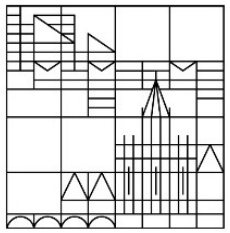

University of Konstanz
Data Analysis and Visualization Group

On Semantic Shifts and Circular Projections

May 05.05.2025

ELLIIT Focus Symposium

Raphael Buchmüller

Data Analysis and Visualization Lab (DBVIS)

Prof. Dr. Daniel A. Keim
Web: vis.uni-konstanz.de

DBVIS Group

Universität Konstanz

Research Overview

Topics

Language Models / Text

- Personalization
- LLM Impact
- Argumention

Document Projections

- Circular Projection
- Projection Explanation / Interaction

Visualization

- Human-Centered
- Text Vis, Digital Humanities, Networks

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Supervision & Collaboration

- **Daniel A. Keim (DBVis, University of Konstanz)**
- **Johannes Fuchs (DBVis, University of Konstanz)**
- **Frederik L. Dennig (DBVis, University of Konstanz)**
- **Miriam Butt (Computational Linguistics Lab, University of Konstanz)**
- **Rita Sevastjanova (IVIA, ETH Zürich)**
- **Mennatallah El-Assady (IVIA, ETH Zürich)**
- **Michael Behrisch (CGGroup, Utrecht University)**
- **Sara di Bartolomeo (ACG, TU Wien)**
- **Alessio Arleo (Visualization Cluster, Eindhoven University of Technology)**
- **Silvia Miksch (cVAST, TU Wien)**

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Raphael Buchmüller, Astrik Jeitler and Daniel A. Keim
Strategies for Personalization through Active Learning and Visual Analytics
IEEE VIS Short (2025)

Raphael Buchmüller, Friedricke Körte and Daniel A. Keim
Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs
2024 IEEE Visualization in Data Science, VDS 2024

Raphael Buchmüller; Mark-Matthias Zymla; Daniel A. Keim, Miriam Butt, Rita Sevastjanova
Exploration of Preference Models using Visual Analytics
MLVis: Machine Learning Methods in Visualisation for Big Data (2024)

Raphael Buchmüller, Mark-Matthias Zymla, Sara di Bartolomeo, Miriam Butt, Daniel Keim, Rita Sevastjanova and Mennatallah El-Assady
Argumentis: A Comprehensive Visual Analytics Application for Exploring Argumentation Perspectives
CHI 2025 (in submission)

Raphael Buchmüller, Bastian Jäckl, Michael Behrisch, Daniel A. Keim, Frederik L. Dennig
cPro: Circular Projections Using Gradient Descent
EuroVA: EuroVis Workshop on Visual Analytics (EuroVA 2024)

Raphael Buchmüller, Manuel Schmidt, Bastian Jäckl, Miriam Butt, Daniel A. Keim, and Frederik L. Dennig
Evaluating Circular Projections for Information Visualization
Eurovis Full (2025)

Raphael Buchmüller, Daniel A. Keim, Mennatallah El-Assady, Alessio Arleo and Johannes Fuchs
LEAPNet: Layered Exploration of Publication Networks
IEEE VIS 2025 Full

Raphael Buchmüller and Daniel A. Keim
GLANCE: Enhancing LLM Communication through Text Highlighting
Eurovis Full (2025)

Buchmüller, R., Fürst, D., Frings, A., Schlegel, U., & Keim, D. (2024)
Visual Bias Detection for Addressing Illegal Fishing Activities
2024 IEEE Visual Analytics Science and Technology VAST Challenge

Raphael Buchmüller, Friedricke Körte, ??, and Daniel A. Keim
NetworkRugs: A Novel Design to Visualize Temporal Network Patterns
Ongoing Work

Zymla, M.-M., Buchmüller, R., Butt, M., & Keim, D. A. (2024)
Deciphering Personal Argument Styles : A Comprehensive Approach to Analyzing Linguistic Properties of Argument Preferences
Robust Argumentation Machines: First International Conference, RATIO 2024

Plenz, Moritz, Raphael Buchmüller, and Alexander Bondarenko. (2023)
Argument Quality Prediction for Ranking Documents
CLEF (Working Notes)

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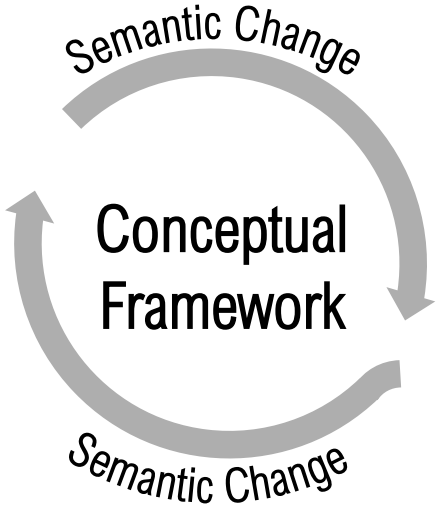
Part I

Semantic Shifts in Times of LLMs

Published at VDS 2024

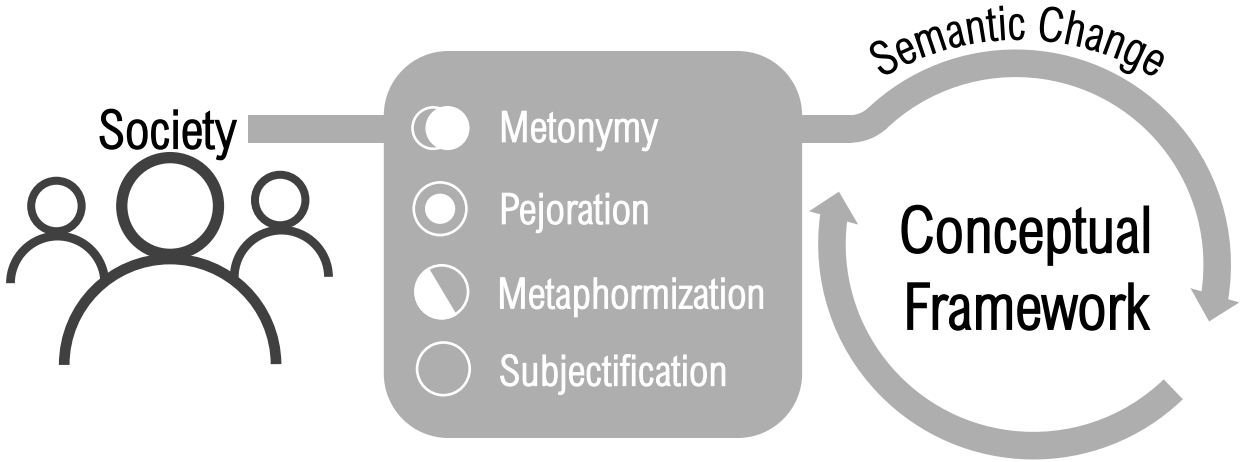
Human language is a constantly evolving phenomenon.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



Semantic change is influenced by context, cognition, and society.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



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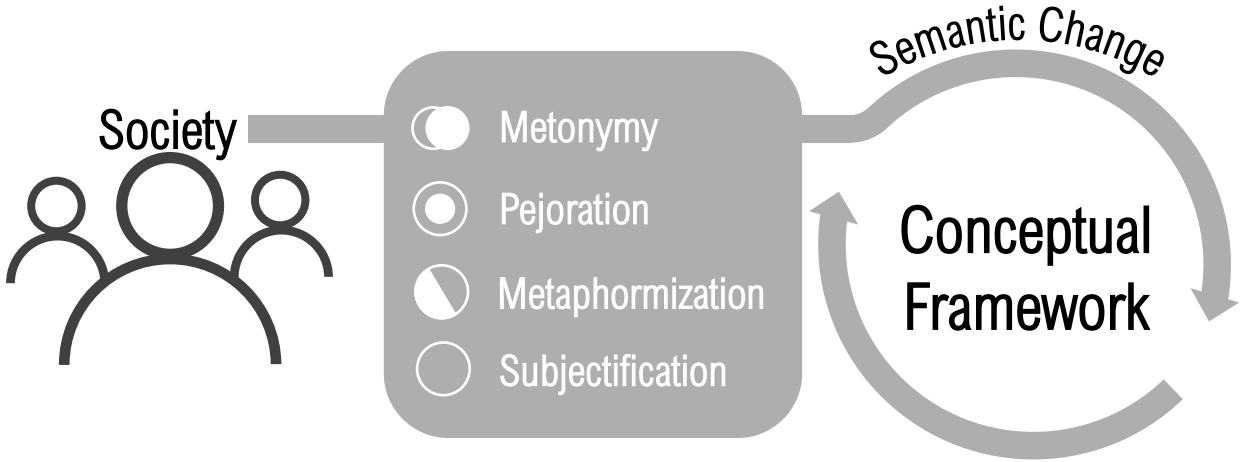


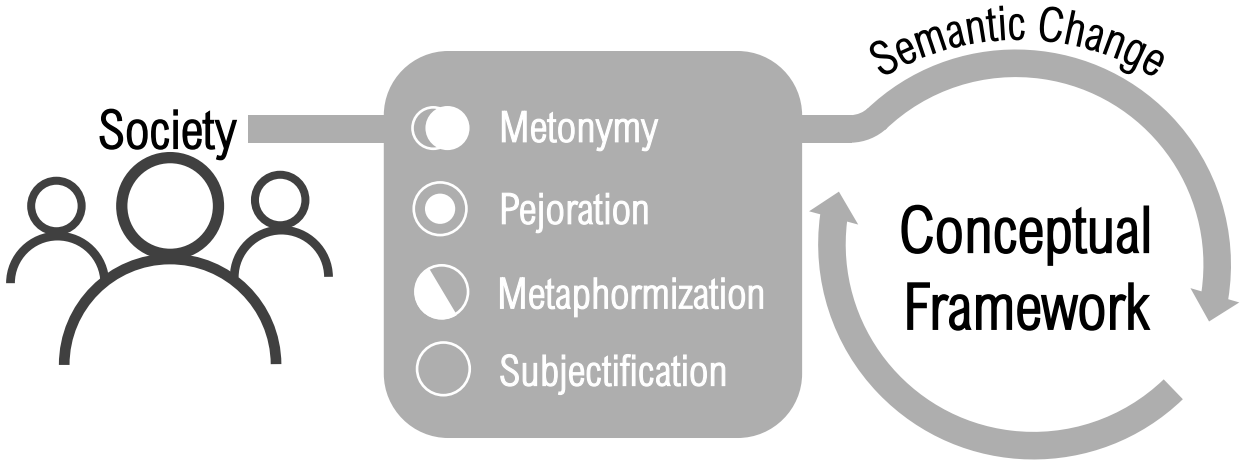
Metonymy

Meaning shift by using an associative link between two concepts

"Number 10" to represent the British Prime Minister, where the address stands for the officeholder

Semantic change is influenced by context, cognition, and society.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



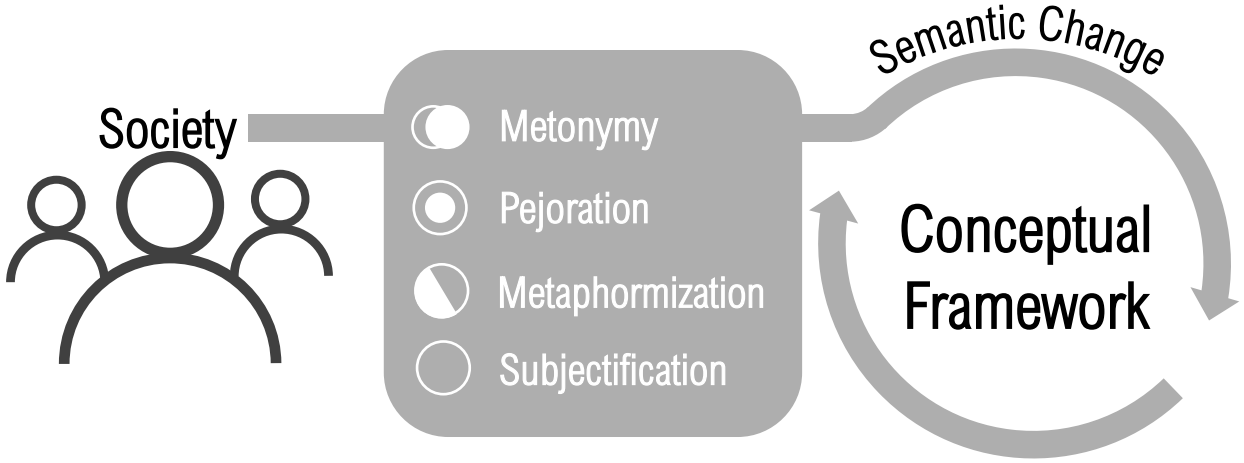
Pejoration

Meaning shift towards a more positive/negative connotation

""Silly" originally meant "blessed" but now means "foolish."

Semantic change is influenced by context, cognition, and society.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



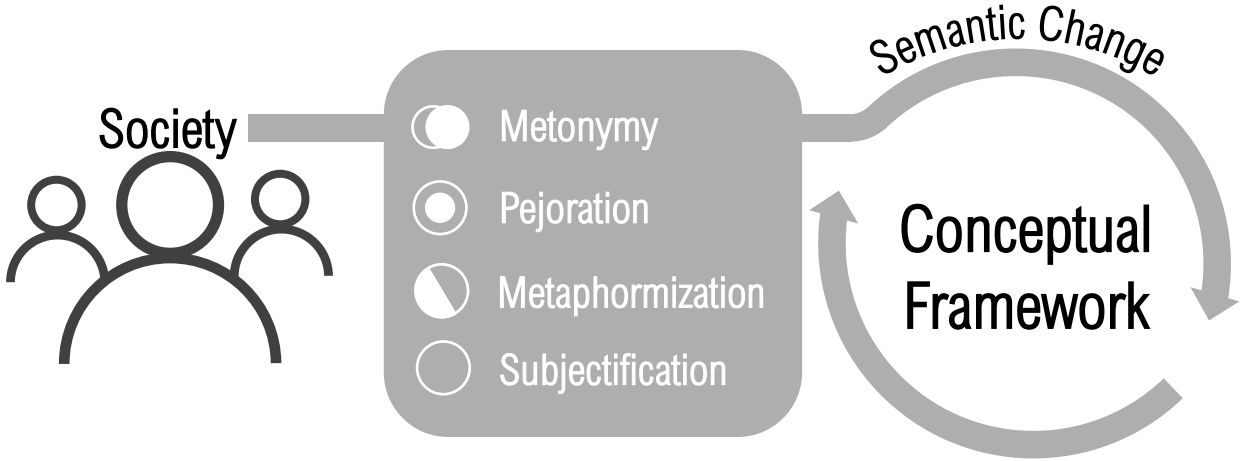
Metaphormization

Meaning shift by transferring meaning based on perceived similarities between two concepts.

Calling an inept person a "doughnut,"
using the image of a doughnut to convey incompetence

Semantic change is influenced by context, cognition, and society.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



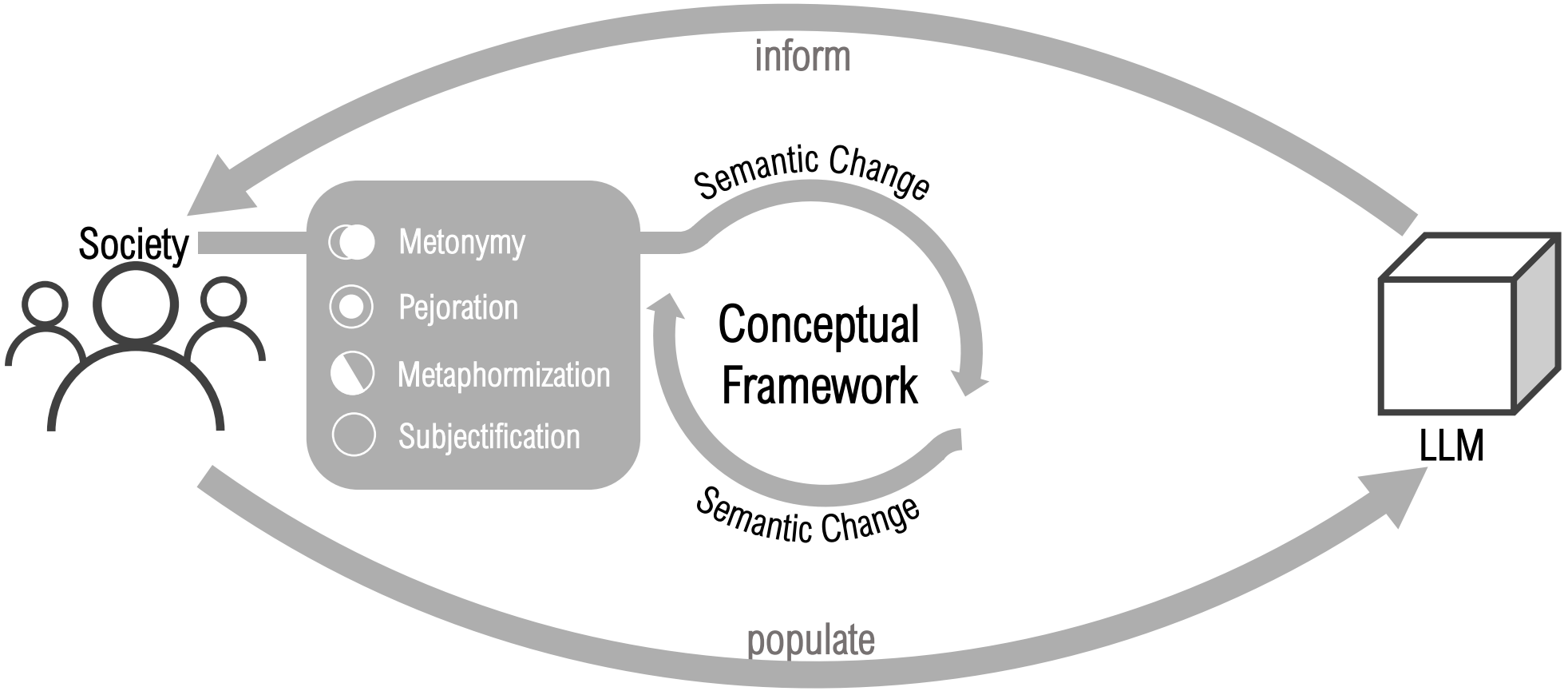
Subjectification

Meaning shift towards becoming more subjective, influenced by personal perspectives.

"Very" originally meant "true"
but now functions as an intensifier

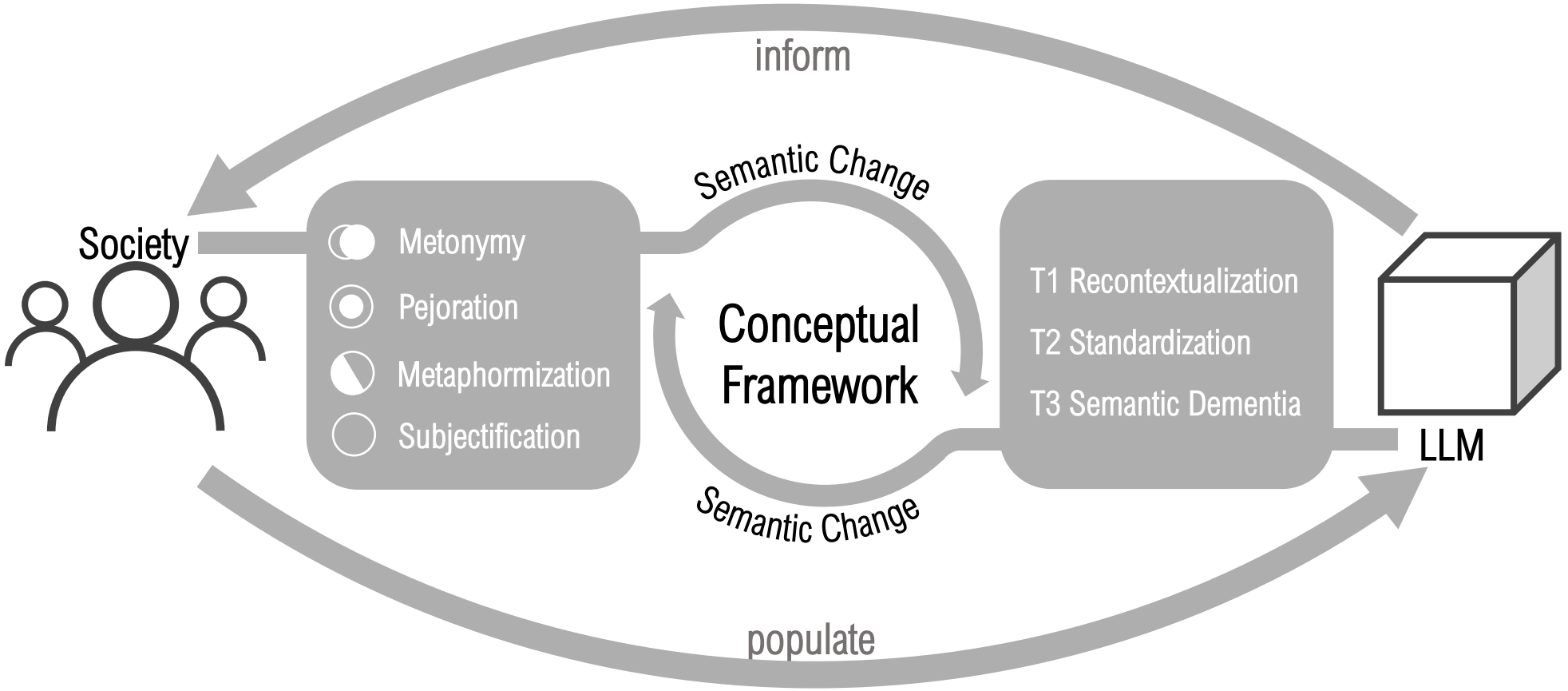
LLMs change the way we produce and process information.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



The increasing use and ongoing development of LLMs drives semantic change.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



T1 Recontextualization

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.

Definition

Large language models generate textual outputs that make learned forms of language accessible to diverse contexts.

Example

LLMs popularizing the term "delve" by reintroducing it into different contexts, increasing its use and meaning in new domains.

Occurences

Drum [11], Radford et al. [46], Floridi and Chiriatti [12], Brown et al. [7]

T2 Standardization

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.

Definition
Standardization involves meaning shifts caused by LLMs imposing uniform language patterns, leading to linguistic convergence and a reduction in diversity.

Example
LLMs leading to the loss of regional dialects or unique linguistic expressions

Occurences
Caines et al. [8], Bender and Koller [4], Prabhu and Birhane [45]

T3 Semantic Dementia

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.

Definition

Semantic Dementia refers to the gradual degradation of language quality due to LLMs propagating oversimplified, biased, or erroneous models, leading to inaccuracies in word meanings.

Example

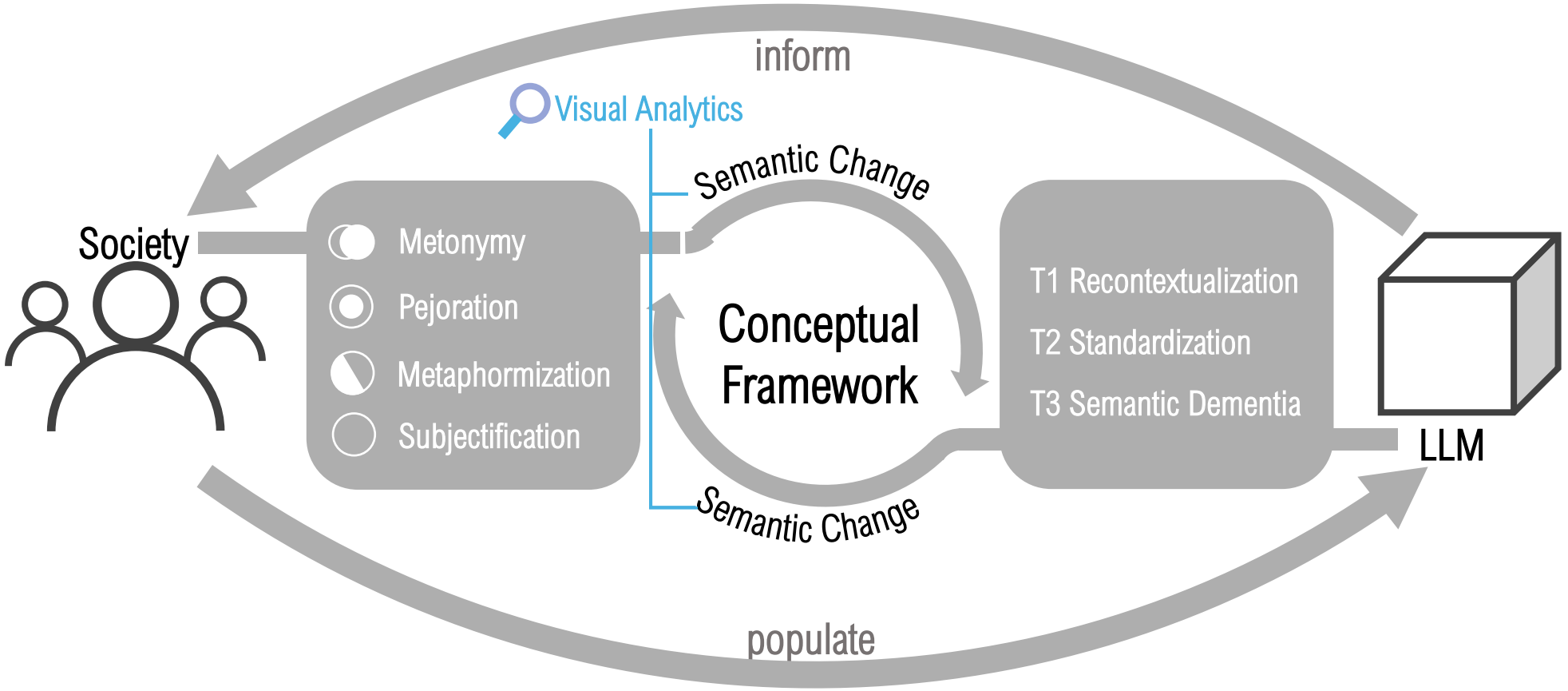
LLMs generating imprecise translations that erode nuanced terminology, as seen in studies of translation errors.

Occurences

Prabhu and Birhane [45], Vincent and Hecht [53], Yao et al. [57]

VA needs to monitor current socio-linguistic changes.

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.



How can we detect and visualize Semantic Change?

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.

			Corpus					Language							Detection Method – Conceptual			Detection Method – Contextual			Visual Approach			Semantic Shift								Visualization														
Author	Citation	Year	Google Ngram	COHA	TIME	Other	Temporal Interval	English	German	Dutch	French	Spanish	Chinese	Others	Co-Occurence	Static Embeddings	Dynamic Embedding	Contextualized Embed.	Topic Modelling	Contextual	Frequency	Embedding	Context	Top Similarity Words	Word Re-Occurence	Similarity Degree	Continuity	Metaphormization	Metonymy	Pejoration	Subjectification	Change Visible	Motion Component	Interactive	Versatile	Scatterplot	Line Chart	Bar Chart	Heatmap	Word Cloud	Graph	Projection	Tabular View	Extra	Detection Focus	Visualization Focus
Hilpert and Gries	[23]	2009			●		1920-2000	●							●						●							●							●	●	●							Dendrogram, Screen Plot	●	
Rohrdantz et al.	[47]	2011			●		1987-2007	●							●				●	●			●	●	●	●	●	●	●			●			●	●	●									●
Wijaya and Yeniterzi	[54]	2011	●				1500-2008	●	●		●	●	●	●	●				●			●	●	●	●		●	●	●	◐		●			●		●				●				●	
Heylen et al.	[22]	2012				●	1999-2005			●					●				●			●	●	●		◐			◐			◐	◐	●	●	●								Motion Chart		●
Odijk and Santucci	[43]	2012					1800-1994			●											●			●				●	●					●	●			●						RadViz		●
Kim et al.	[31]	2014	●				1850-2009	●								●							●	●	●	●	●	●	◐			●			●		●						●		●	
Jatowt and Duh	[27]	2014	●	●			1810-2009	●							●	●			●	●			●	◐	●	◐	●	●				●			●		●		●				●			●
Hilpert and Perek	[24]	2015		●		●	1810-2009	●							●	●					●	●	●	●				●				◐	●	●		●								Motion Chart		●
Xu and Kemp	[56]	2015	●				1890-1999	●							●						●	●	●	●	●			●	◐		◐	●			●			●				●			●	
Theron and Fontanillo	[51]	2015				●	1732-2001					●													●		●				●	●		●										Parallel Coordinate Plot		●
Kulkarni et al.	[33]	2015	●			●	-	●							●	●					●	●	●	●	●		●	●			●	●			●		●					●			●	
Hamilton et al.	[20]	2016	●	●			1800-1999	●	●		●		●		●	●						●	●	●	●			●				●			●							●			●	
Frerman and Lapata	[13]	2016				●	1700-2010	●							●	●			●	●			●	●	●		●	●	●	◐	●	●			●			●					●	Stacked Bar Chart	●	
Martinez-Ortiz et al.	[39]	2016				●	1950-1990			●						●					●	●	●	●	●		●	●				●		●	●						●			Stream Graph, Network Graph		●
Benito et al.	[5]	2016				●	-		●												●							●					●	●				●								●
Mahmood et al.	[37]	2016				●	-	●								●						●	●	●				◐							●	●								Story Lines		●
Xu and Crestani	[56]	2017			●	●	1900-200	●								●							●	●	●	●	●	●	●			●			●				●	●						●
Bamler and Mandt	[3]	2017	●				1850-2008	●									●						●	●	●	●	●	●	●			●			●		●								●	
Rudolph and Blei	[49]	2018				●	1858-2015	●									●					●	●	●	●		●	●	◐			●			●		●					●	●		●	
Rosenfeld and Erk	[48]	2018	●				1900-2009	●									●						●	◐	●	●	●	●	◐		●	●			●		●								●	
Yao et al.	[58]	2018			●		1990-2016	●									●					●	●	●	●		◐	●	●		◐	●			●							●			●	
Jatowt et al.	[27]	2018	●	●			1600-2010	●							●	●				●	●		●	●	●	●	●	●	●			●		●	●		●			●				Tree		●
Hellrich et al.	[21]	2018	●	●		●	-	●	●						●	●							●		●	●	●		●	●		●			●		●									●
Giulianelli et al.	[15]	2020					1910-2009	●										●					●		●		●		●			●			●			●						Stacked Bar Chart	●	
Martinc et al.	[38]	2020				●	2011-2019	●						●				●					●	◐		●	●		◐		◐	●				●	●								●	
Hofmann et al.	[25]	2021				●	2000-2020	●									●	●				●			●	●			●		●	◐			●						●				●	
Li et al.	[34]	2021				●	1800 - 1950	●								●						●		●	●	●	●	●	●			●			●		●				●				●	
Gruppi at al.	[18]	2022				●	-	●	●					●		●						●		●					●			●		●	●	●										●
Kazi et al.	[30]	2022				●	1970-2020	●								●							●	●	●	●	●	●	●		●	●		●	●		●	●		●	●			Spiral Line Chart, Radial Bar Chart		●

How can we detect and visualize Semantic Change?

Seeing the Shift: Keep an Eye on Semantic Changes in Times of LLMs – Buchmüller et al.

Detection

Dynamic word embeddings capture real-time shifts without artificial time bins, allowing continuous tracking of how meanings evolve.

Frequency-based methods help detect significant changes in word usage but don’t provide deeper insights into meaning shifts.

Visualization

Embedding-based techniques (scatter plots, PCA, t-SNE) are the most effective for visualizing shifts in semantic relationships over time.

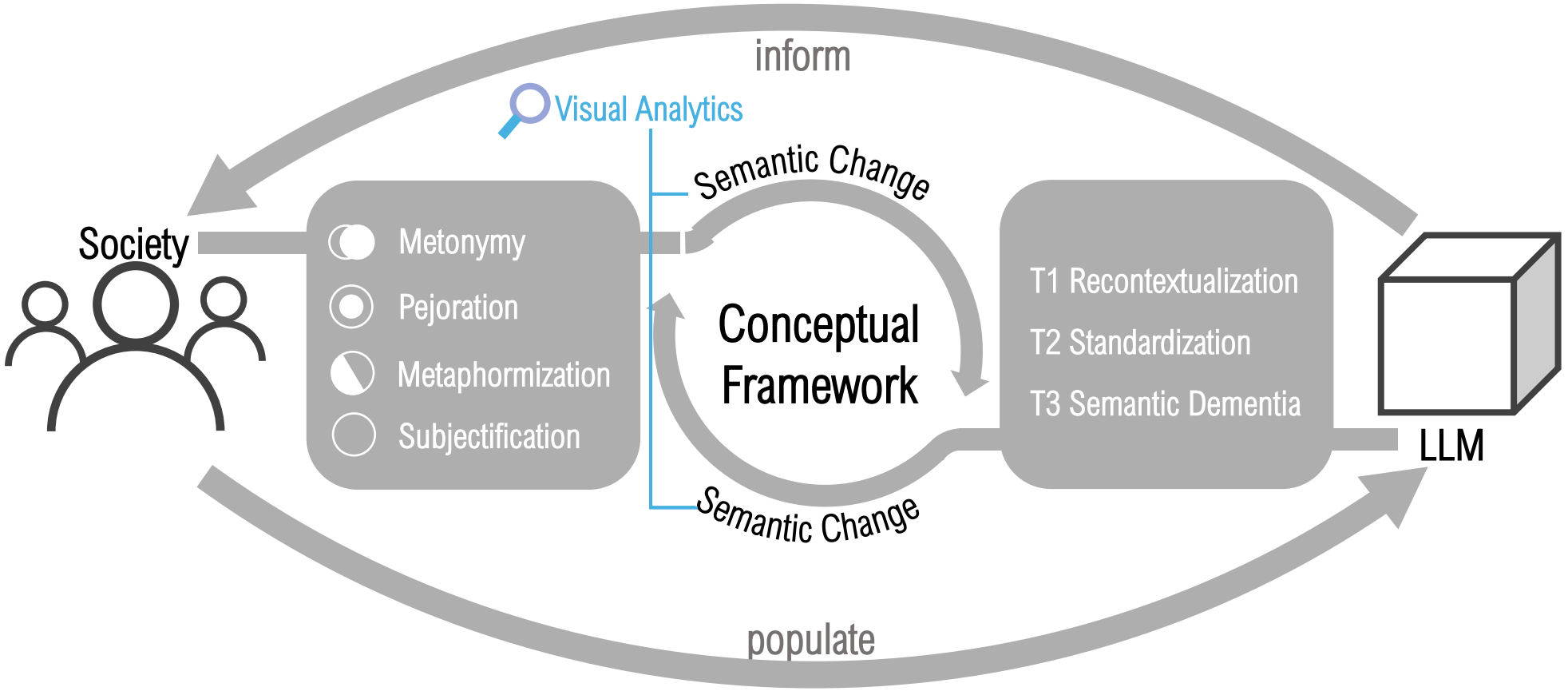
Context-based visualizations (heat maps, word clouds) highlight evolving word associations and usage environments.

Integration of multiple methods is necessary!

Seeing the Shift:

Keep an Eye on Semantic Changes in Times of LLMs

Raphael Buchmüller, Friederike Körte, Daniel Keim



The Role of VA and Interaction in LLM Research

ELLIIT - Questions and Discussion

VA for Creating the Model

Training, Fine-tuning & Alignment

VA for Explaining the Model

xAI & Behavioral Analysis (e.g. Fairness)

VA for Using the Model

AI4VA & VA4A

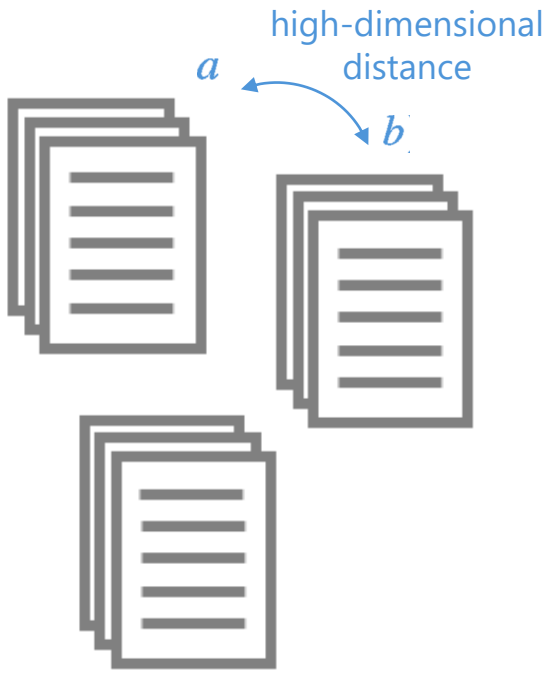
Part II

Circular Projection

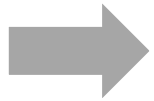
Published/Submitted Work

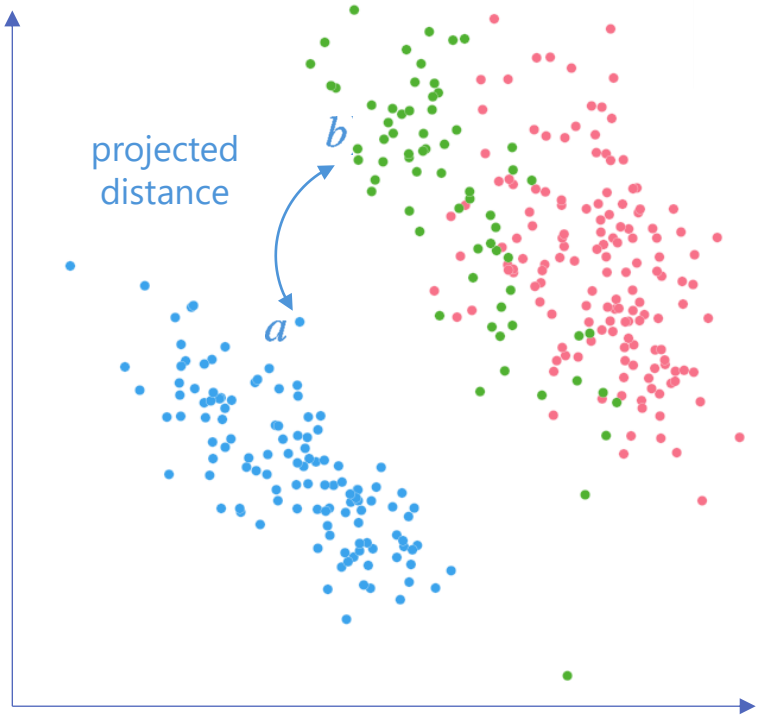
High-dimensional Data Projection

cPro: Circular Projections using Gradient Descent



High-Dimensional Data

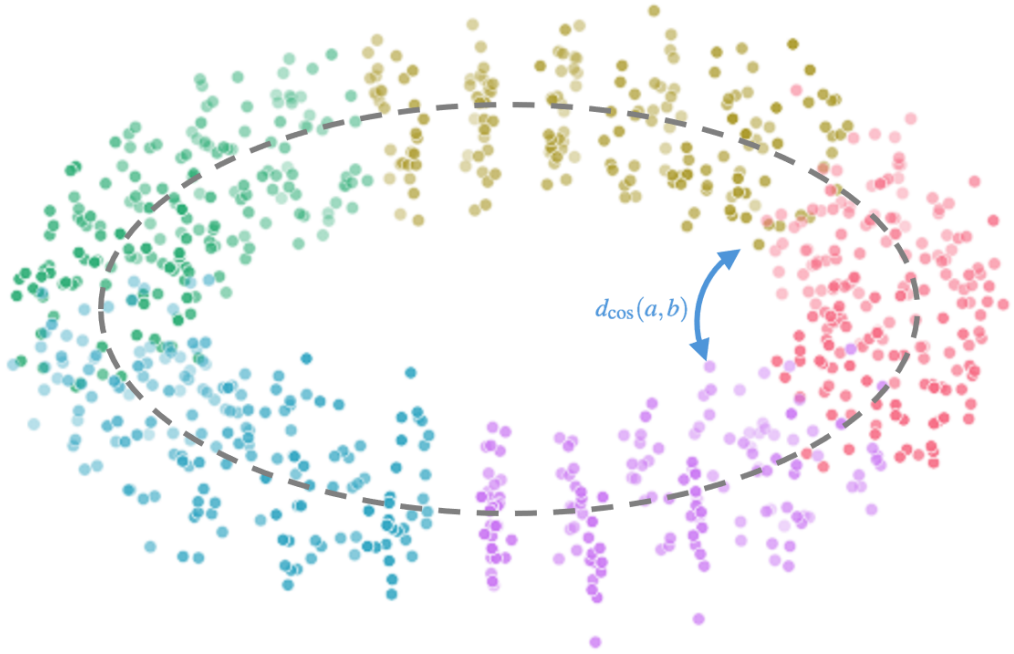




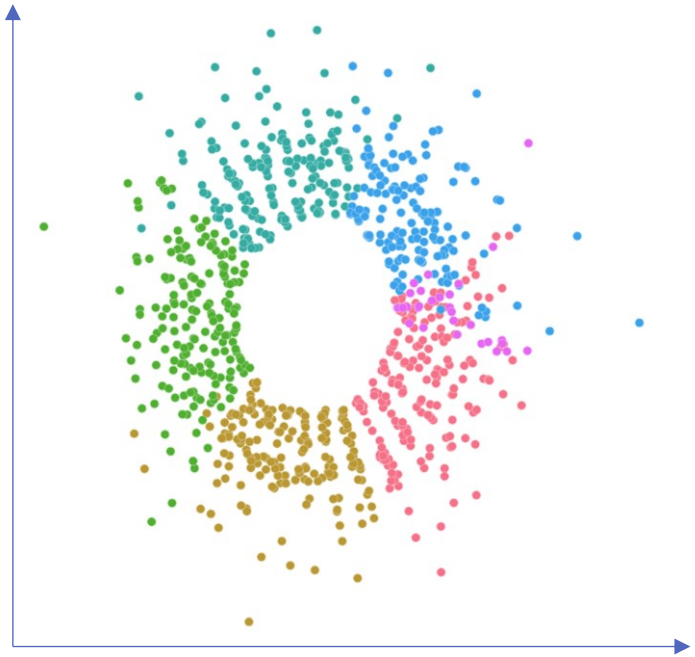
Projection on 2D Plane

High-dimensional Data Projection

cPro: Circular Projections using Gradient Descent



High-Dimensional Data

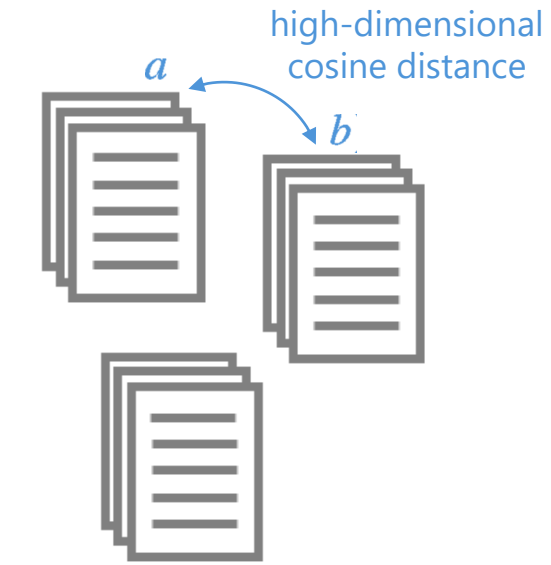


2D MDS

1D MDS

- limited to lines, planes and cubes
- fail to capture intrinsic, spherical topologies
- difficult layout enrichments

cPro: Circular Projections using Gradient Descent



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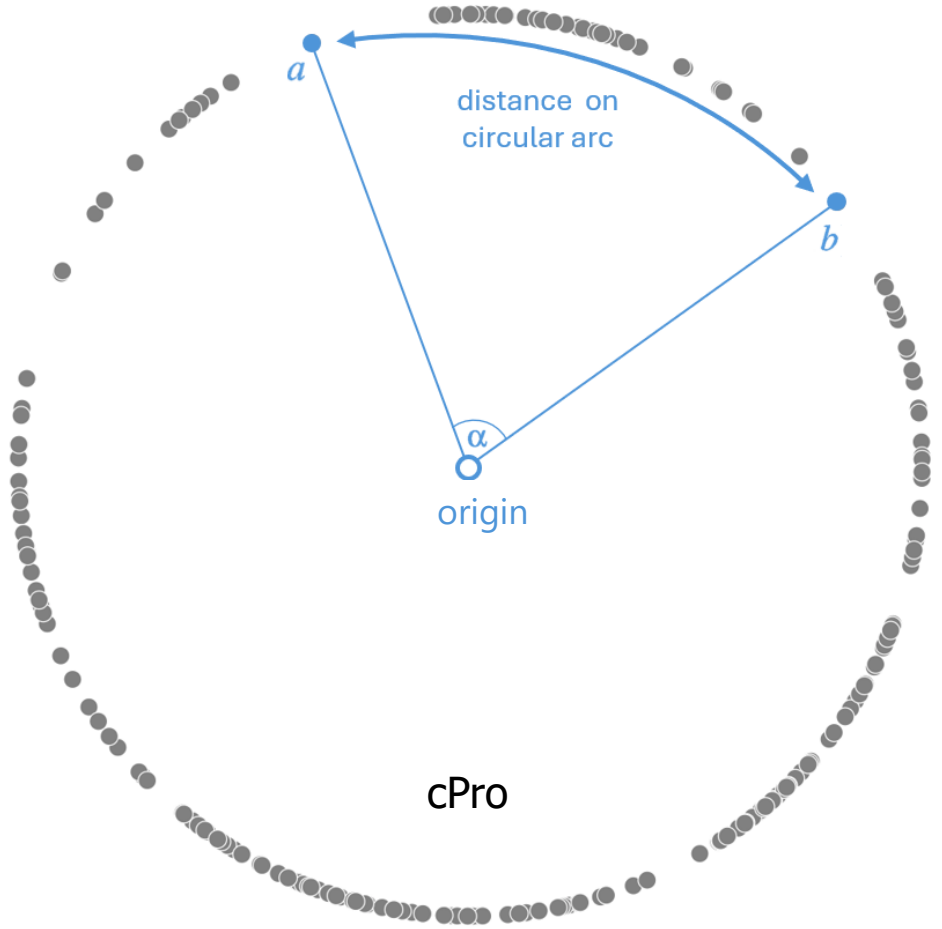

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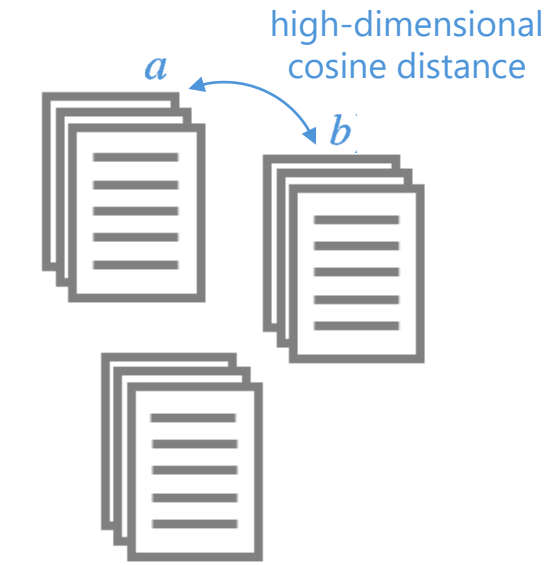

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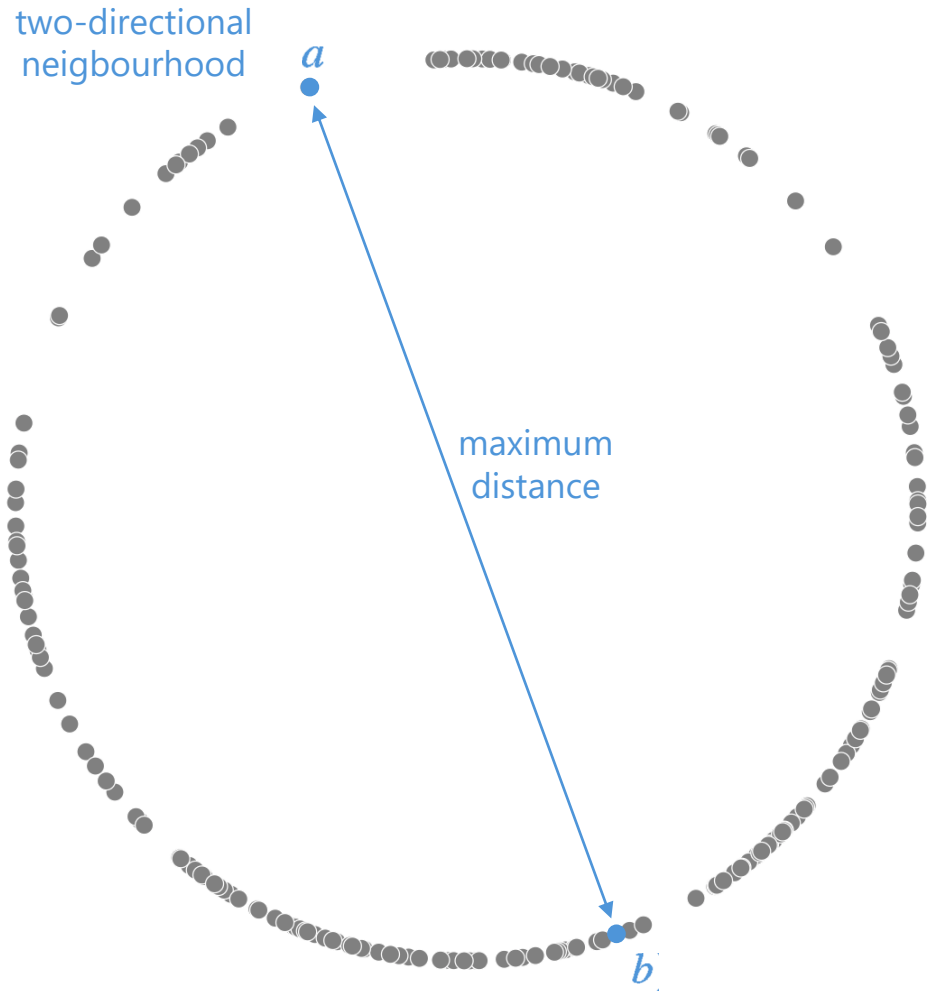
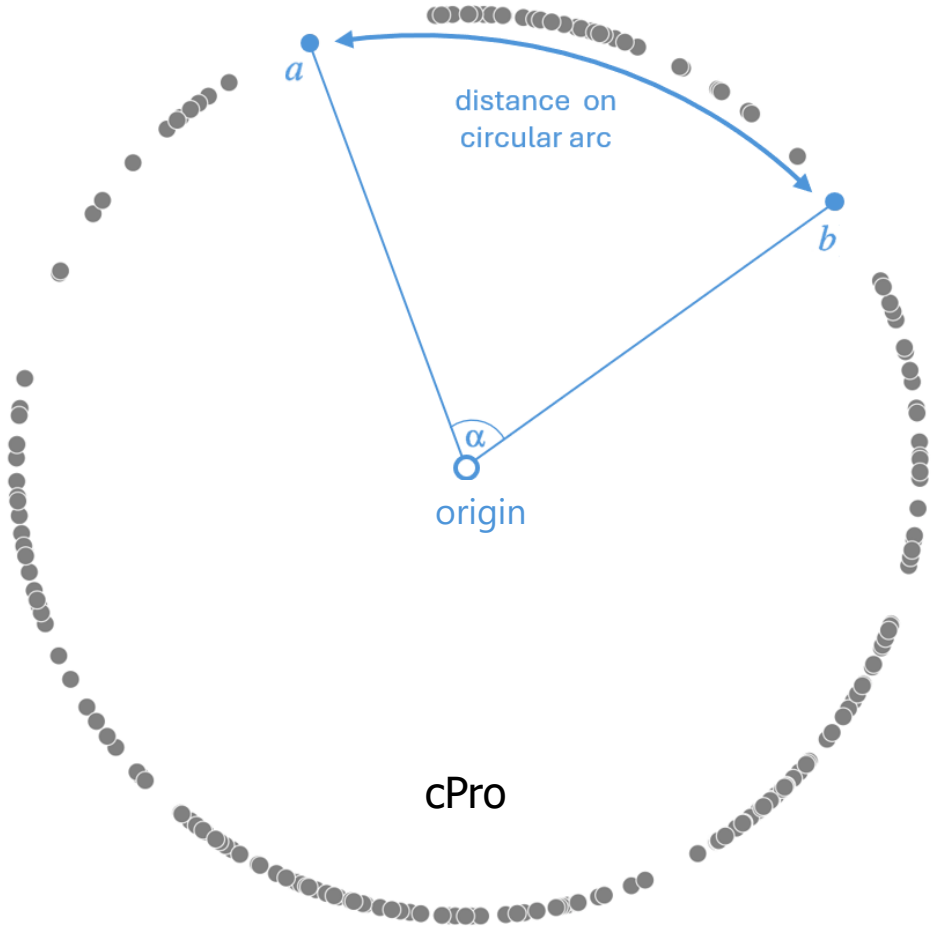


cPro: Circular Projections using Gradient Descent

Optimize Loss function

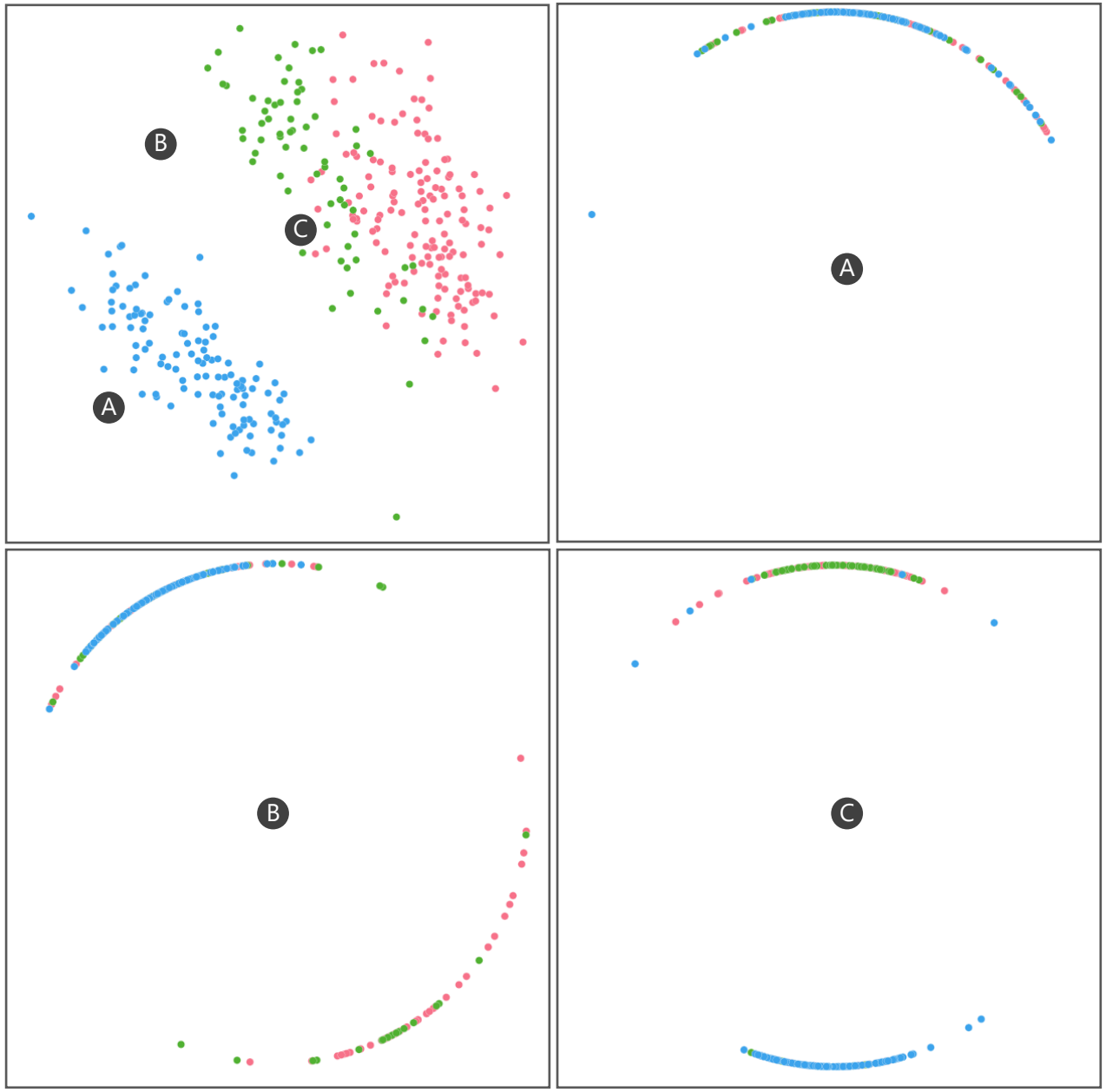
$$\mathcal{L}(M,P) := \frac{1}{|D|^2} \sum_{i=1}^{|D|} \sum_{j=1}^{|D|} \left| m_{i,j} - d_{\circ}(p_i, p_j) \right|$$

using Gradient Descent, Adam, PSO



Finding the origin

cPro: Circular Projections using Gradient Descent



Finding the origin

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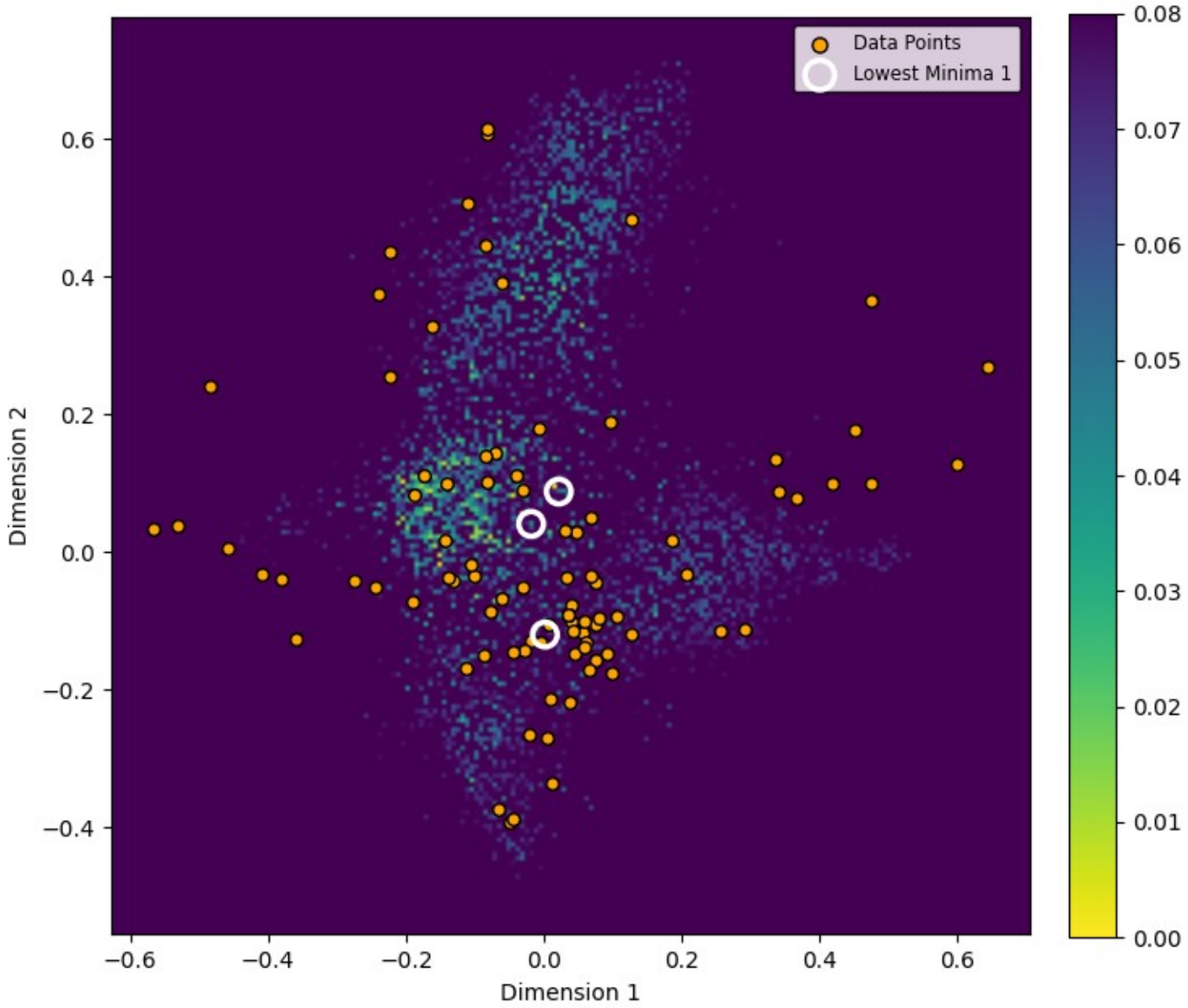


Quantitative Evaluation

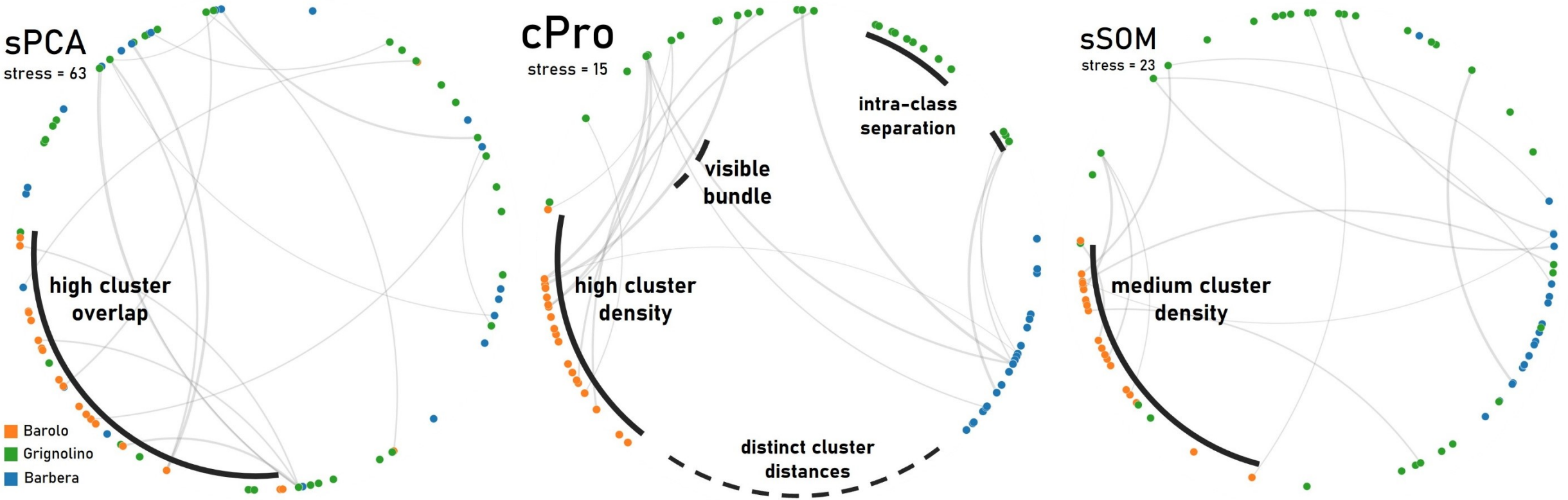
cPro: Circular Projections using Gradient Descent

Dataset	Metric	*cPro* Techniques				Related		2D MDPs					1D MDPs	
		DA	**Adam**	PSO	L-BFGS	sSOM	sPCA	IsoMap	MDS	PCA	t-SNE	UMAP	MDS	PCA
wine	Stress ↓	.23	**.15**	.18	.30	.23	.70	.24	.22	.20	.21	.23	.86	.89
	Correlation ↑	.89	**.91**	.88	.70	.58	.28	.86	.85	.87	.83	.84	.25	.33
	Silhouette Score ↑	.38	.40	.39	.33	-.10	-.3	**.42**	.41	.40	.39	.43	.24	.15
	Trustworthiness ↑	.76	.80	.79	.61	.58	.36	.77	.76	**.78**	.75	.76	.16	.14
	Continuity ↑	.71	**.74**	.72	.24	.62	.20	.73	.70	.73	.71	.73	.33	.34
	Distance Consistency ↑	.65	.69	.68	.10	**.72**	.26	.66	.65	.67	.66	.66	.28	.27
	Average Distance ↑	.58	.62	.61	.46	.44	.42	.20	.19	**.63**	.60	.61	.50	.51
	Neighborhood Hit ↑	.48	.52	.50	.39	.17	.16	.51	.50	.49	.48	**.54**	.44	.42
	Shepard Goodness ↑	.77	**.80**	.78	.75	.75	.24	.73	.78	.77	.71	.69	.20	.25
20 News	Stress ↓	.34	**.26**	.28	.32	.38	.50	.33	.31	.30	.29	.32	.87	.89
	Correlation ↑	.82	**.88**	.83	.72	.70	.37	.85	.84	.86	.83	.87	.16	.14
	Silhouette Score ↑	.22	.24	.23	-.20	.16	-.25	**.26**	.25	.24	.23	.25	.10	.11
	Trustworthiness ↑	.72	.76	.75	.63	.60	.58	**.78**	.74	.73	.72	.77	.26	.24
	Continuity ↑	.67	.71	.69	.56	.53	.54	.70	.69	.68	**.73**	.72	.32	.31
	Distance Consistency ↑	.61	**.65**	.63	.21	.72	.51	.64	.63	.62	.64	.66	.18	.17
	Average Distance ↑	.55	**.59**	.57	.46	.44	.43	.57	.56	.58	.57	.60	.12	.11
	Neighborhood Hit ↑	.45	.48	.47	.39	.37	.35	.50	**.51**	.49	.47	.50	.42	.21
	Shepard Goodness ↑	.74	**.79**	.75	.66	.63	.62	.77	.76	.75	.74	.78	.28	.17
protein	Stress ↓	.42	**.33**	.36	.47	.44	.46	.40	.38	.35	.36	.39	.87	.89
	Correlation ↑	.82	**.88**	.85	.73	.71	.69	.84	.83	.86	.82	.87	.77	.76
	Silhouette Score ↑	.25	**.28**	.26	.21	-.18	-.12	.27	.26	.25	.24	.29	.22	.23
	Trustworthiness ↑	.72	**.78**	.74	.63	.60	.58	.76	.74	.75	.73	.77	.68	.66
	Continuity ↑	.67	.71	.69	.58	.56	.54	**.73**	.70	.68	.69	.72	.63	.61
	Distance Consistency ↑	.62	.66	.64	.28	**.67**	.50	.64	.63	.62	.63	.65	.58	.57
	Average Distance ↑	.54	**.59**	.57	.48	.45	.43	.57	.55	.56	.54	.58	.51	.52
	Neighborhood Hit ↑	.44	.48	.47	.39	.37	.35	**.50**	.49	.48	.46	.51	.42	.41
	Shepard Goodness ↑	.75	.80	.77	.67	.64	.62	**.79**	.78	.76	.74	.80	.69	.68

Table 3: Evaluation Results for all Optimization and Projection Techniques on the *wine*, *20 News* and *protein* datasets.

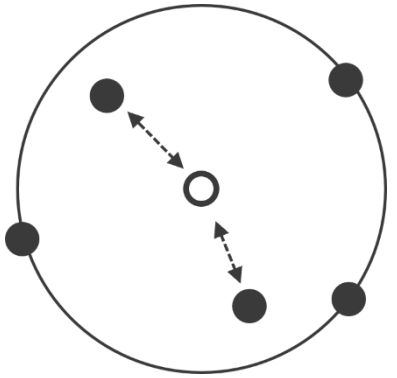
Quantitative Evaluation

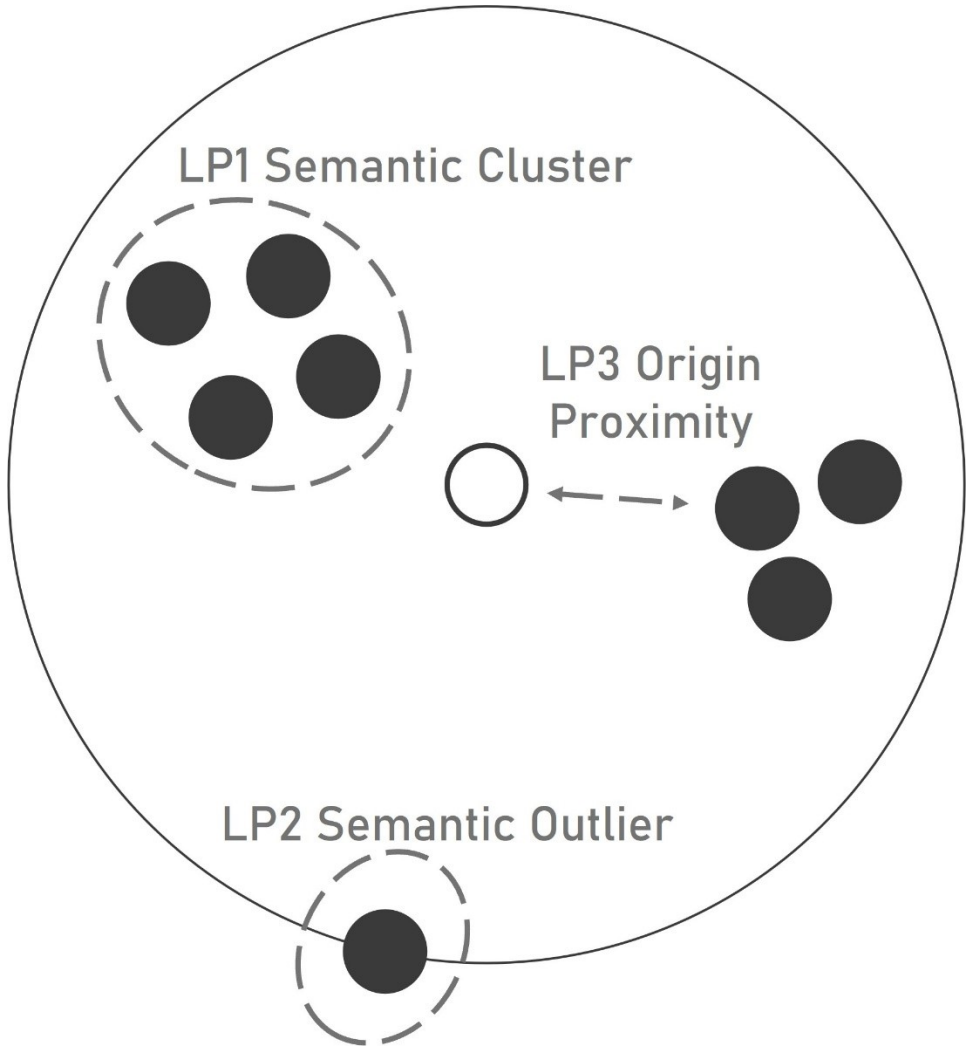
cPro: Circular Projections using Gradient Descent



Visualization Design Extentions

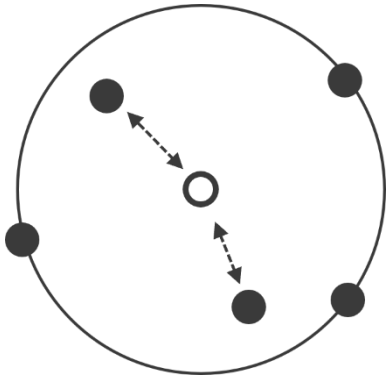
Design Extention 1 – Origin Proximity

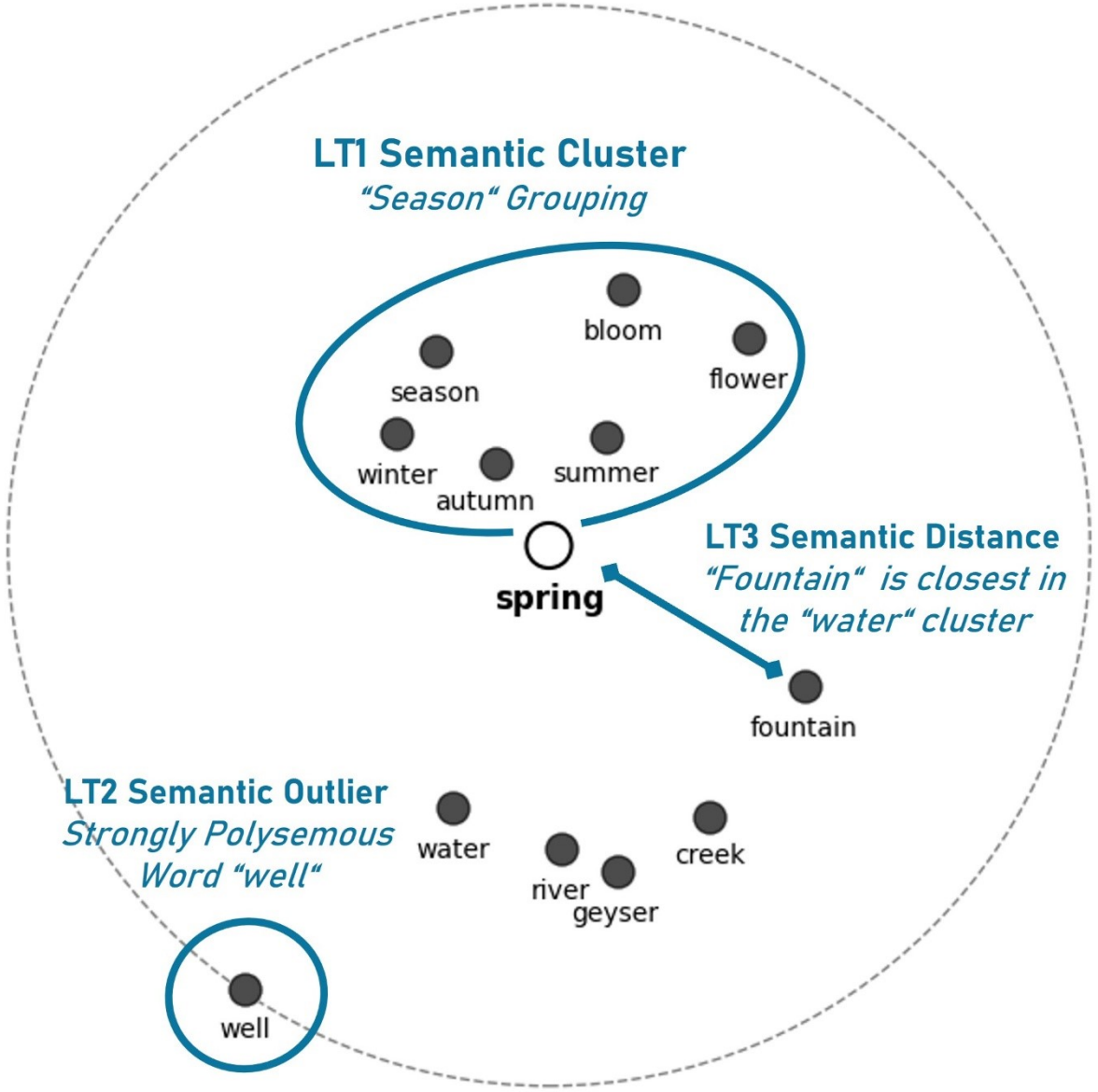




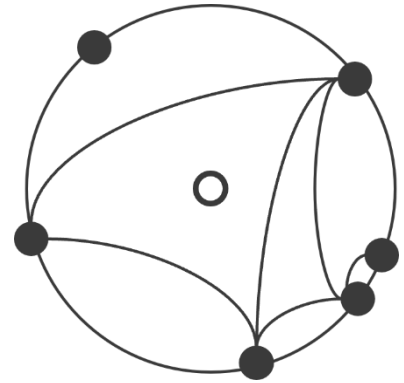
Word embeddings to find polysemous distribution on the term ‘spring’

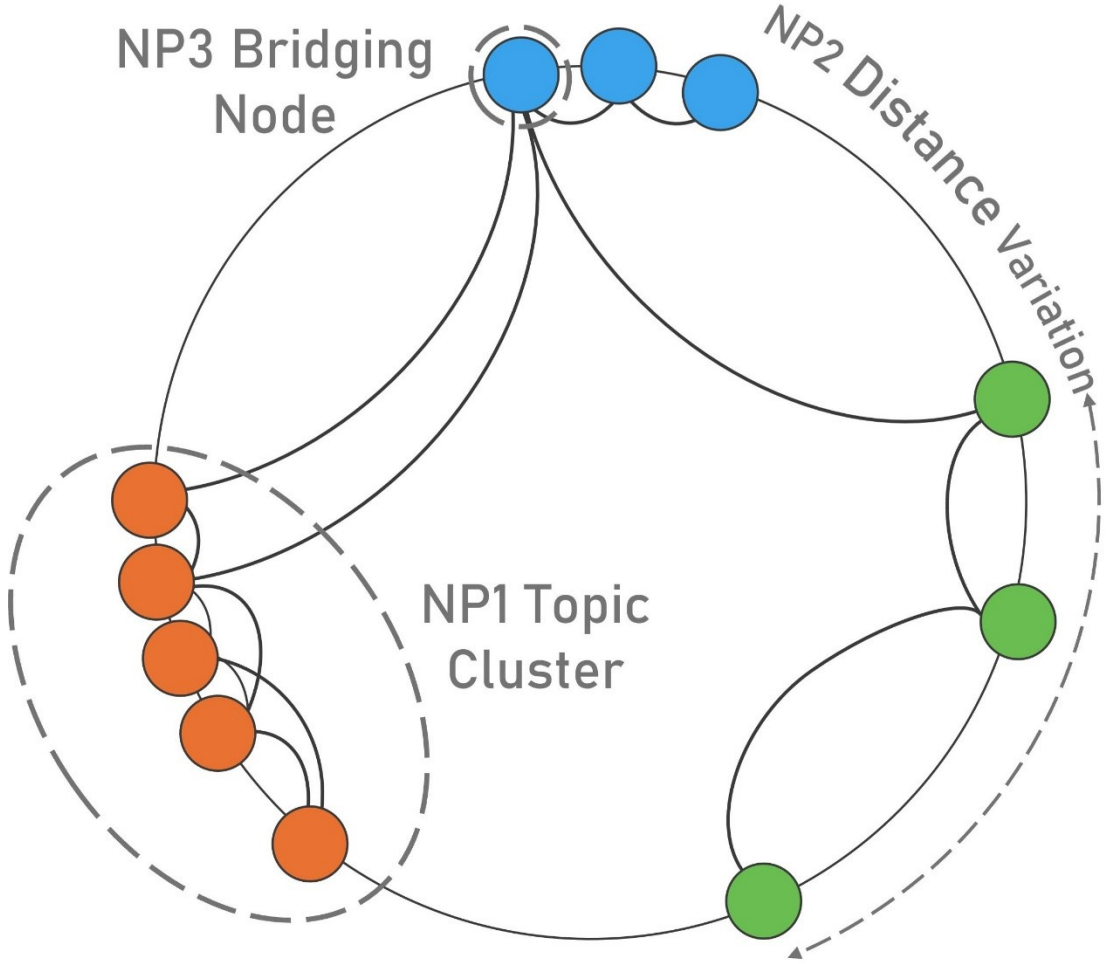
Use Case 1



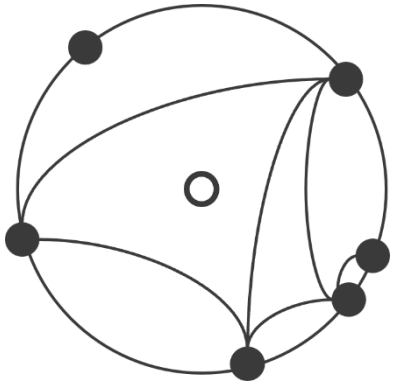


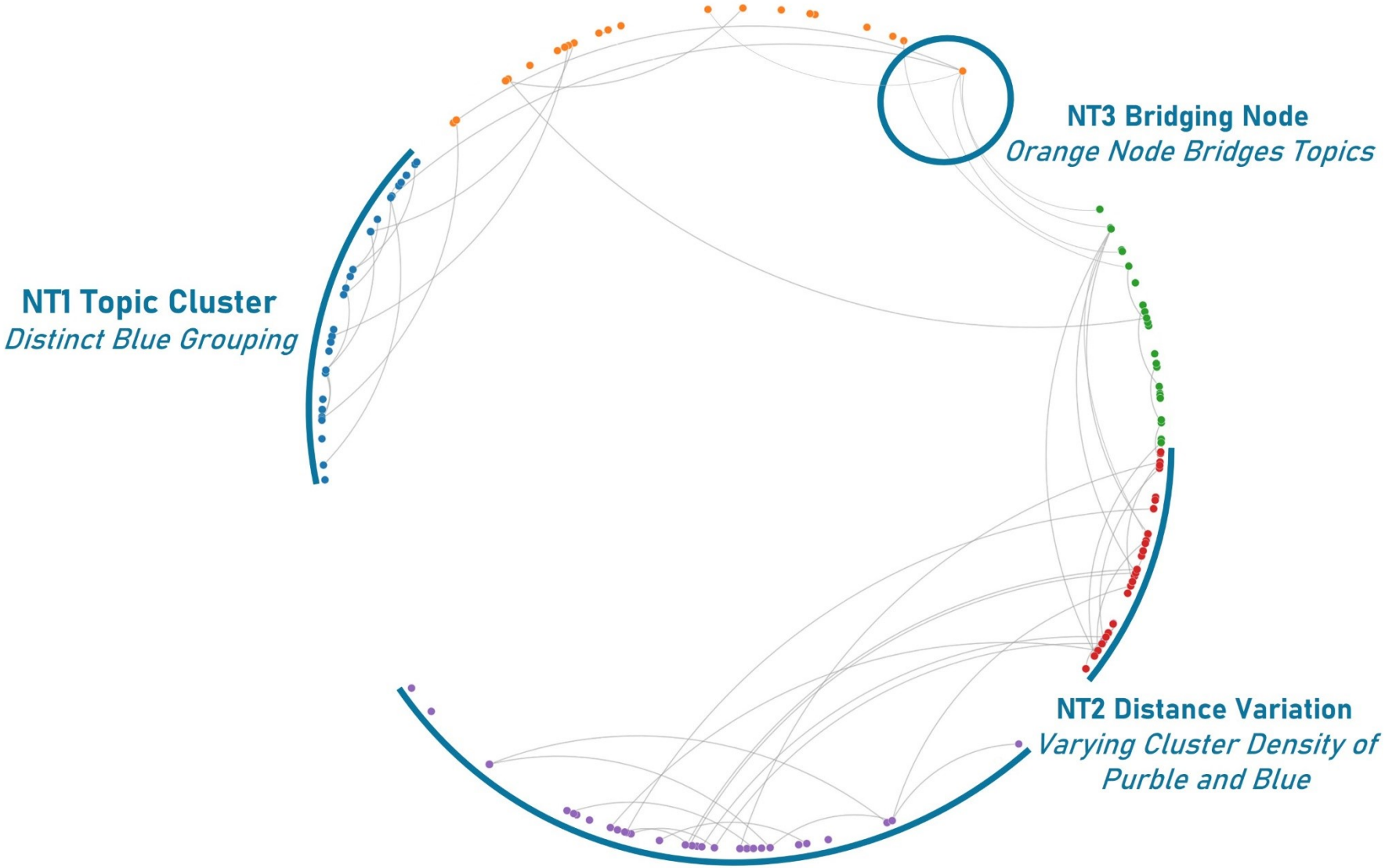
Design Extention 2 – Networks



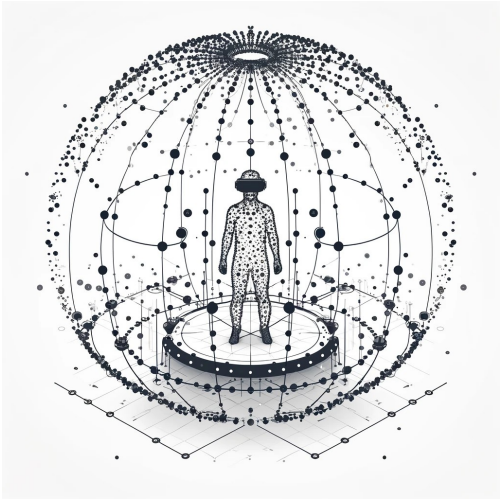


Find Topical Clusters and Bridging Nodes in Network Projections
Use Case 2





Towards Enhanced & Novel Visualization Designs



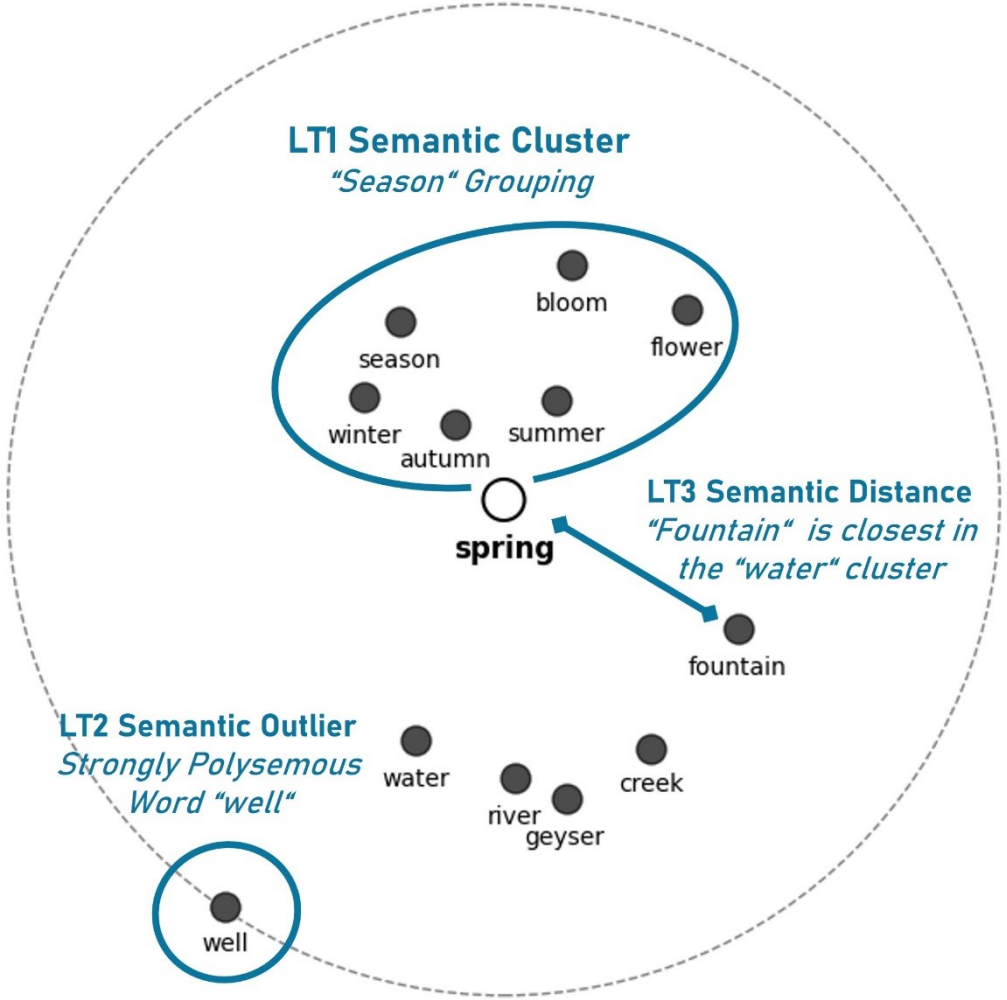
https://chatgpt.com/

https://observablehq.com/@d3/collapsible-tree

El-Assady, Mennatallah, et al. "NEREx: Named-entity relationship exploration in multi-party conversations." *Computer Graphics Forum*. Vol. 36. No. 3. 2017.

Further Usage of cPro

ELLIIT - Questions and Discussion



Part III

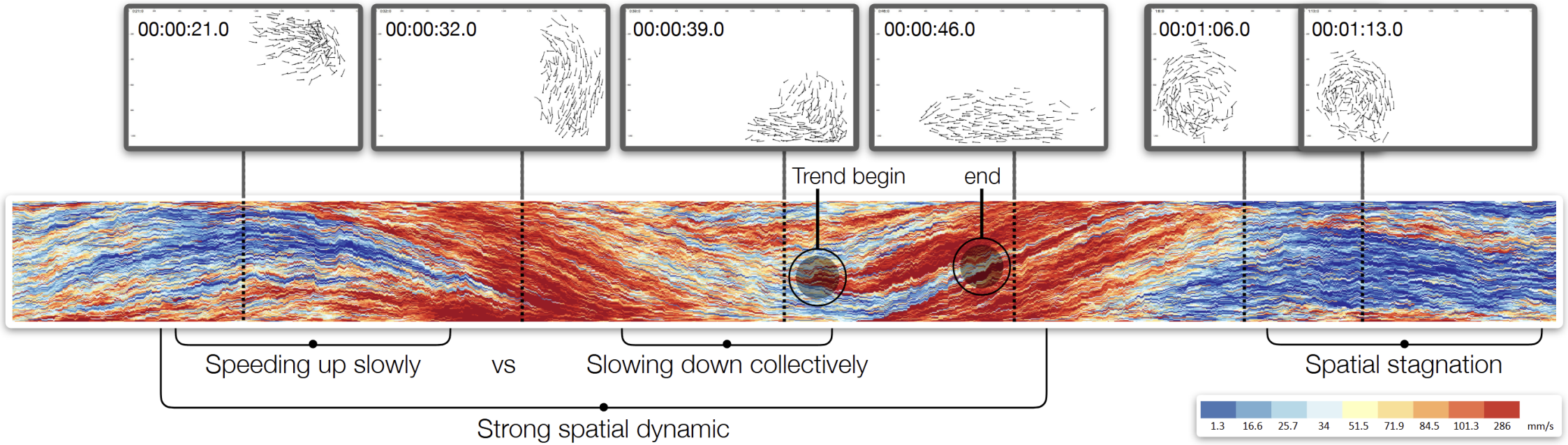
NetworkRugs: Visualizing Trends in Dynamic Networks

Current Work

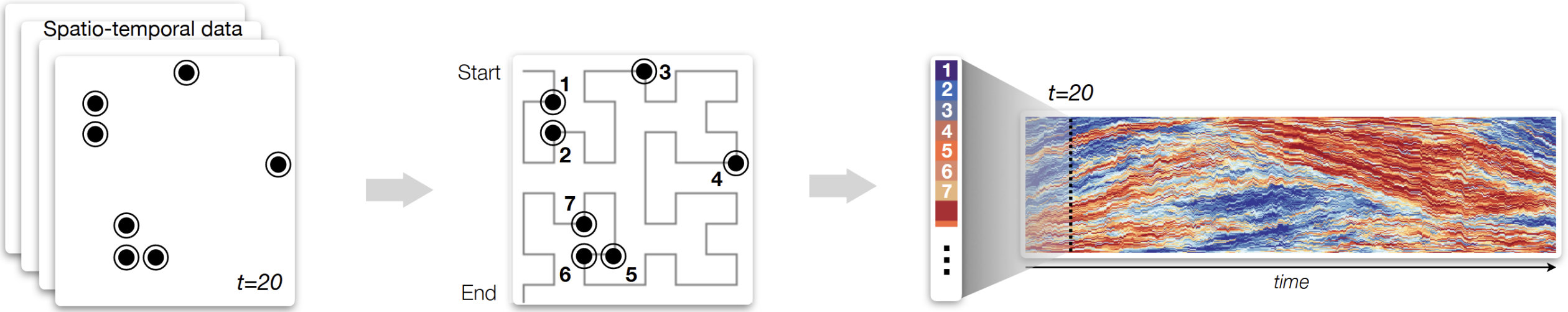
Related Work

MotionRugs: Visualizing Collective Trends in Space and Time

Juri Buchmüller, Dominik Jäckle, Eren Cakmak, Ulrik Brandes, Daniel A. Keim



Related Work - MotionRugs



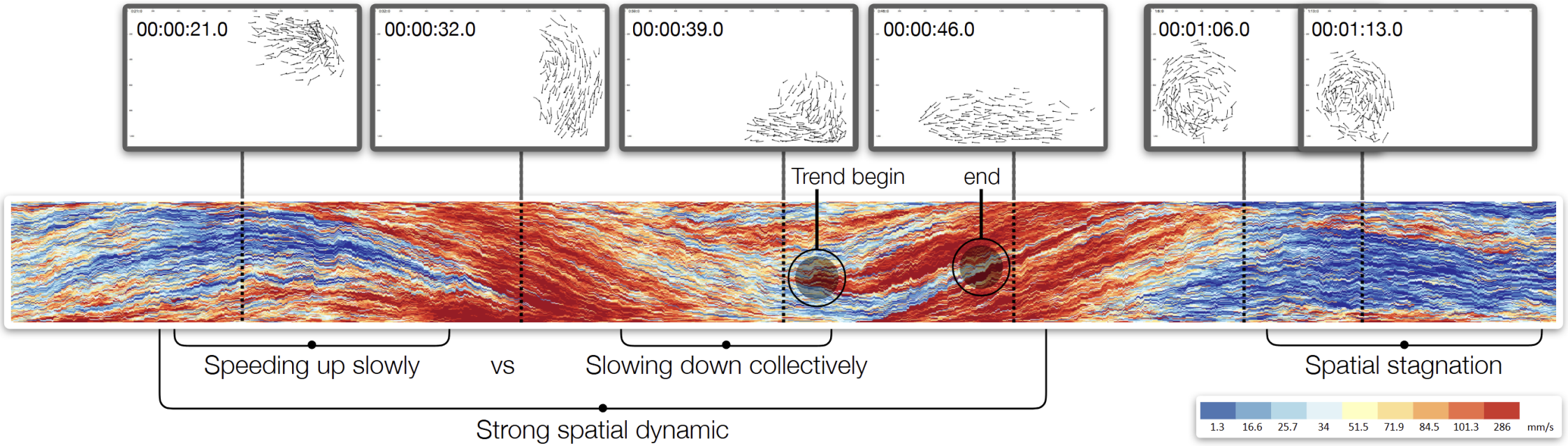
For each frame:

1. **Apply spatial data structure**
2. **Generate 1D ordering**
3. **Sequential alignment of the slice**

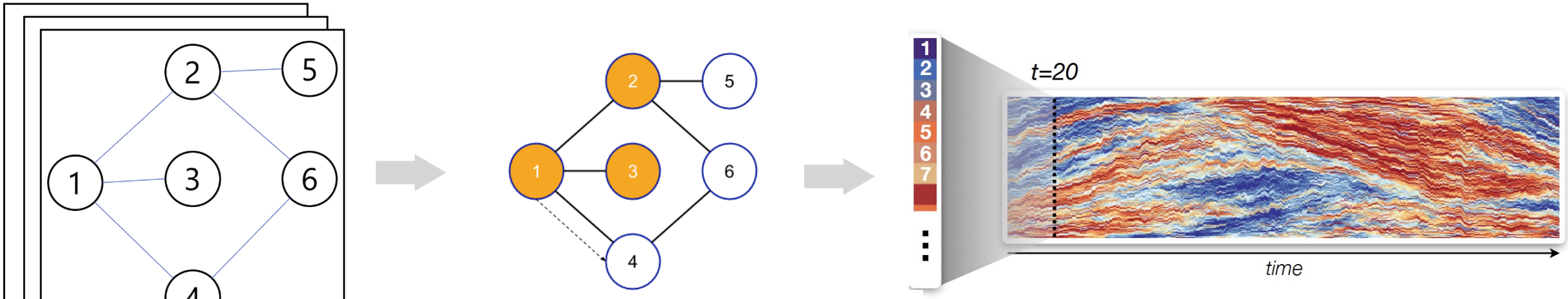
Related Work

MotionRugs: Visualizing Collective Trends in Space and Time

Juri Buchmüller, Dominik Jäckle, Eren Cakmak, Ulrik Brandes, Daniel A. Keim



NetworkRugs

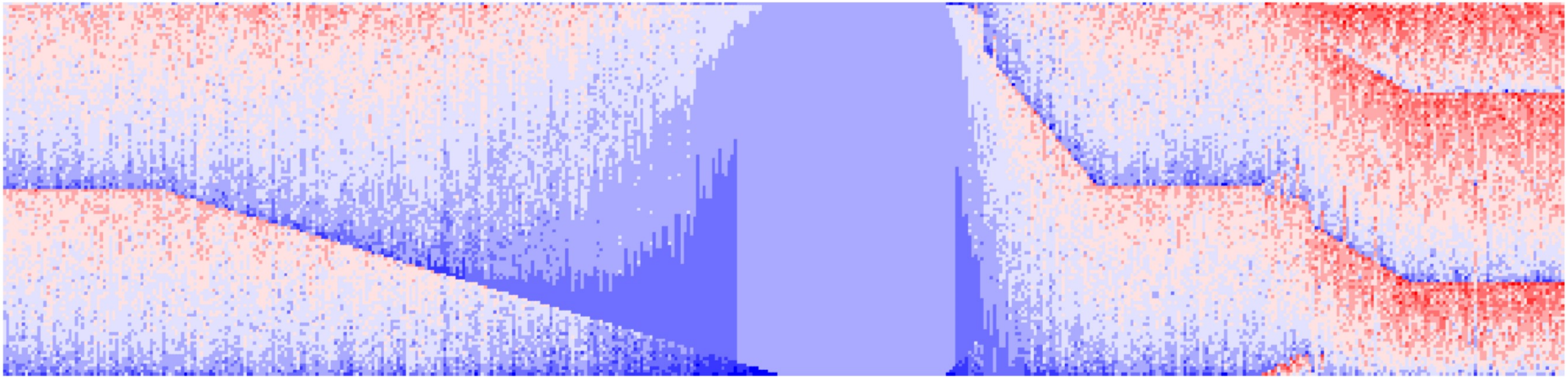


1 **Apply dynamic network structure**

2 **Generate 1D ordering**

3 **Sequential alignment of the slice**

Colored by closeness_centrality



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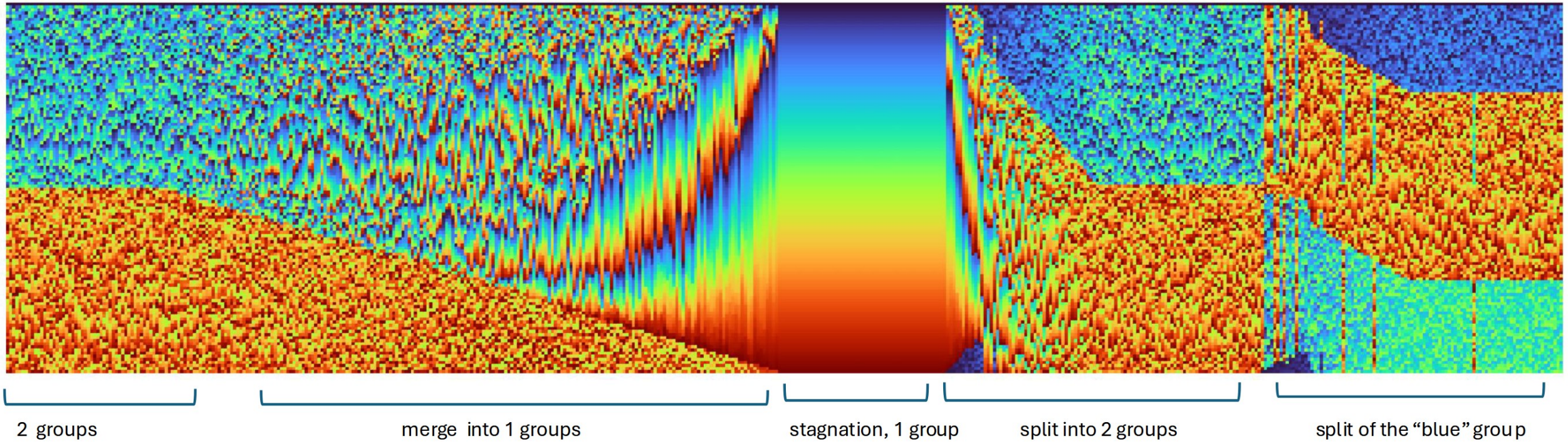
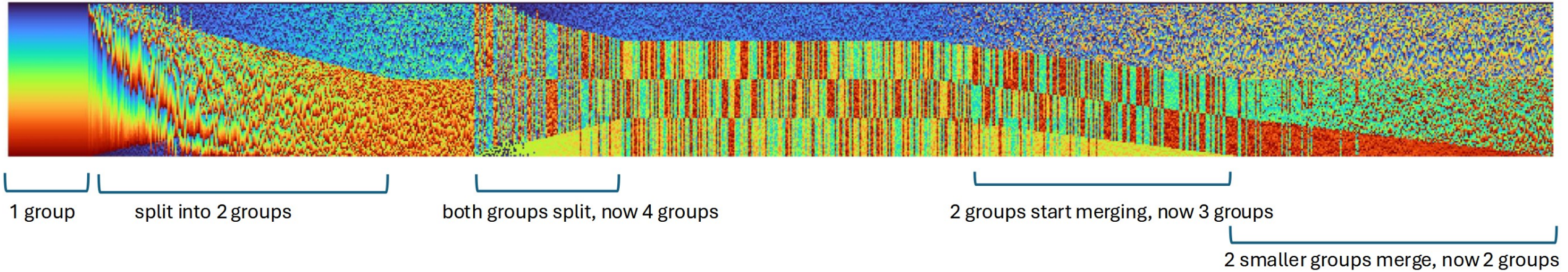
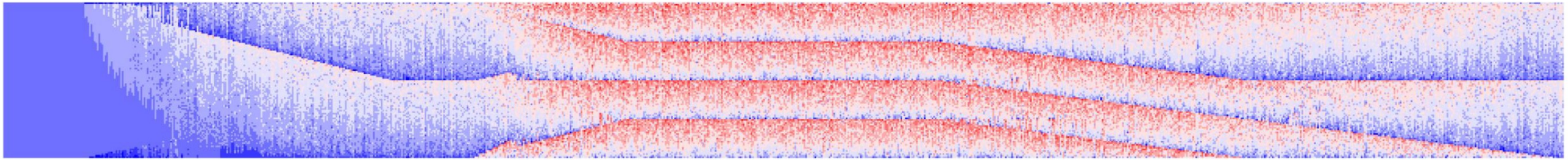
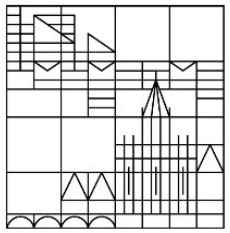


NetworkRugs







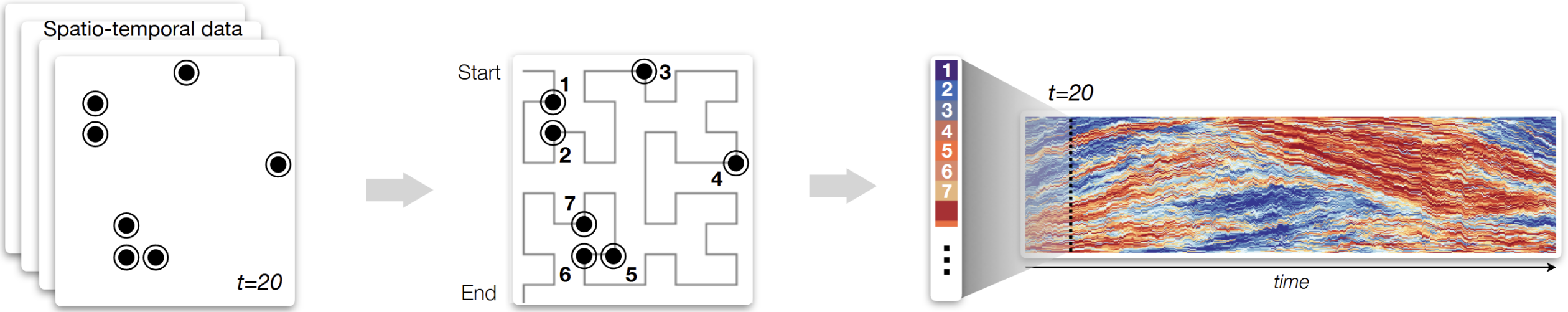
University of Konstanz
Data Analysis and Visualization Group

On Semantic Shifts and Circular Projections

January 05.05.2025

ELLIIT Focus Symposium
Raphael Buchmüller

Attachements



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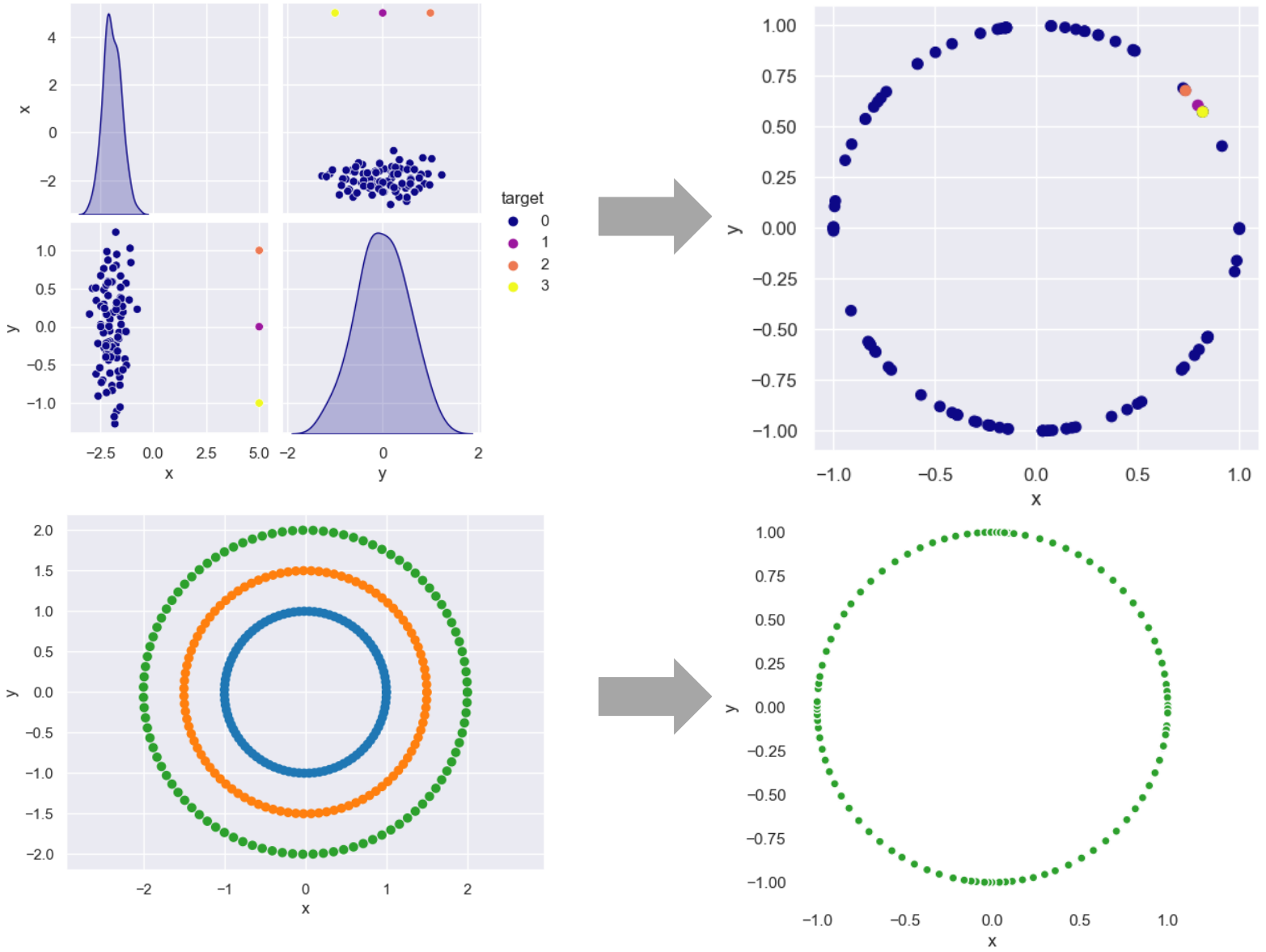
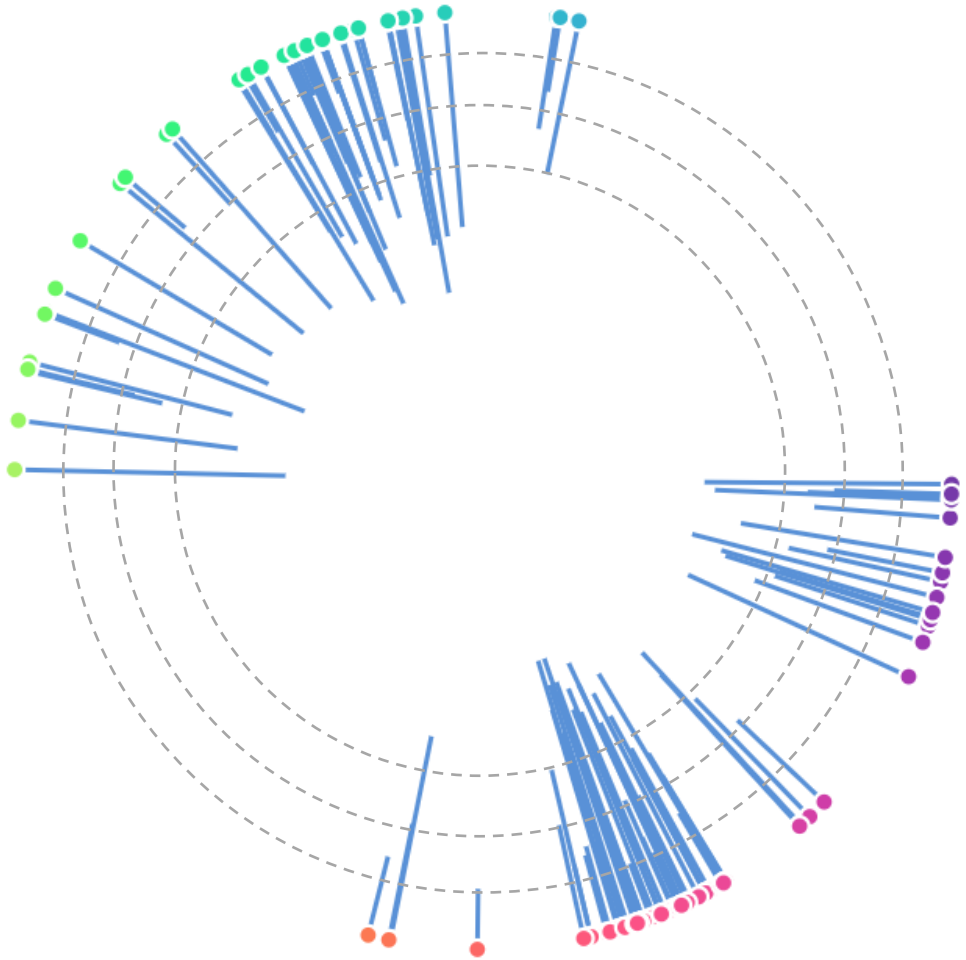
Limitations

cPro: Circular Projections using Gradient Descent



Towards Enhanced & Novel Visualization Designs

cPro: Circular Projections using Gradient Descent



Towards Enhanced & Novel Visualization Designs

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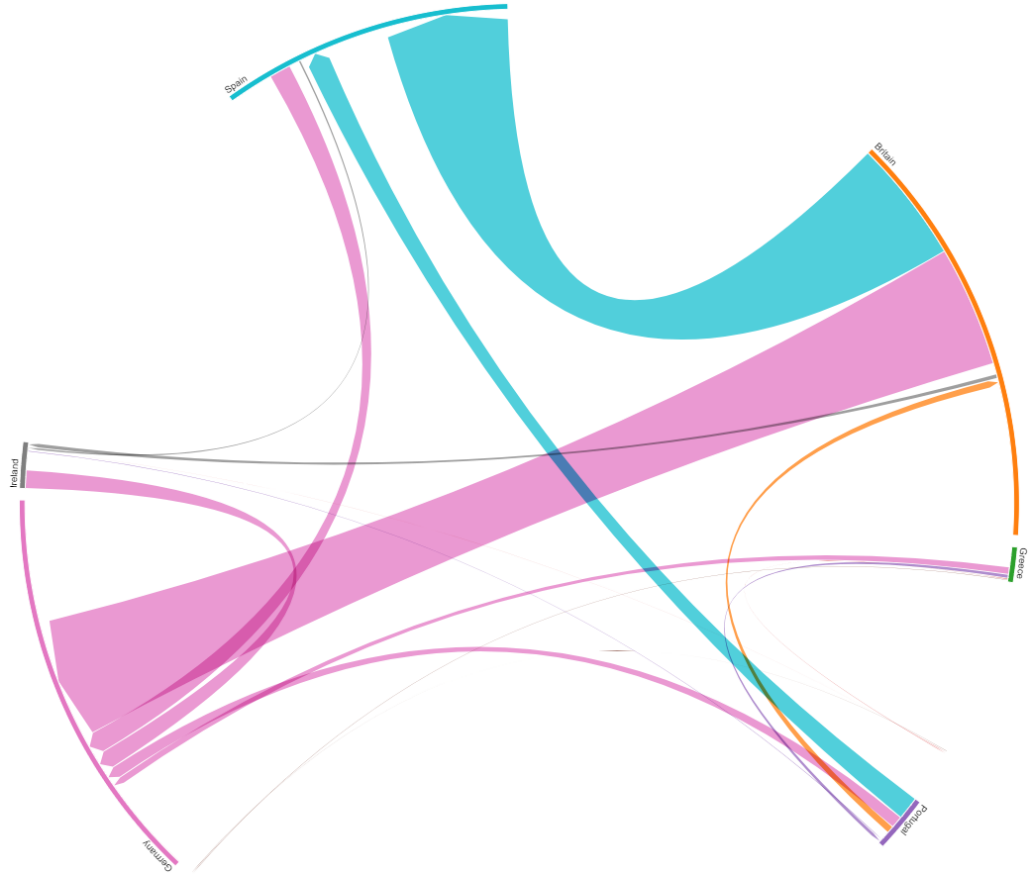
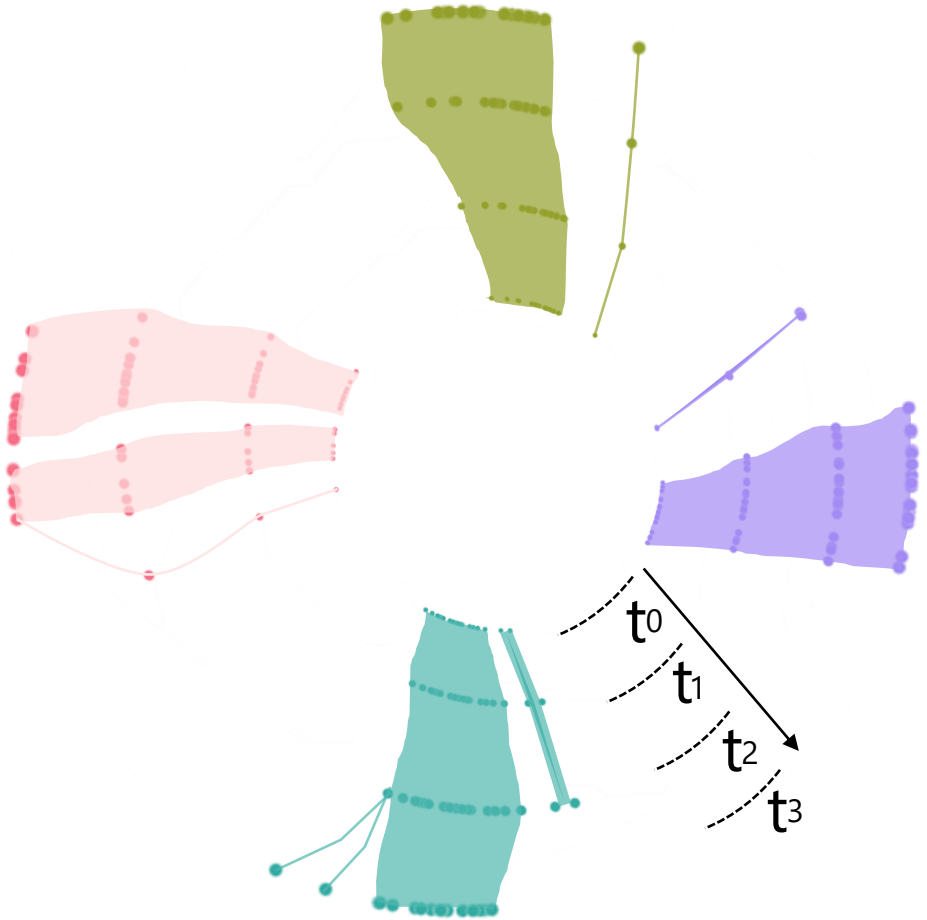
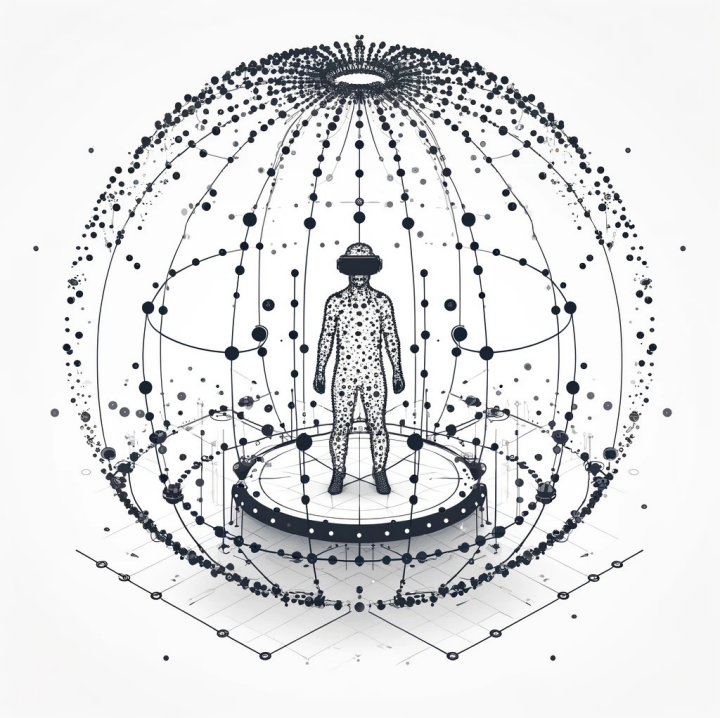




Towards Enhanced & Novel Visualization Designs

cPro: Circular Projections using Gradient Descent



Towards Novel Visualization Designs

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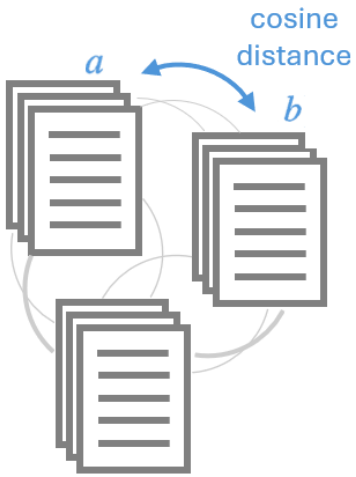

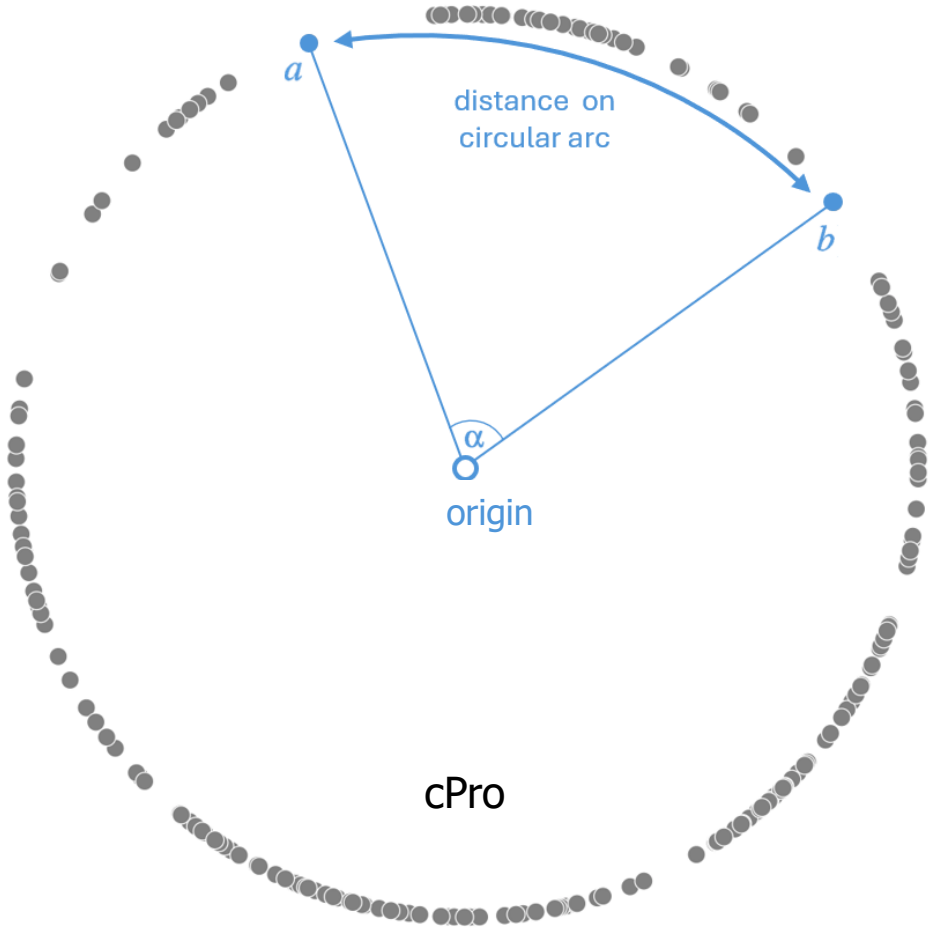

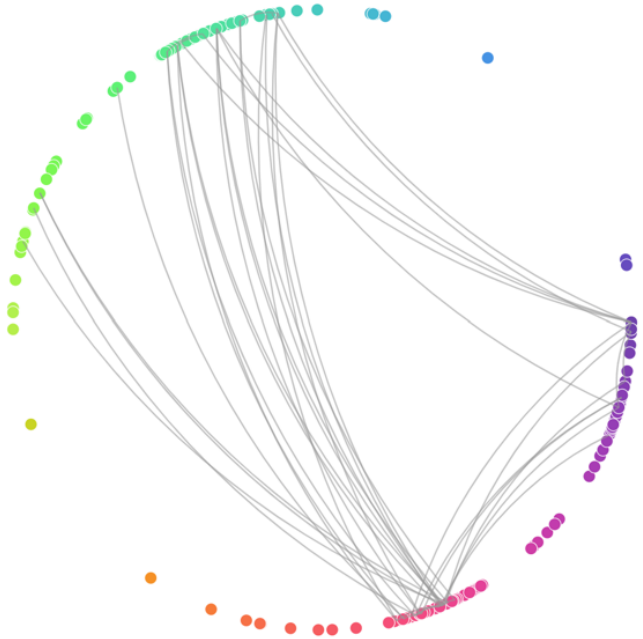

High-Dimensional Data

cPro

Visualization