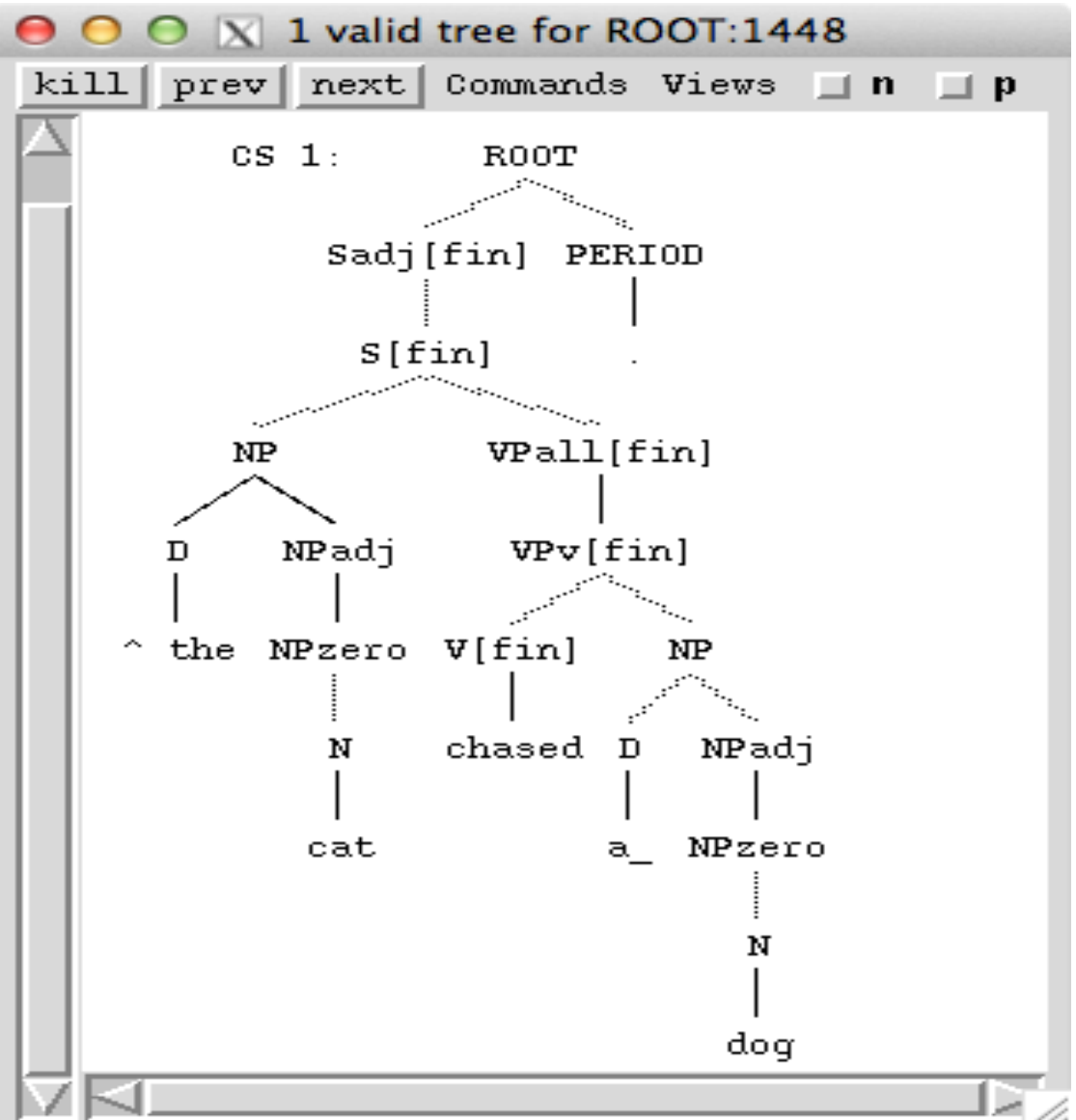
x	disaster	indonesia	earthquake	bush	war	iraq	louisiana	hurricane	florida
disaster	0	0.916525	0.911134	0.819823	0.861211	0.869453	0.970912	0.724439	0.843196
indonesia	0.916525	0	1	0.962663	0.945219	0.939884	0.939723	1	0.978338
earthquake	0.911134	1	0	0.973501	0.97084	0.968001	1	0.93921	0.953878
bush	0.819823	0.962663	0.973501	0	0.272805	0.217123	0.869894	0.89318	0.516845
war	0.861211	0.945219	0.97084	0.272805	0	0.01	0.942732	0.963832	0.75646
iraq	0.869453	0.939884	0.968001	0.217123	0.01	0	0.947629	0.940465	0.732742
louisiana	0.970912	0.939723	1	0.869894	0.942732	0.947629	0	0.880611	0.803738
hurricane	0.724439	1	0.93921	0.89318	0.963832	0.940465	0.880611	0	0.713962
florida	0.843196	0.978338	0.953878	0.516845	0.75646	0.732742	0.803738	0.713962	0

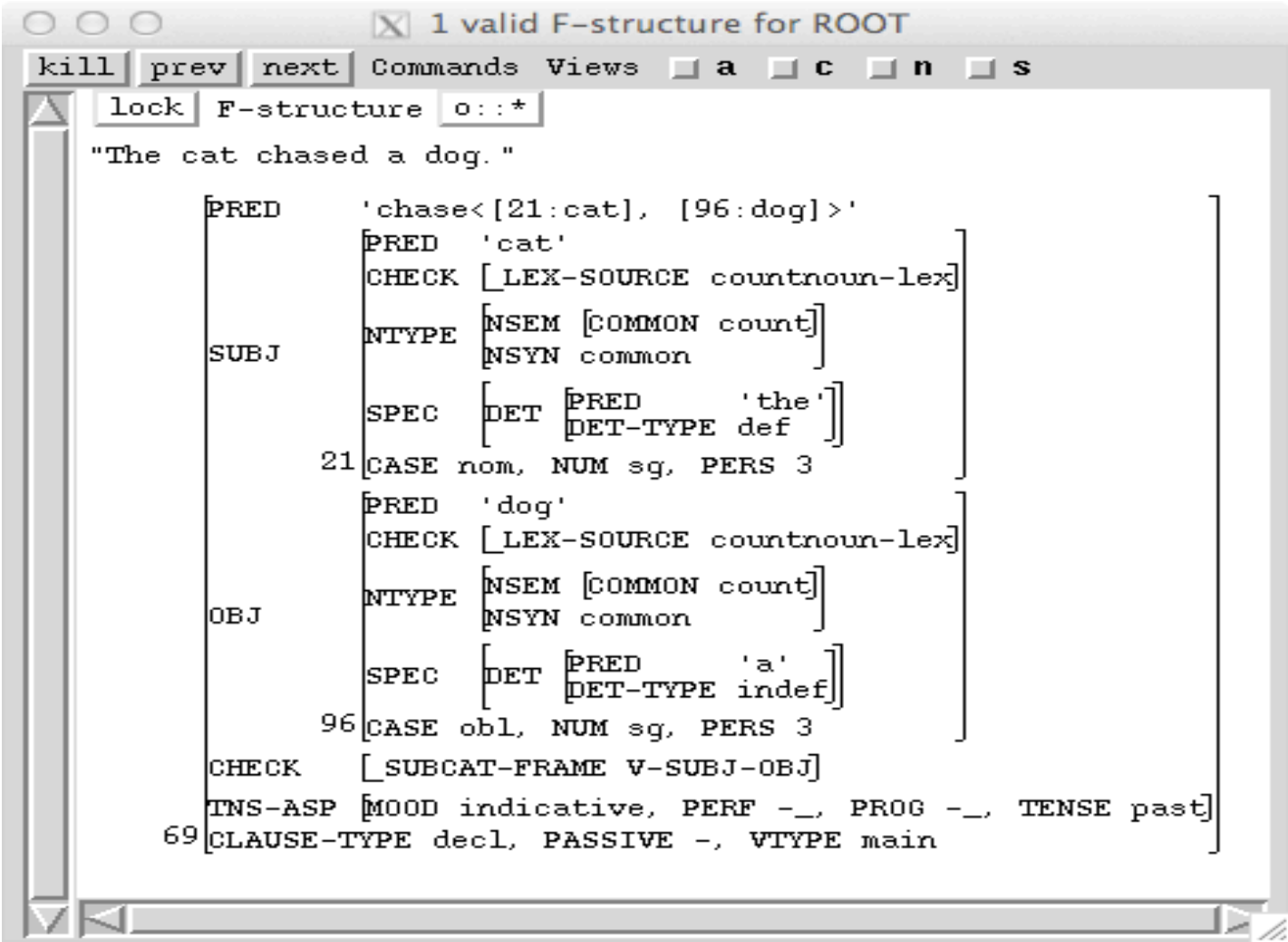
14 matrices

Tree Comparison via Sunburst

- Various types of trees are used to represent data in terms of hierarchical relationships.
  - XML hierarchies
  - Linguistic structure
- Concrete Example: LFG
  - c-structures via standard trees
  - f-structures: dependency structure via AVMs

English LFG ParGram Grammar

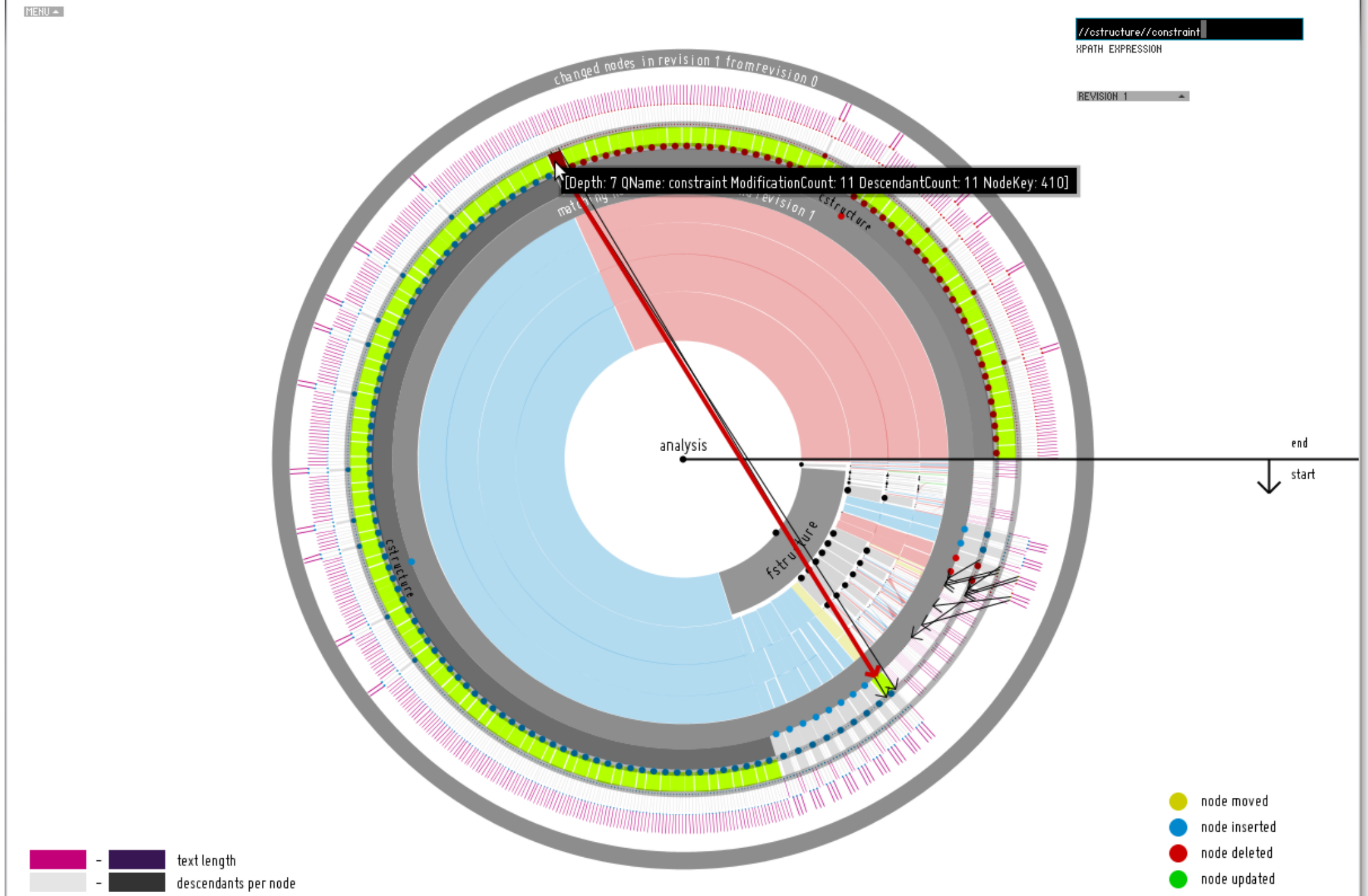


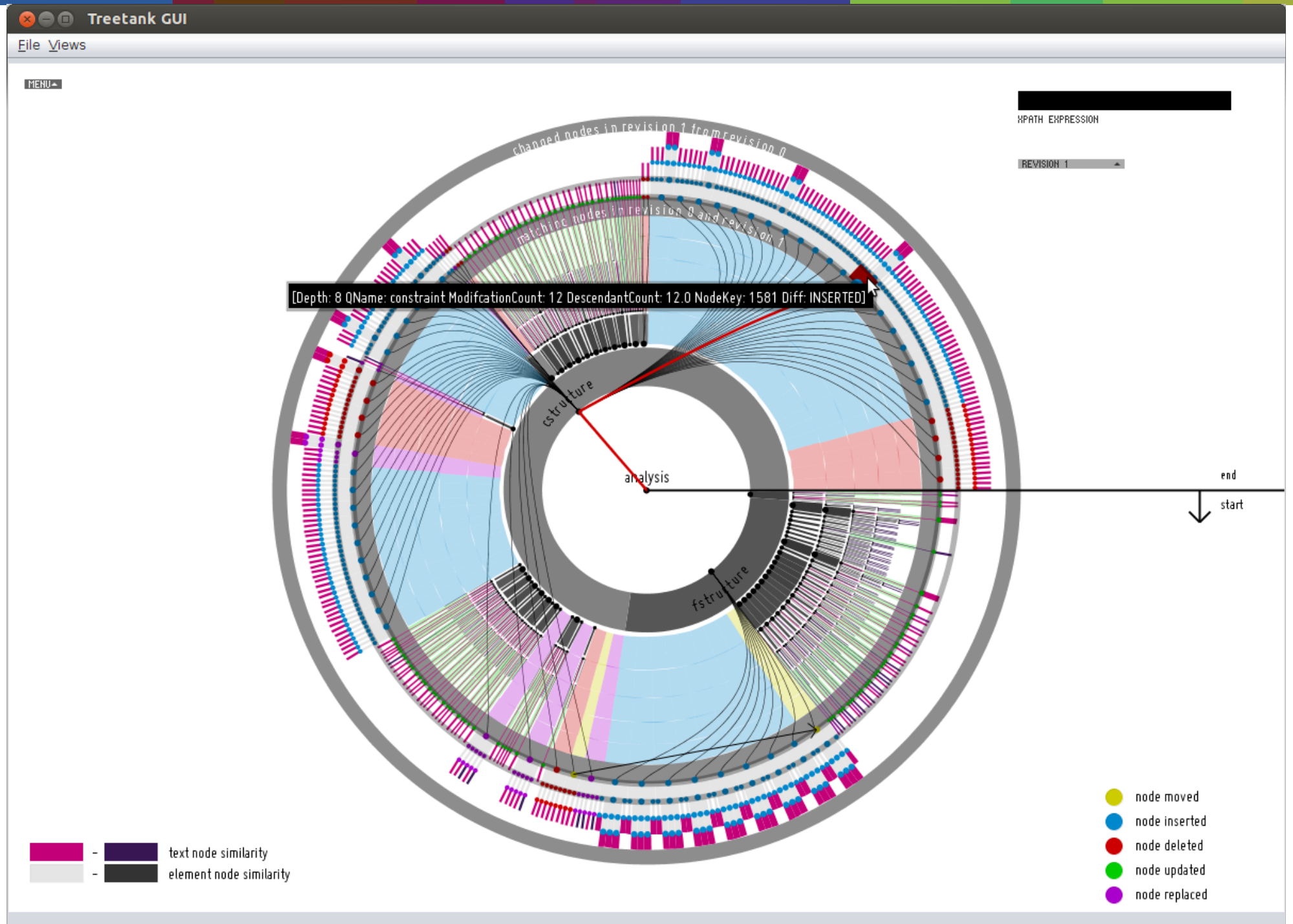


Tree Comparison for Grammar Development

- In Grammar Development the grammar is routinely updated/changed.
- This necessarily means that the output will differ.
- Would be good to have an automatic visual tree comparison method.
- The following are proposals by Lichtenberger (2012).

Johannes Lichtenberger. 2012. A Visual Analytics Approach for Comparing Tree Structures. MSc., University of Konstanz. http://kops.ub.uni-konstanz.de/handle/urn:nbn:de:bsz:352-210419


MENU
//cstructure//constraint
XPATH EXPRESSION
REVISION 1
changed nodes in revision 1 fromrevision 0
[Depth: 7 QName: constraint ModificationCount: 11 DescendantCount: 11 NodeKey: 410]
cstructure
cstructure
fstructure
analysis
end
start
text length
descendants per node
node moved
node inserted
node deleted
node updated


Treetank GUI
File Views
MENU
XPATH EXPRESSION
REVISION 1
changed nodes in revision 1 from revision 0
matching nodes in revision 0 and revision 1
[Depth: 8 QName: constraint ModifcationCount: 12 DescendantCount: 12.0 NodeKey: 1581 Diff: INSERTED]
cstructure
analysis
fstructure
end
start
text node similarity
element node similarity
node moved
node inserted
node deleted
node updated
node replaced

Outlook

- Further Exploration of Possibilities offered by Visual Analytics
  - The systems illustrated here are very new.
  - Interactive exploratory linguistic analysis is on-going.
  - Systems are being fine-tuned.

- Workflow
  - Use cases for Digital Humanities /eHumanities are being developed.
  - **Infrastructure** Platforms (mix and match the available tools)

- Measuring Success
  - Development of **Evaluation Metrics** for LingVis.
  - Use cases, work flow and result comparison.

What interests Visualizers?

- Need interesting interactions
- Multiple dimensions
- Time depth
- Cross-modular interactions.
- Not just coloring in bits of text that are of interest for linguists.

Summary and Outlook

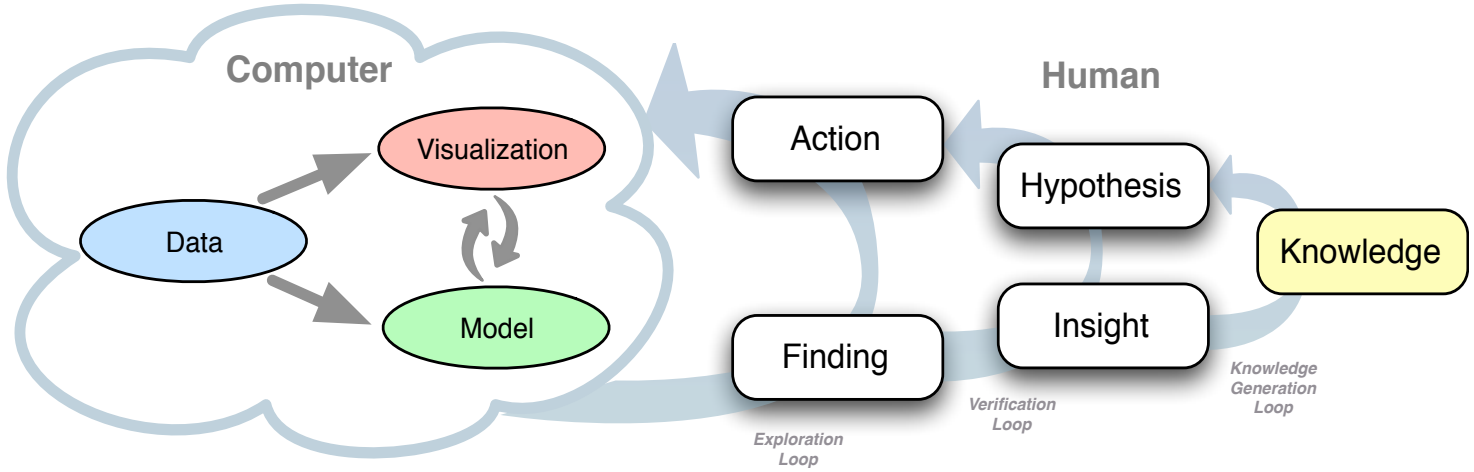
- Have seen examples of different kinds of visualizations.
- These visualizations allow a new approach to linguistic data.
- Flexible, interactive, make use of the highly skilled human perceptual system.
- More examples to follow tomorrow.
- Now first some design basics.

THANK YOU!

Questions?

For more information
about our work
please contact

Dominik Sacha
Tel. +49 7531 88-4046
dominik.sacha@uni-konstanz.de



http://vis.uni-konstanz.de/