AToMS: Author-Topic Manifold Summarization for Interpretable Author-Collaboration Forecasting

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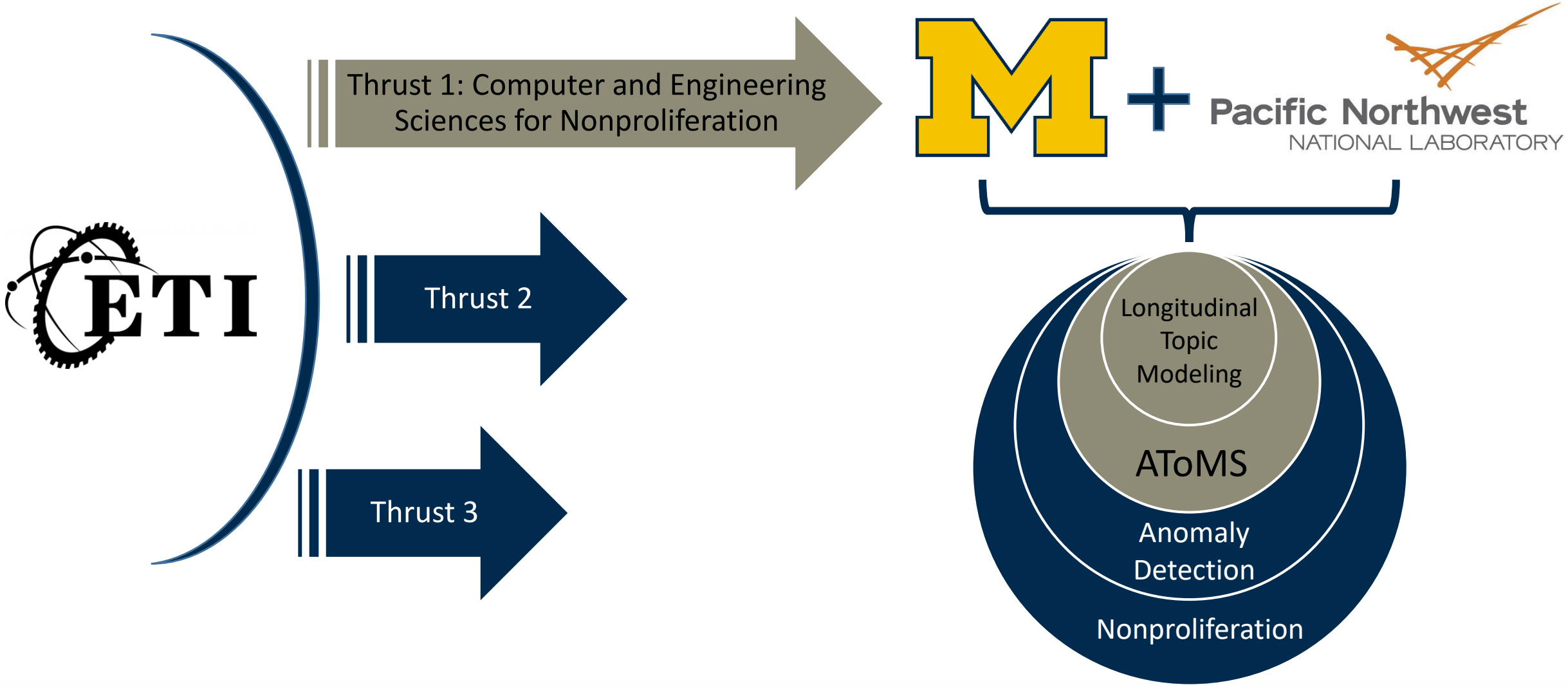
University of Michigan[§], Pacific Northwest National Laboratory[⁑]

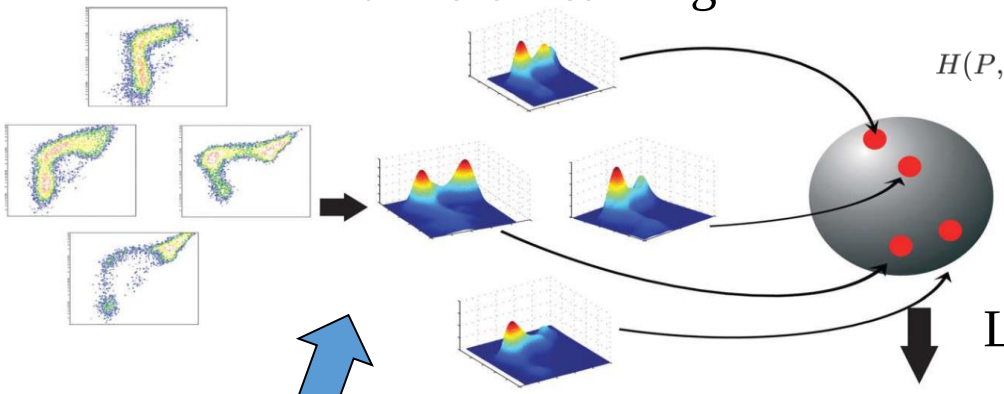
Date 02/08/23

PNNL-SA-181770


Thrust 1: Computer and Engineering Sciences for Nonproliferation
Thrust 2
Thrust 3
Pacific Northwest
NATIONAL LABORATORY
Longitudinal Topic Modeling
AToMS
Anomaly Detection
Nonproliferation

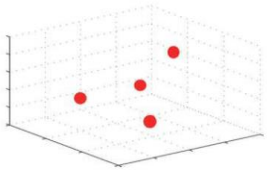
Foundations

Manifold Learning

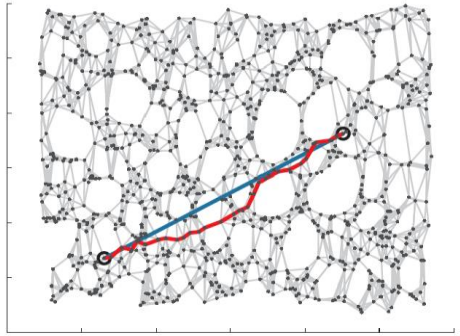


$$H(P,Q) = \frac{1}{\sqrt{2}}\sqrt{\sum_{n=1}^{N}(\sqrt{p_n}-\sqrt{q_n})^2}$$

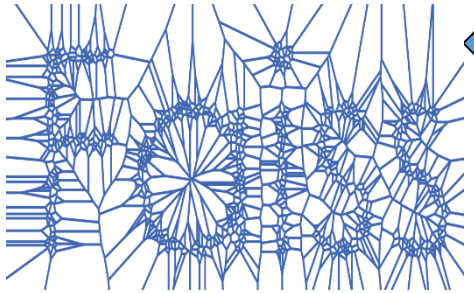
Low-Dimensional Embedding

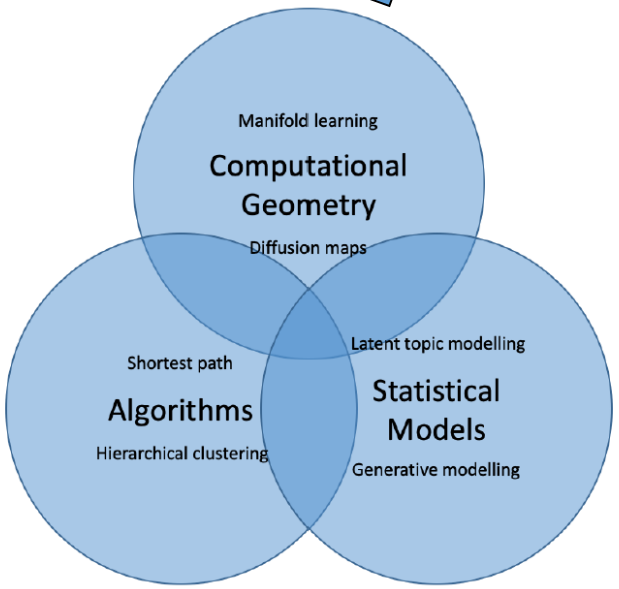


Dijkstra's Algorithm

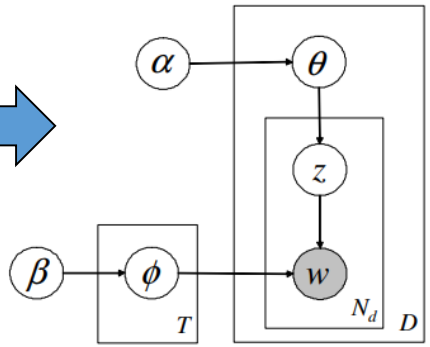


Similarity Search

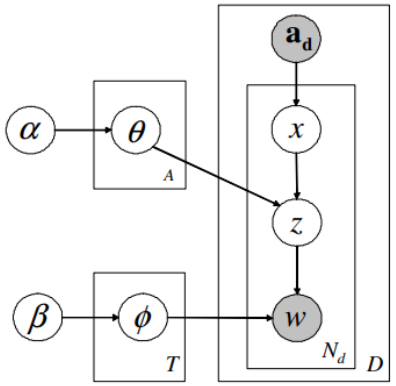




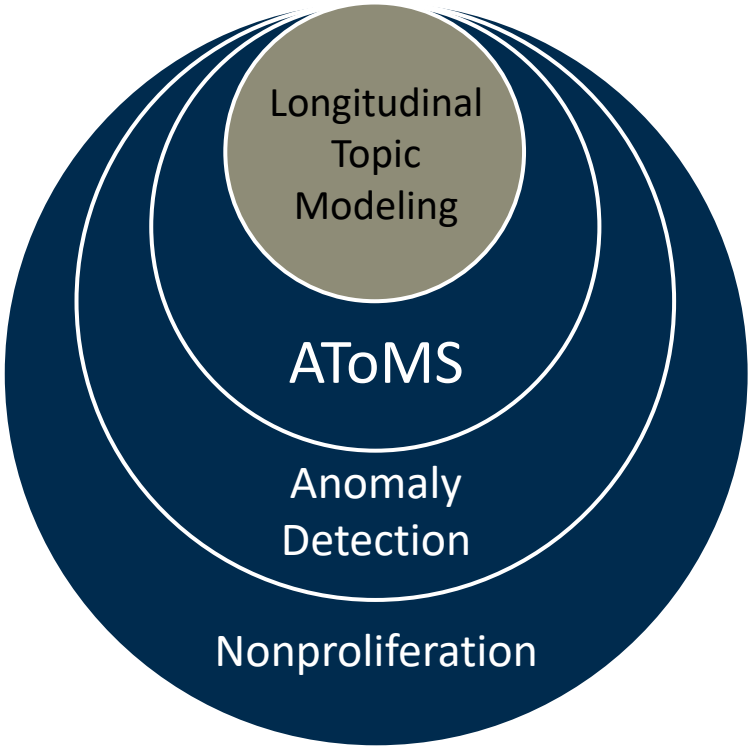
LDA



Author-Topic Model



GDLTM: A Geometry-Driven Longitudinal Topic Model



[1] Wang, Y., Hougen, C., Oselio, B., Dempsey, W., & Hero, A. "A Geometry-Driven Longitudinal Topic Model." Harvard Data Science Review (2021).

GDLTM: A Geometry-Driven Longitudinal Topic Model

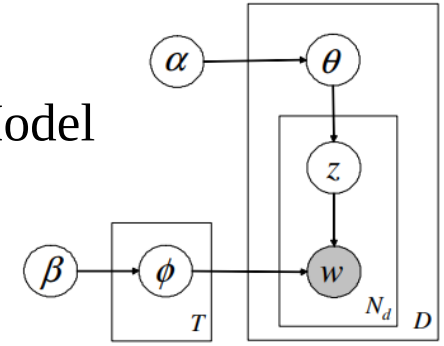
Temporal Smoothing

d_1	d_2	d_3	d_4	d_5
Doc1	Doc6	Doc11	Doc16	Doc21
Doc2	Doc7	Doc12	Doc17	Doc22
Doc3	Doc8	Doc13	Doc18	Doc23
Doc4	Doc9	Doc14	Doc19	Doc24
Doc5	Doc10	Doc15	Doc20	Doc25

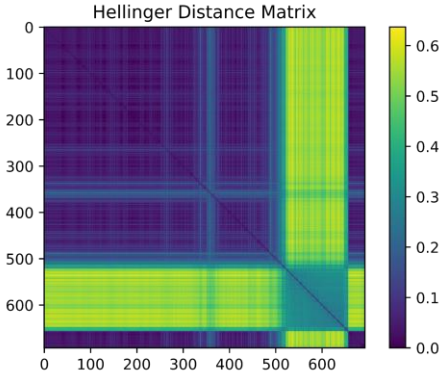
r_1	r_2	r_3	r_4	r_5
Doc1	Doc6	Doc11	Doc17	Doc23
Doc2	Doc8	Doc12	Doc19	
Doc3	Doc9	Doc13		
Doc4	Doc10			
Doc5				

s_1	s_2	s_3	s_4	s_5
Doc1	Doc6	Doc11	Doc17	Doc23
Doc2	**Doc7**	Doc12	Doc19	**Doc24**
~~Doc3~~	Doc8	Doc13	**Doc20**	
Doc4	Doc9	**Doc15**		
Doc5	Doc10			

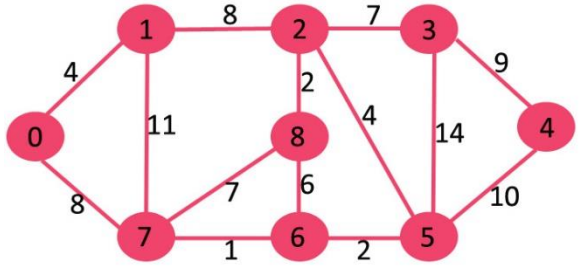
Topic Model



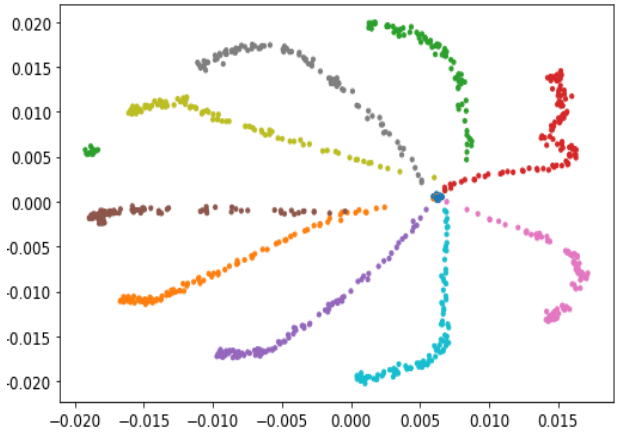
Distance Matrix



Shortest Path Algorithm



Low-Dimensional Embedding



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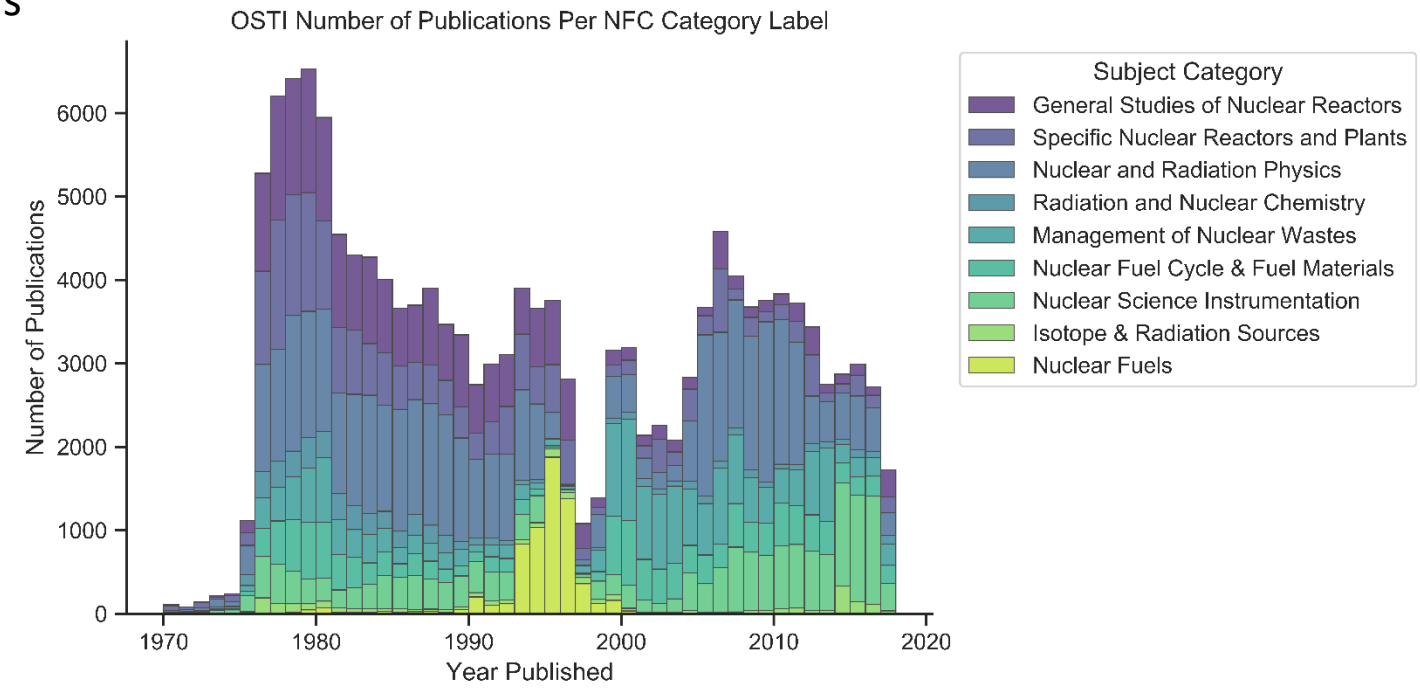
GDLTM: A Geometry-Driven Longitudinal Topic Model

- GDLTM on OSTI dataset of manuscript abstracts
- Filtered on **Nuclear Fuel Cycle** labeled papers
  - ~150,000 manuscripts
  - ~360,000 authors



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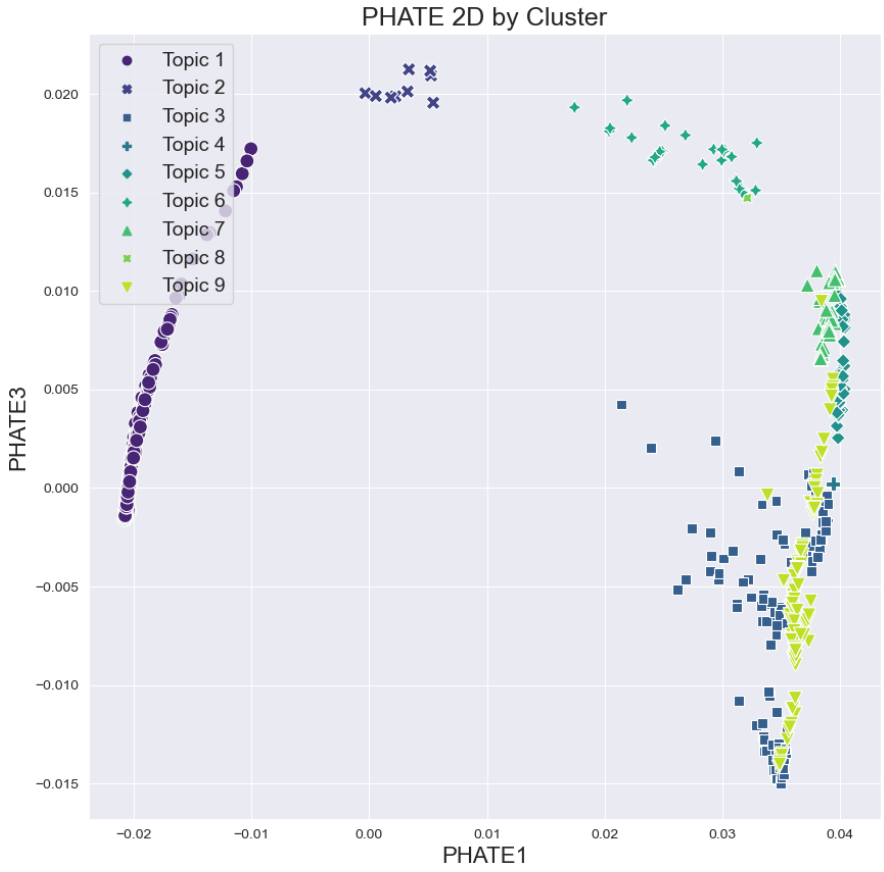
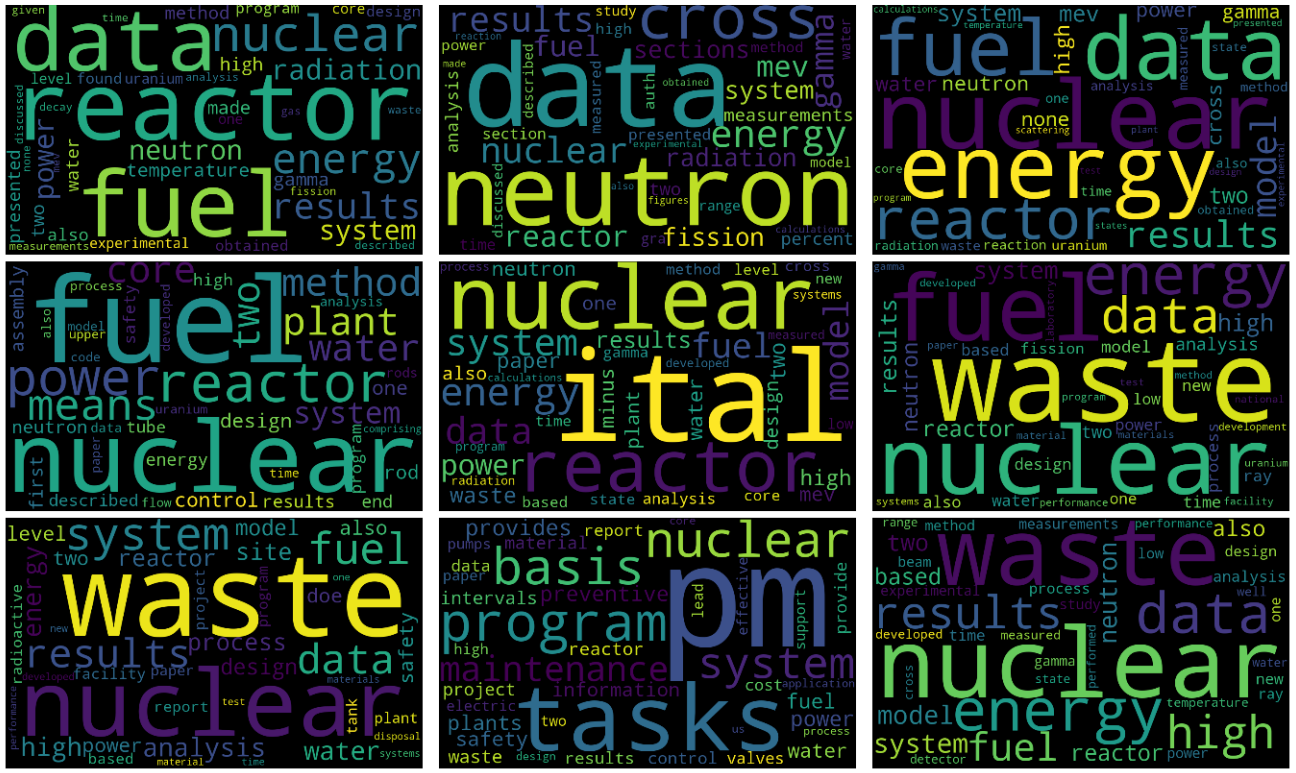


Clustered Topic Wordclouds



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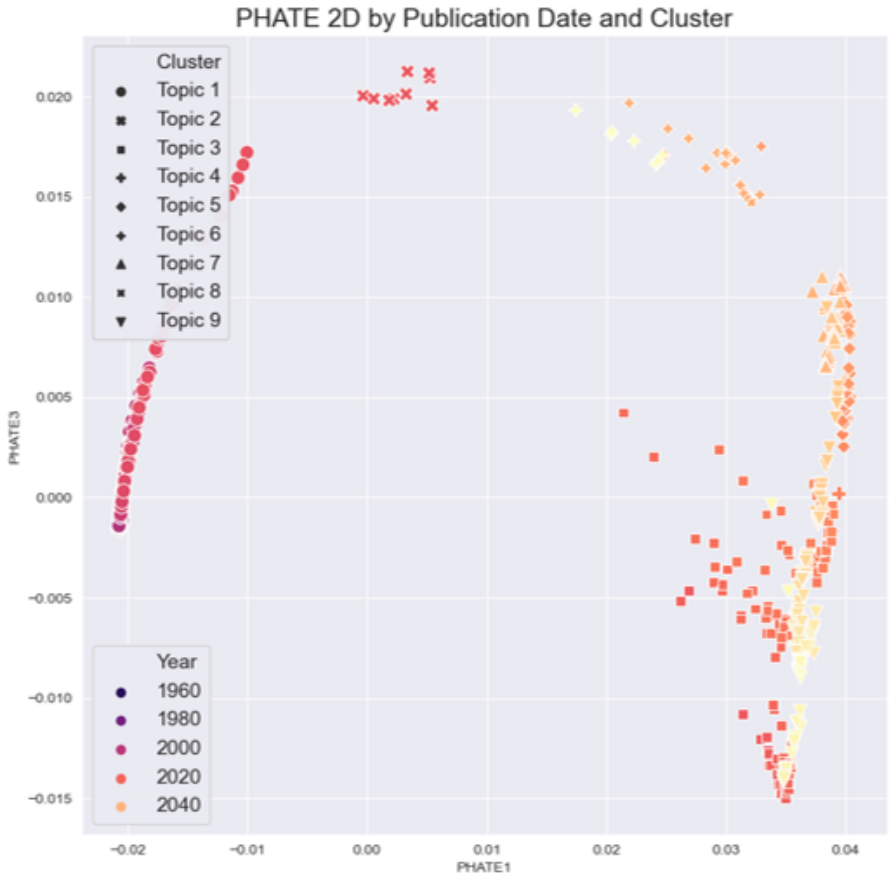

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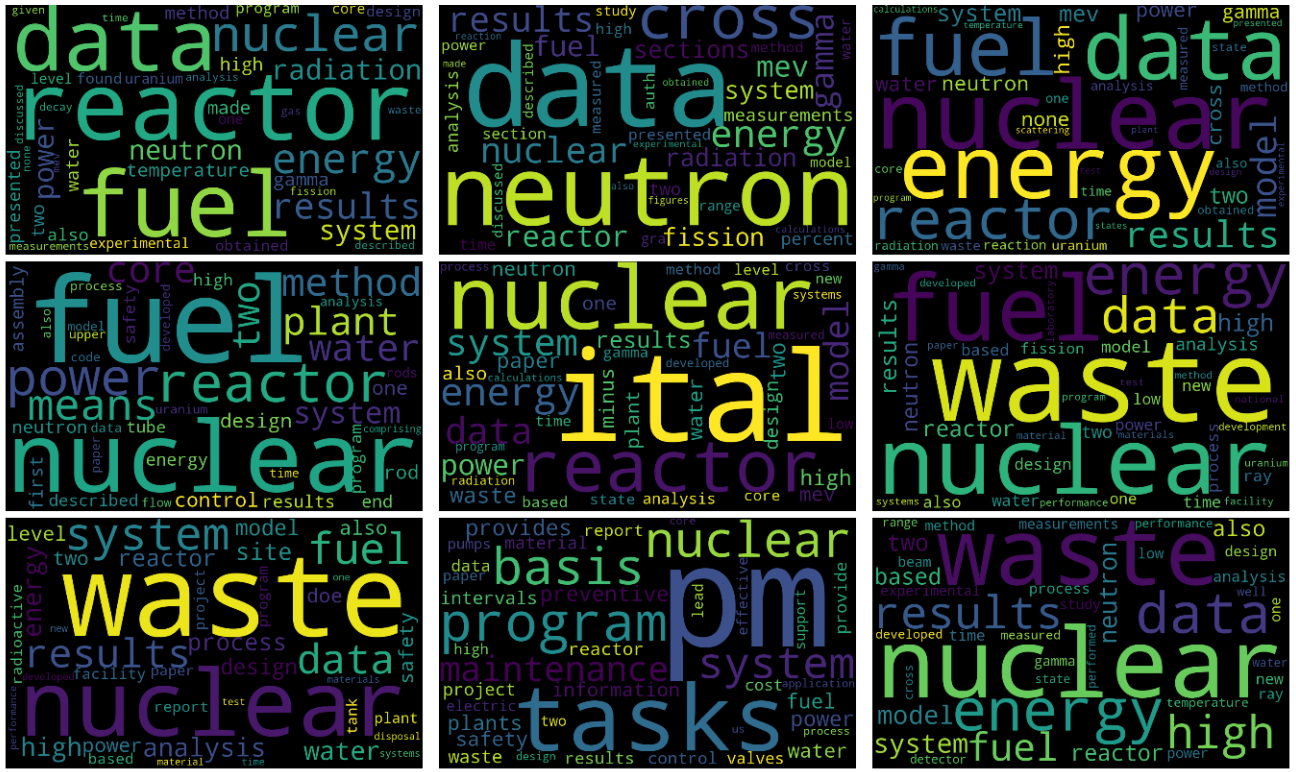

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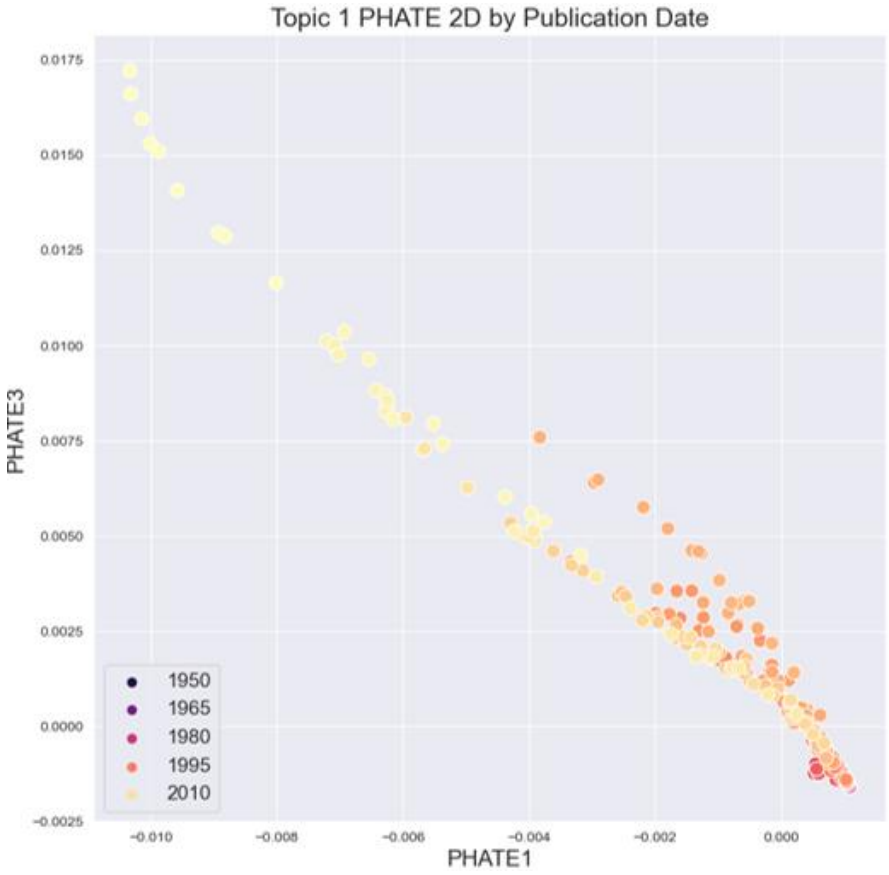

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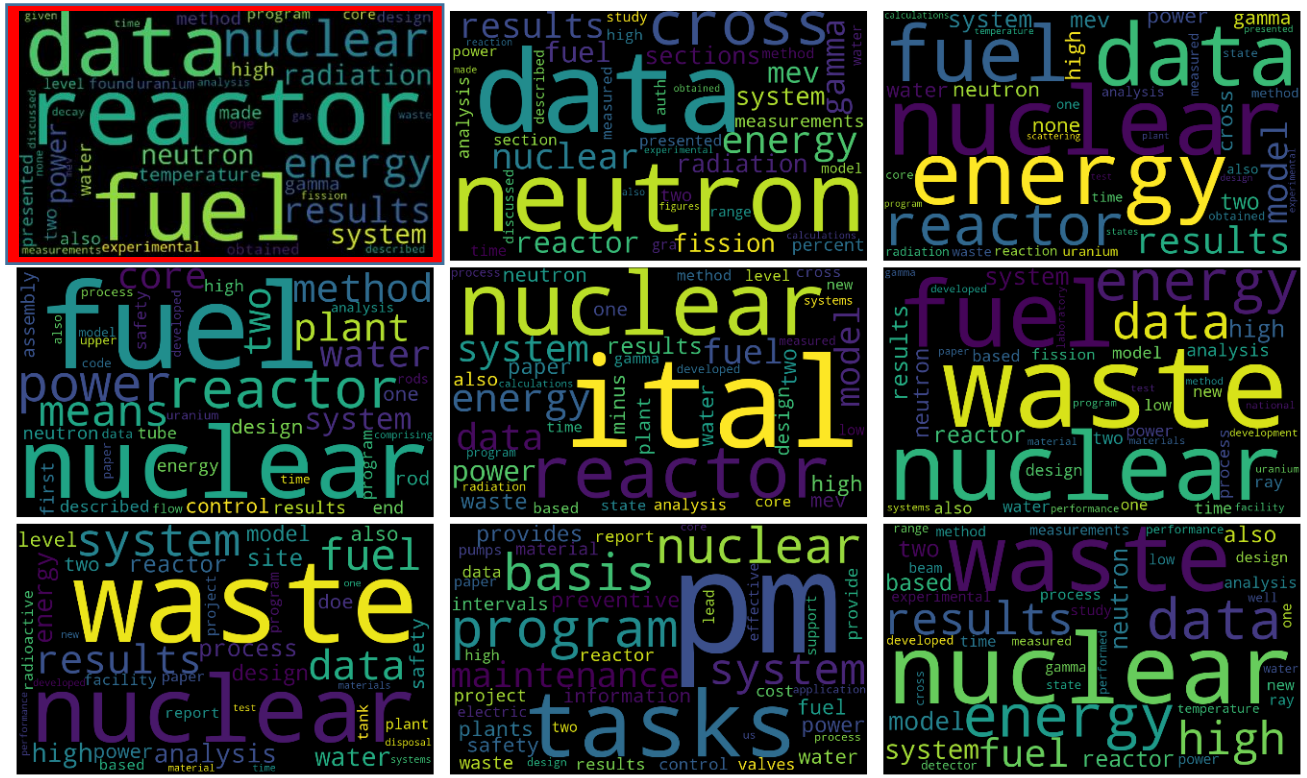

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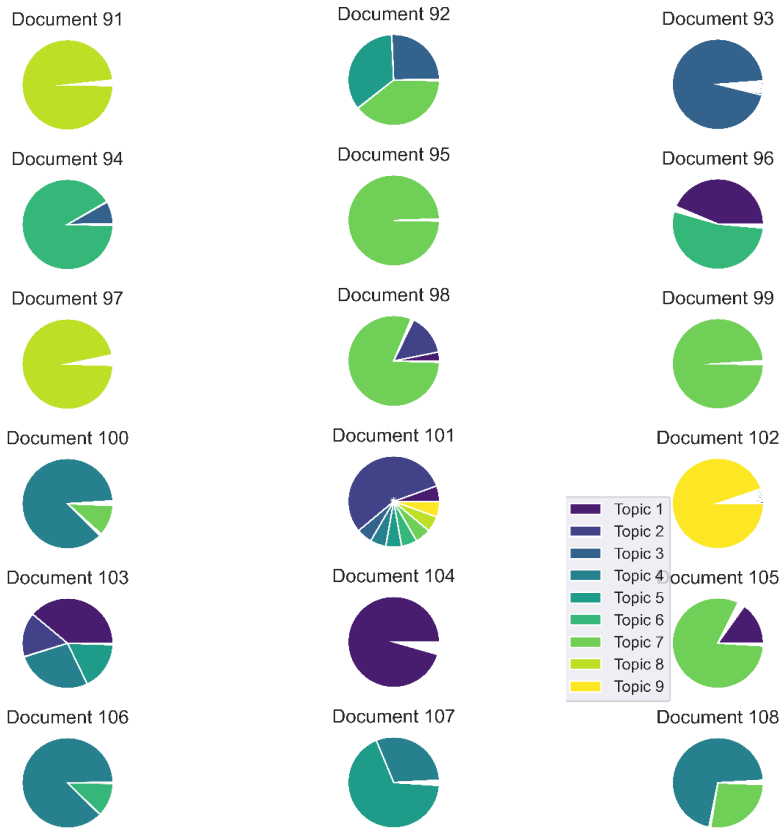
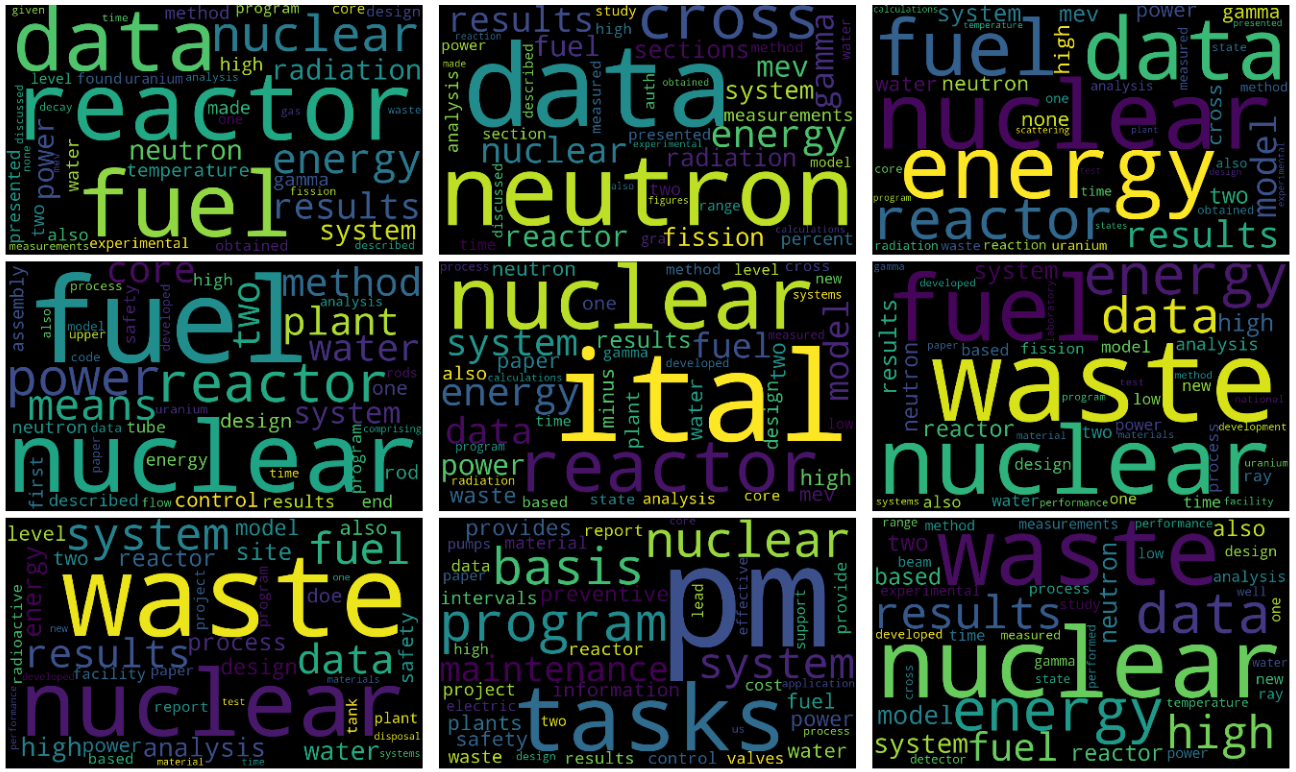


Clustered Topic Wordclouds



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National Nuclear Security Administration

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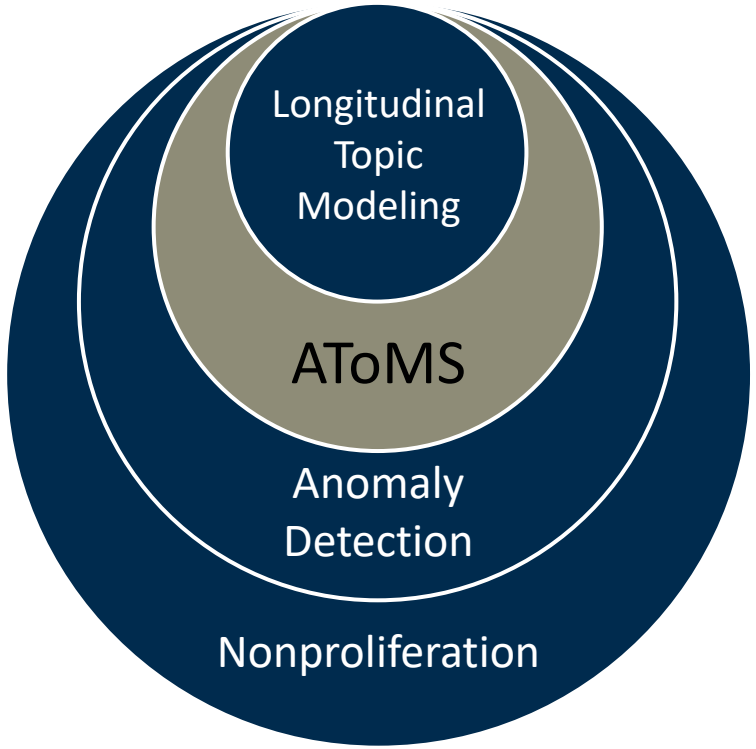
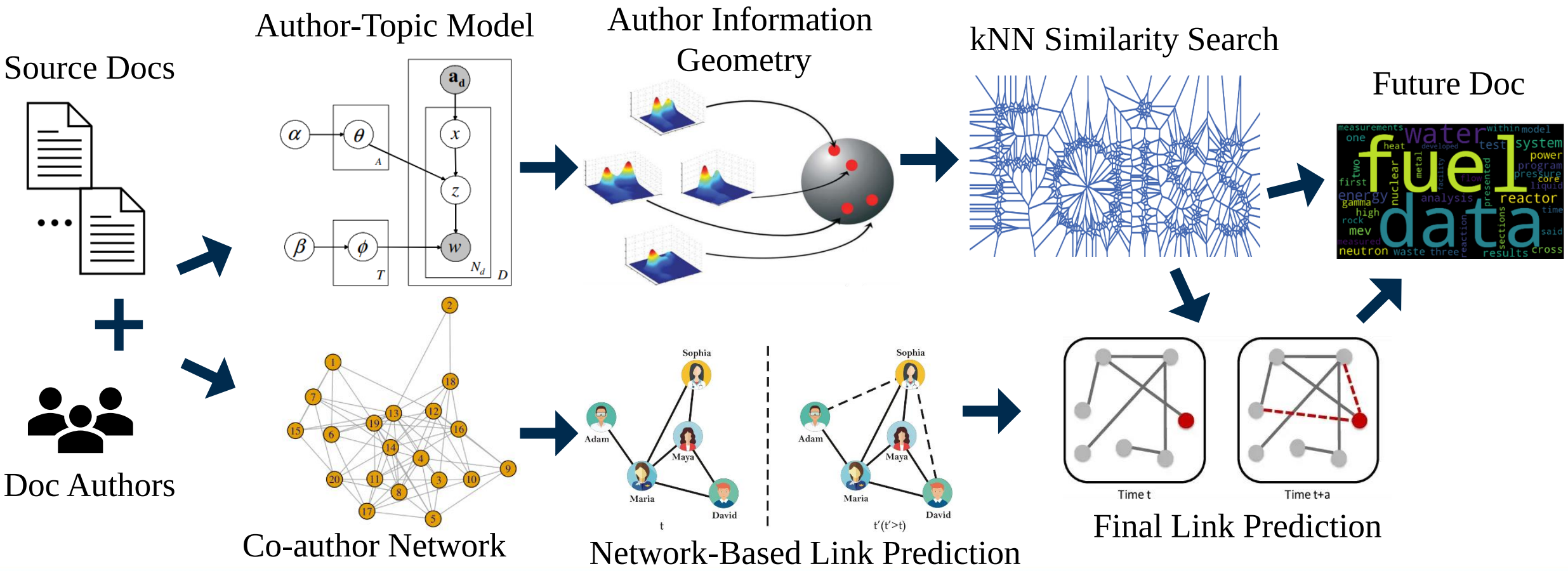
AToMS: Author Topic Manifold Summarization



ATOMS: Author Topic Manifold Summarization



[2] Ahmad, I., Akhtar, M.U., Noor, S. *et al.* Missing Link Prediction using Common Neighbor and Centrality based Parameterized Algorithm. *Sci Rep* 10, 364 (2020).

[3] Michal Rosen-Zvi, Thomas Griffiths, Mark Steyvers, and Padhraic Smyth. 2004. The author-topic model for authors and documents. In Proceedings of the 20th conference on Uncertainty in artificial intelligence (UAI '04). AUAI Press, Arlington, Virginia, USA, 487–494.

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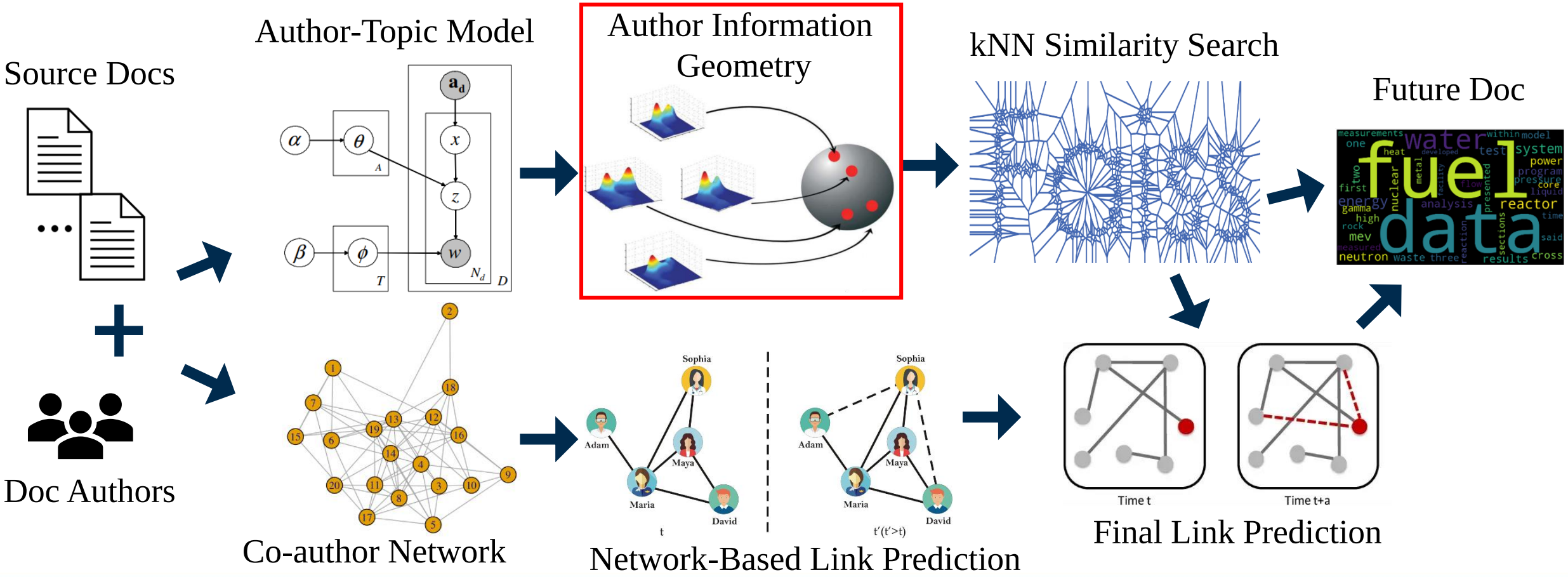

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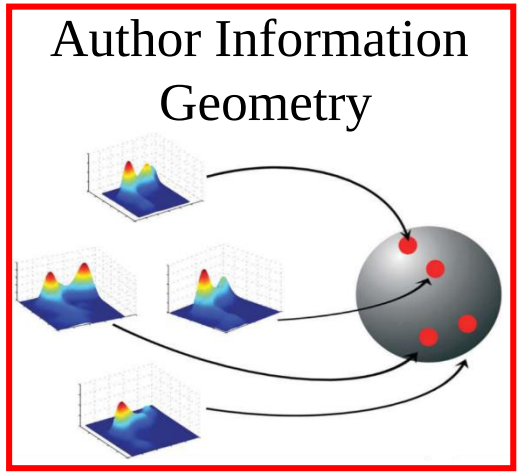
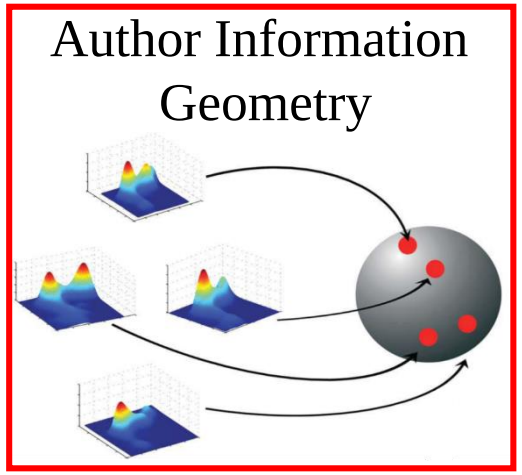
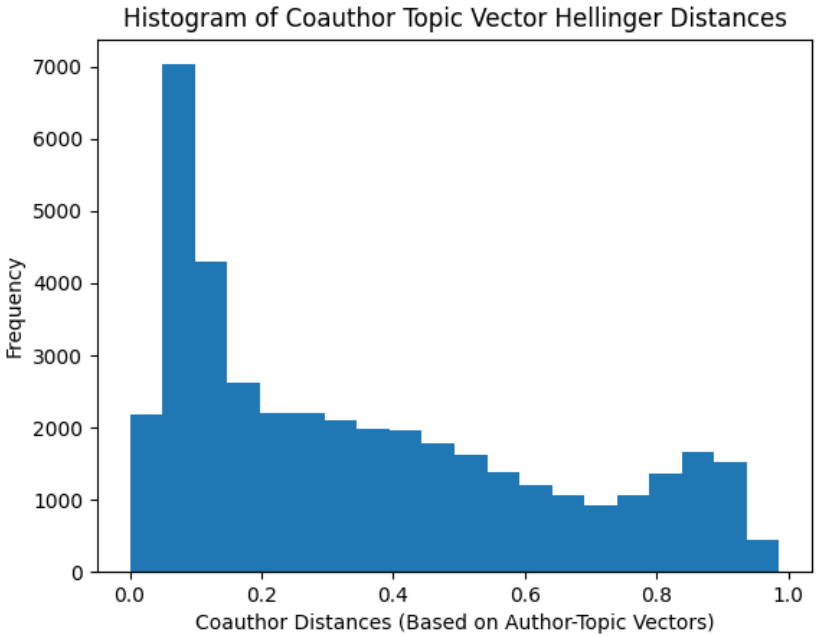
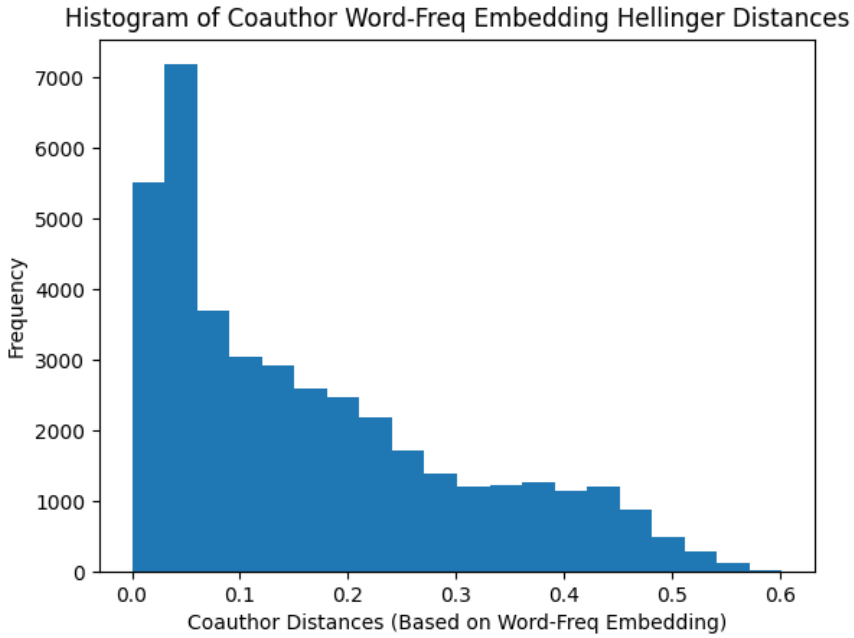


- Important Question: How should we represent authors?
  - Representation depends on distance metric
  - Hellinger distance: $H(P,Q) = \frac{1}{\sqrt{2}}\sqrt{\sum_{n=1}^{N}\left(\sqrt{p_n} - \sqrt{q_n}\right)^2}$
  - Topic vectors are not always well-separated
  - Alternative symmetric distance metrics may have disadvantages
    - E.g. Wasserstein, cosine, etc.
    - Depends on the author embedding

AToMS Author Vectors

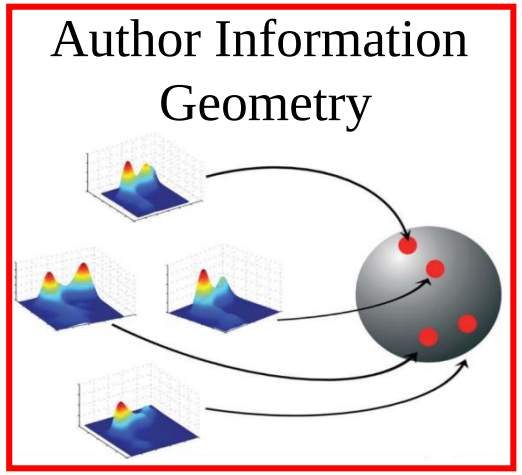


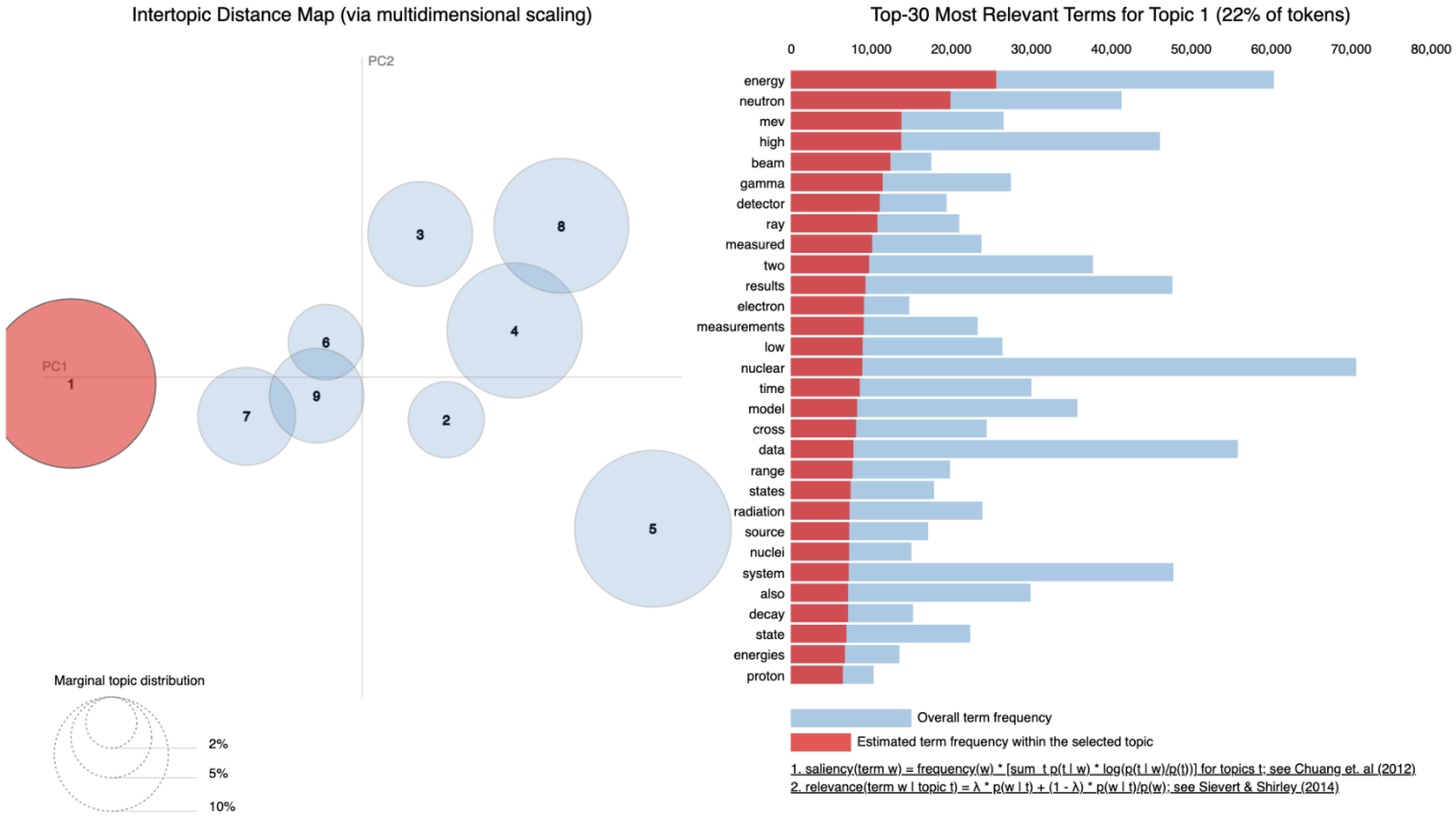




- Topic vectors are not always well-separated

AToMS: Author Topic Manifold Summarization





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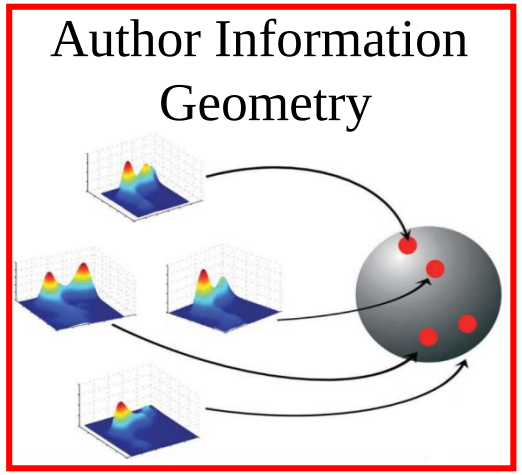
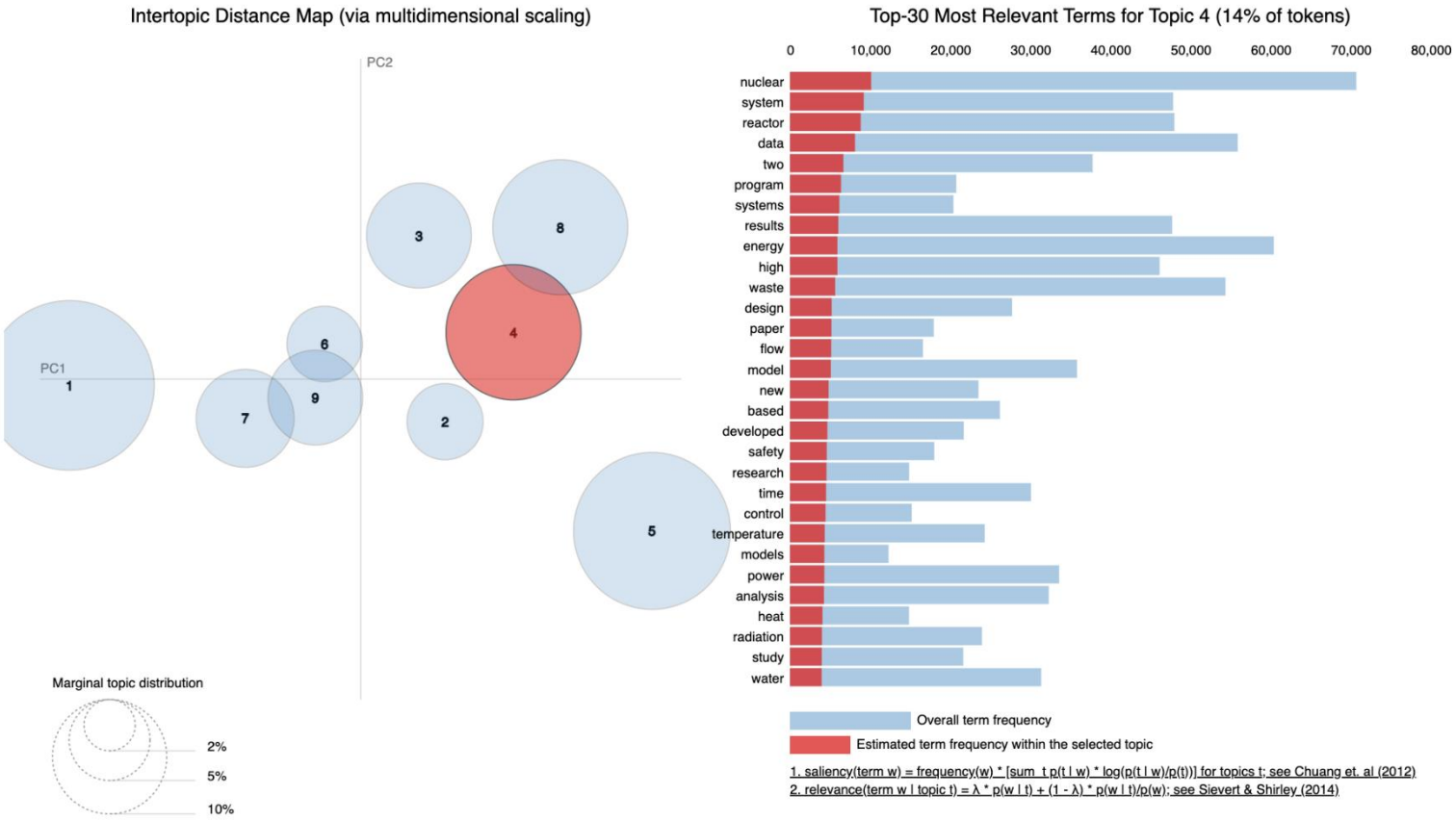
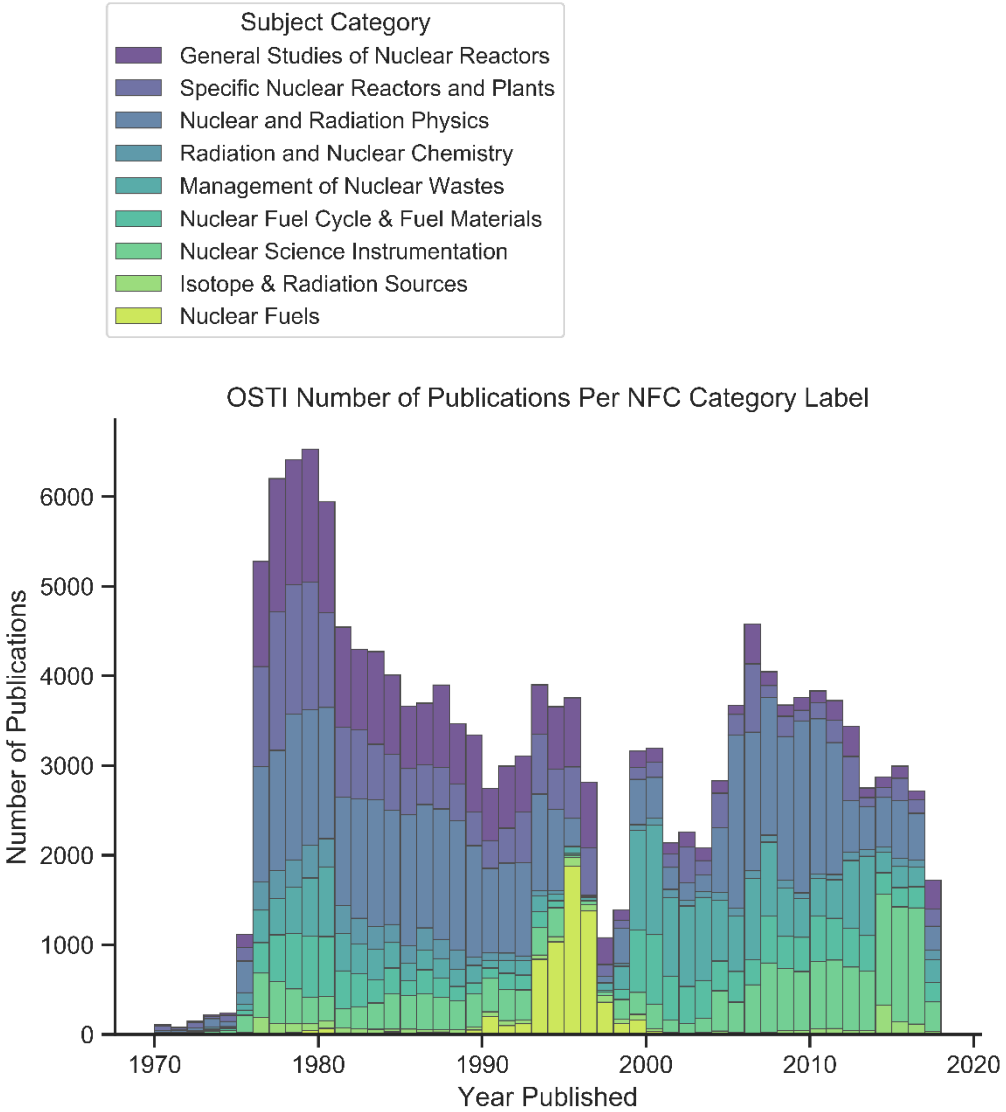




- Topic vectors are not always well-separated

Experimental Setup

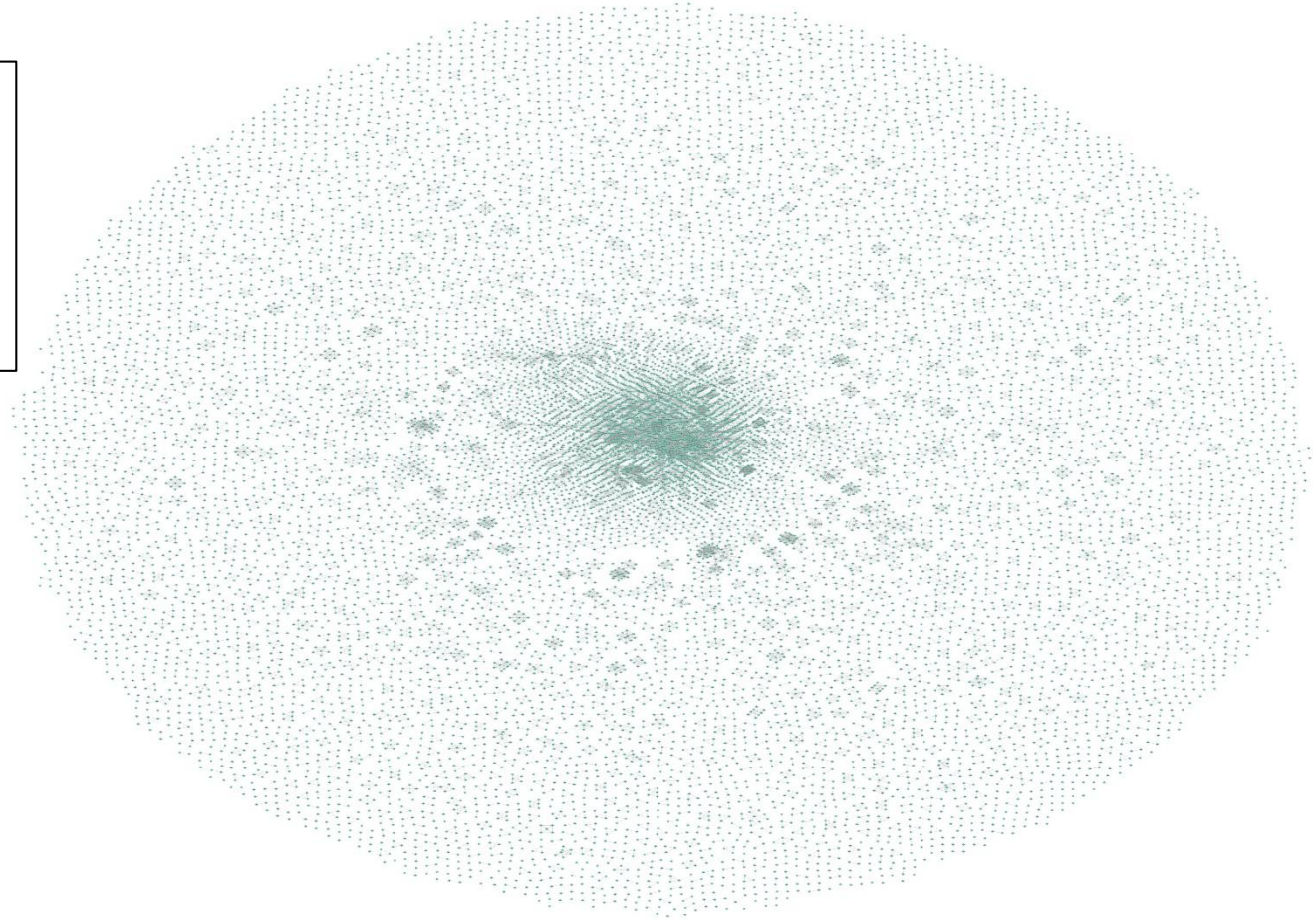
- OSTI (DOE Office of Scientific and Technical Information)
  - Database of articles from DOE-funded R&D
  - Title, author, OSTI subject label, abstract text, etc.
- Nuclear Fuel Cycle Documents
  - Filtered from OSTI using subject labels
  - 9 OSTI subject labels are considered NFC related
- Preprocessing
  - Filter out “stop words” – standard practice in NLP
  - Author entity disambiguation
  - Remove documents with missing abstract or authors
- Experimental Setup
  - Reduce corpus to specific subsets for train and test
  - Consider only authors that exist in the training set
  - Predict links between pairs of authors

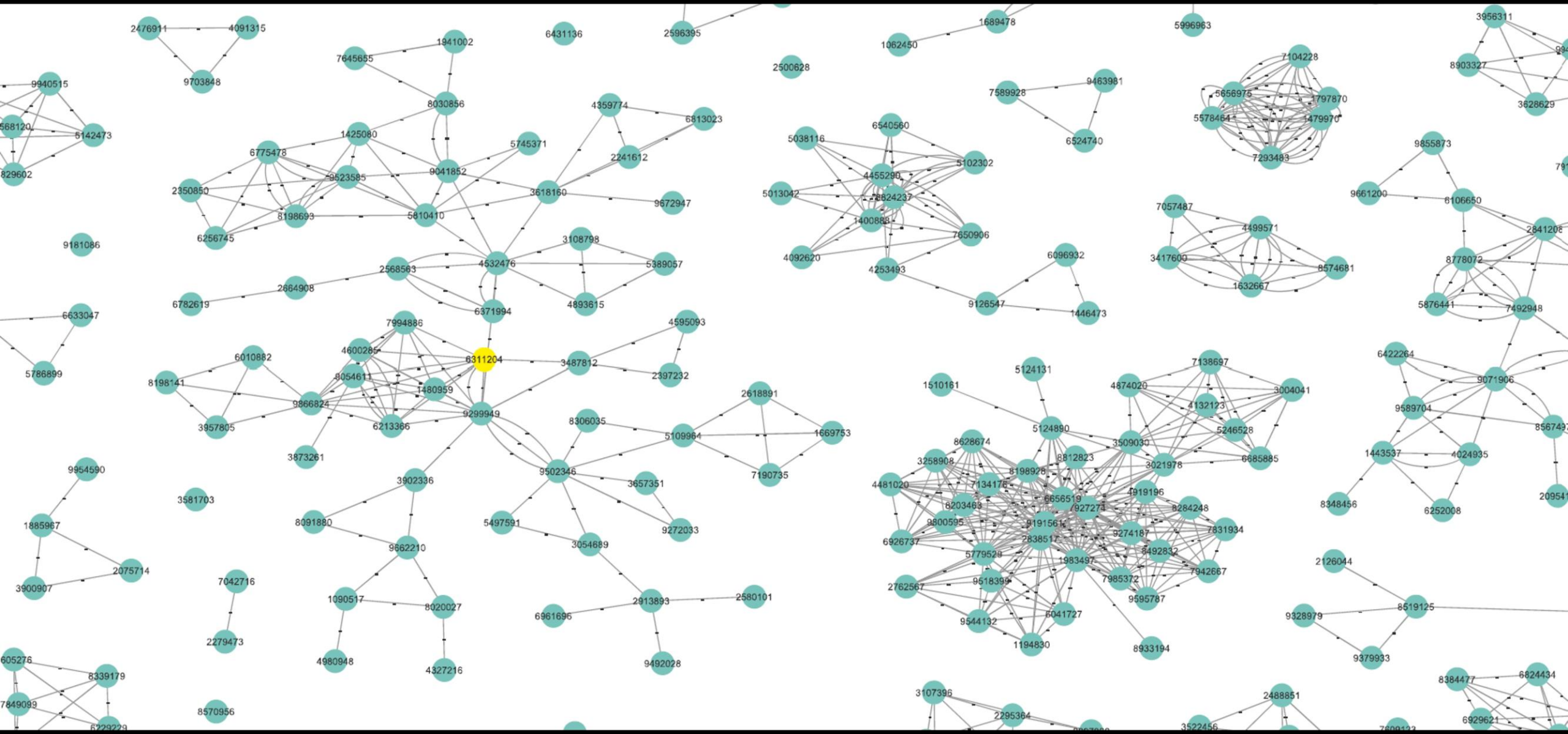


OSTI NFC: [’81-’82][’90][15,471][36,282][52,779]

- Training Data
  - OSTI NFC documents from 1981 through 1982
  - 15,471 authors
  - 36,282 edges in coauthorship network
  - 8,846 manuscript abstracts

Property Name	Value
Avg. Number of Neighbors	8.602
Network Diameter	29
Clustering Coefficient	0.767
Network Density	0.002
Connected Components	4251

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2500628
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4359774
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7589928
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9544132
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8933194
9379933
8384477
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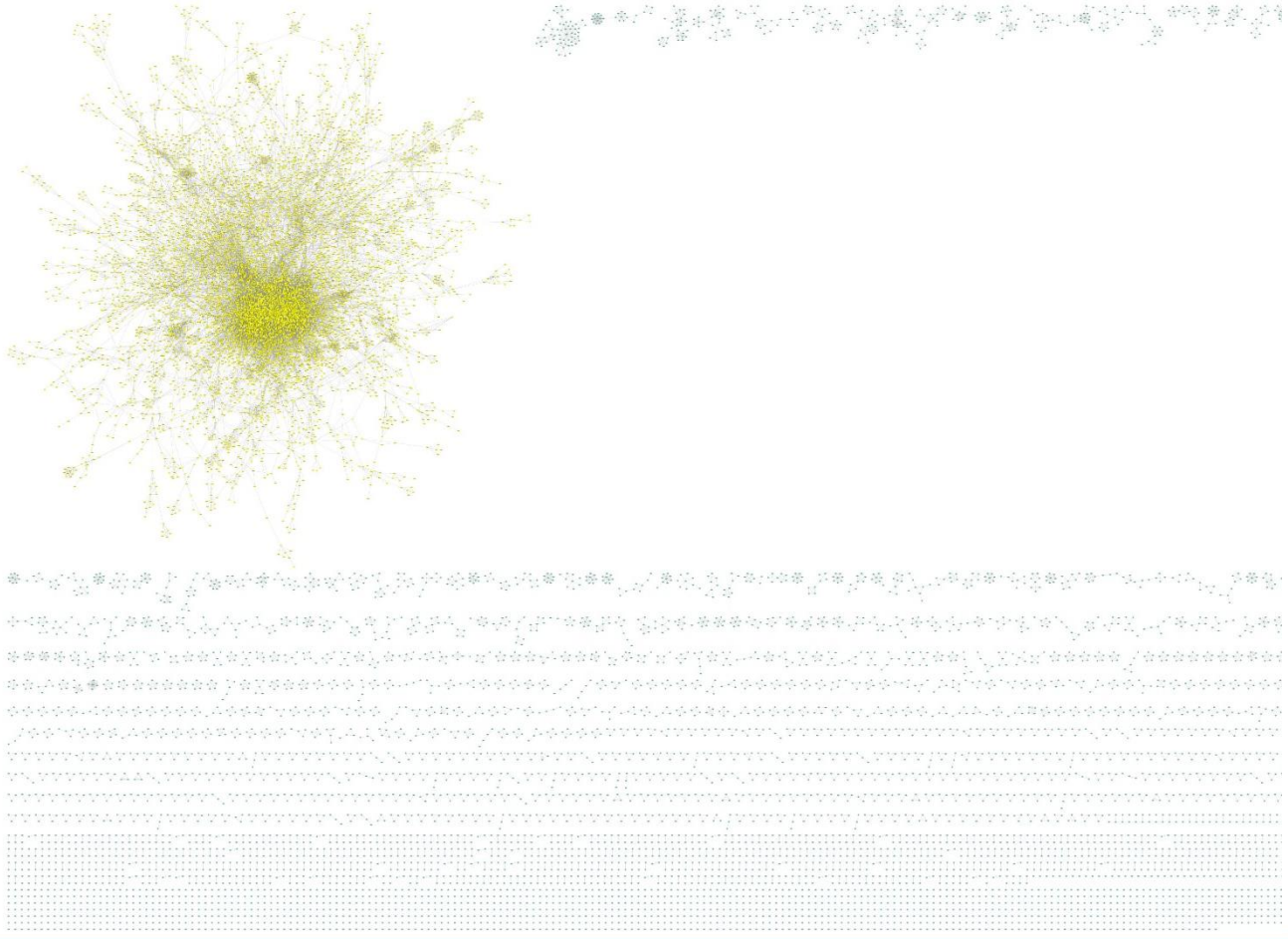
2488851
6929621
3522456

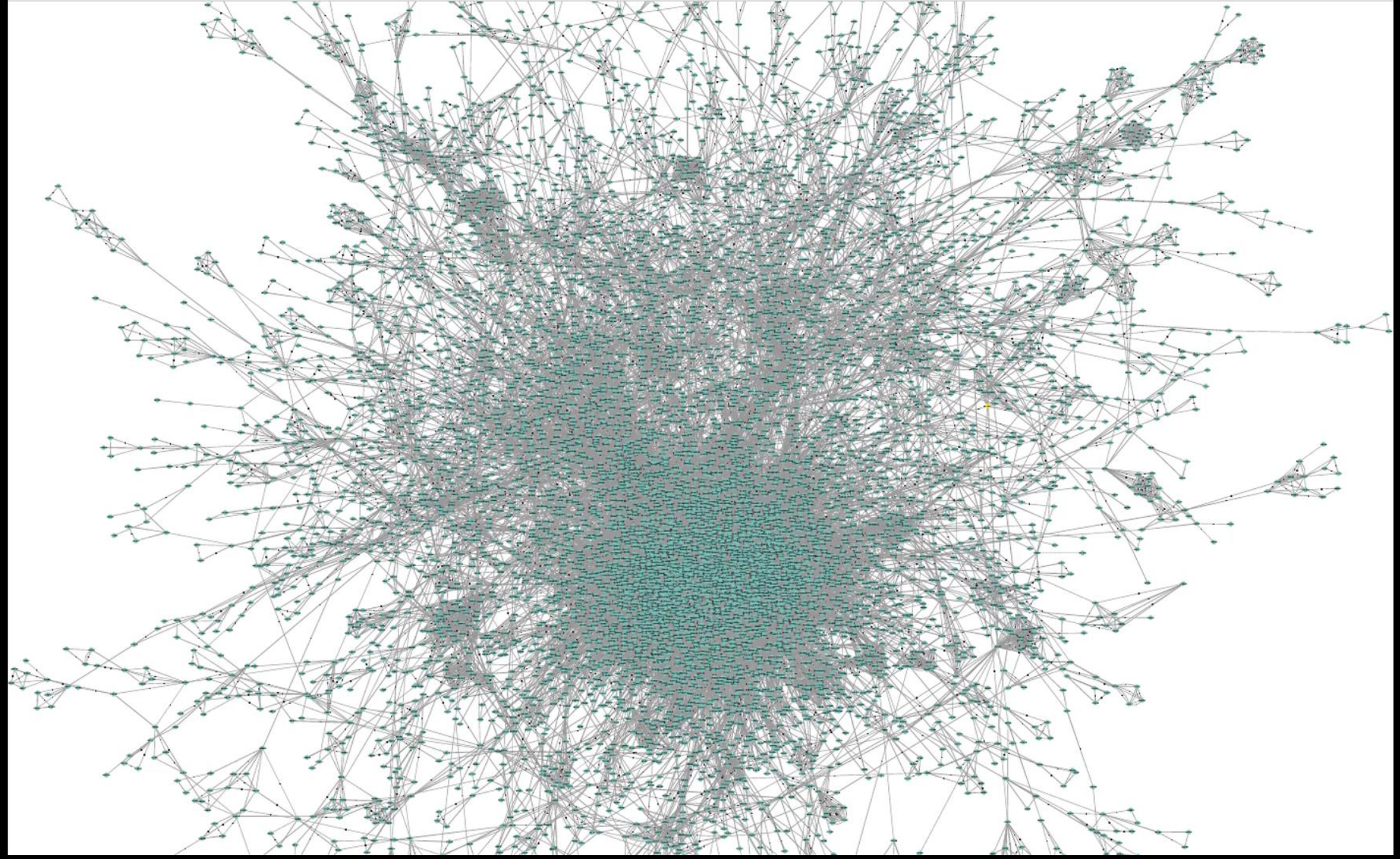
OSTI NFC: [’81-’82][’90][15,471][36,282][52,779]

- Test Data
  - OSTI NFC documents from 1983 through 1990
  - Restricted to same 15,471 authors
  - 52,779 – 36,282 = 16,497 new edges
  - 29,100 new manuscript abstracts



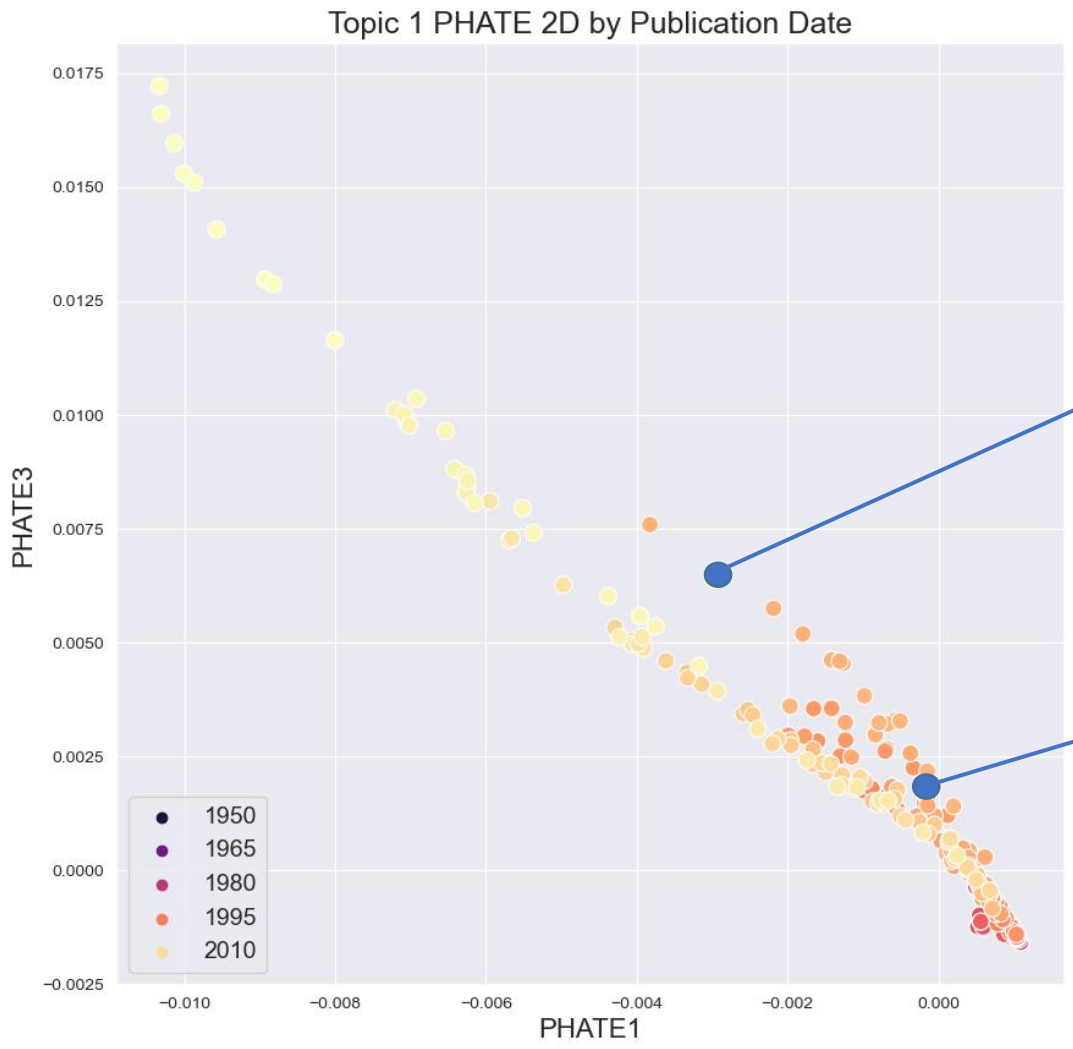
Property Name	Value
Avg. Number of Neighbors	8.864
Network Diameter	25
Clustering Coefficient	0.615
Network Density	0.001
Connected Components	3119

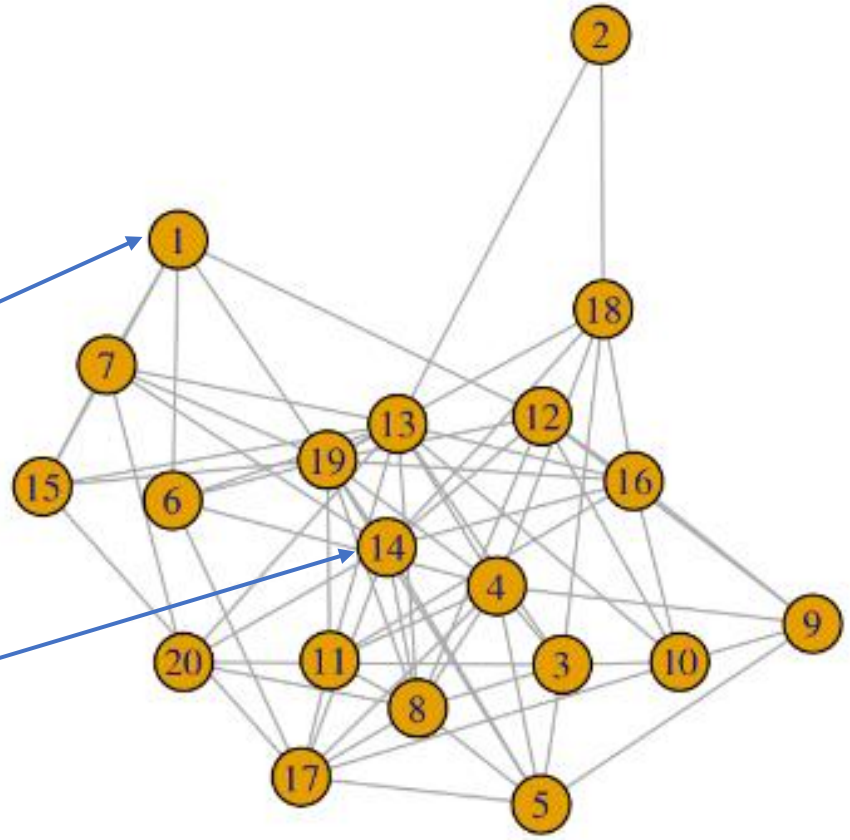
0



OSTI NFC: [’81-’82][’90][15,471][36,282][52,779]

Baseline Method	TP	FP	FN	Precision	Recall	F1-Score
Graph Distance 2 (GD2)	426	17,715	16,071	0.0235	0.0258	0.0246
Common Neighbors (CN)	**939**	**17,202**	**15,558**	**0.0518**	**0.0569**	**0.0542**
Adamic-Adar (AA)	905	17,236	15,592	0.0499	0.0549	0.0523
Jaccard Coefficient (JC)	619	17,522	15,878	0.0341	0.0375	0.0357
Resource Allocation (RA)	774	17,367	15,723	0.0427	0.0469	0.0447
AToMS Method	**TP**	**FP**	**FN**	**Precision**	**Recall**	**F1-Score**
Common Neighbors/Hellinger	**944**	**17,197**	**15,553**	**0.0520**	**0.0572**	**0.0545**
Adamic-Adar/Hellinger	907	17,234	15,590	0.0500	0.0550	0.0524
Jaccard Coefficient/Hellinger	527	17,614	15,970	0.0291	0.0319	0.0304
Resource Allocation/Hellinger	781	17,360	15,716	0.0431	0.0473	0.0450





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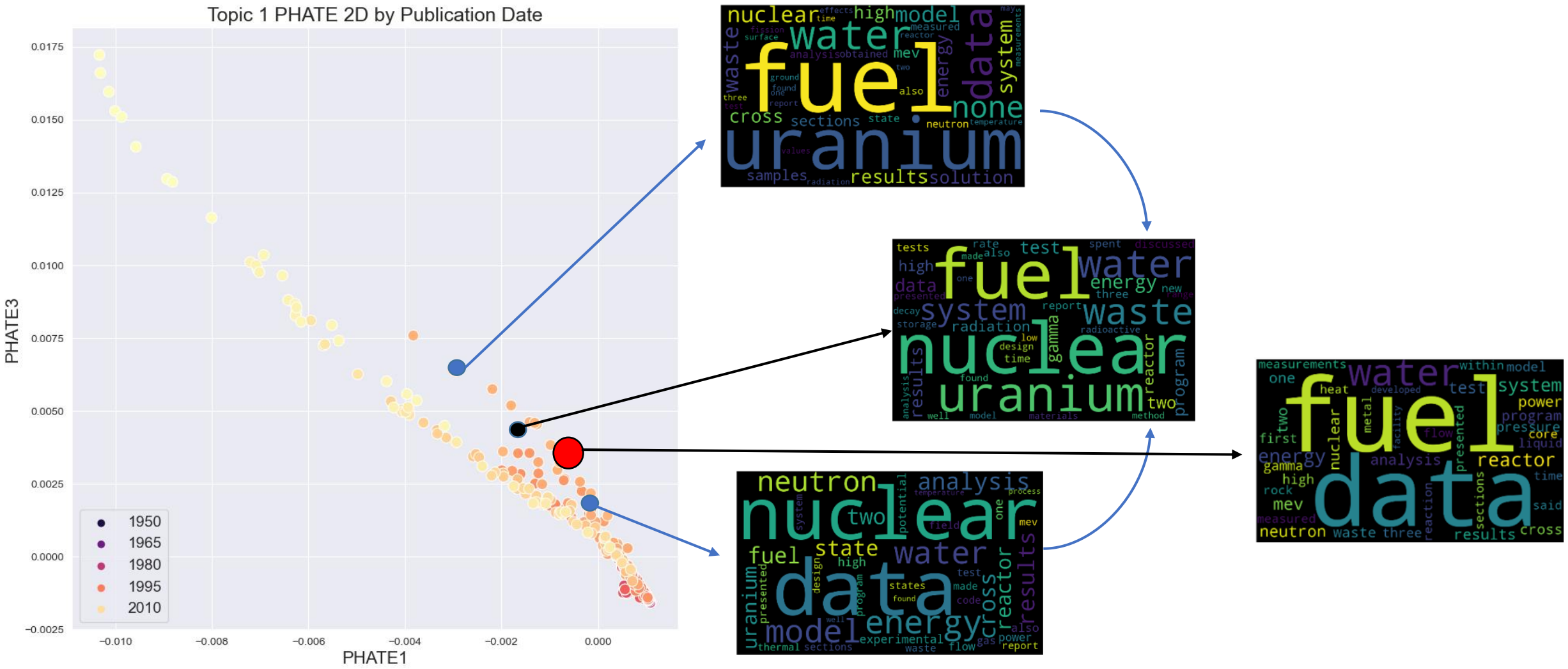
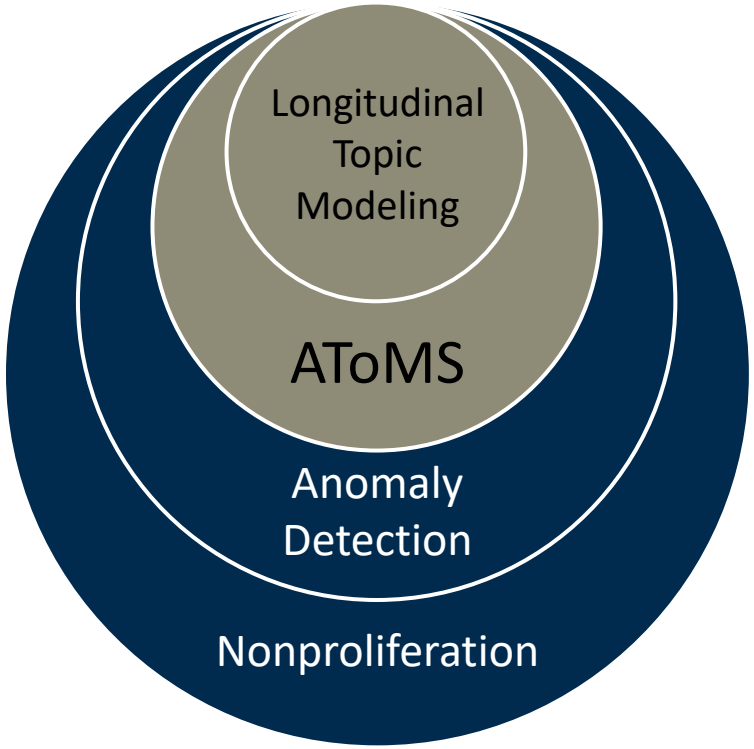

Topic 1 PHATE 2D by Publication Date
PHATE3
PHATE1
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
−0.0025
−0.010
−0.008
−0.006
−0.004
−0.002
0.000
1950
1965
1980
1995
2010
fuel
uranium
water
nuclear
data
model
system
waste
energy
none
cross
sections
results
solution
samples
neutron
analysis
reactor
two

Conclusions and Future Work

- Link Prediction
  - Challenging problem in bibliographic networks
    - Networks are extremely sparse
  - AToMS outperforms “network-only” algorithms
    - Common neighbors is surprisingly effective
- Interpretability
  - AToMS provides predictive document modeling
  - Topic modeling reveals author interests
- Longitudinal Author-Topic Modeling
  - AToMS can be improved by using temporal information
  - Combine GDLTM longitudinal topics with AToMS model
- Nonproliferation Objective
  - Computational tools assist understanding bibliographic data
  - Can signal knowledge-based threats



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Georgia Tech

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The Ohio State University

Spelman College — A Choice to Change the World

Texas A&M University

The University of Texas at Austin

Washington State University

Argonne National Laboratory

Berkeley Lab

Brookhaven National Laboratory

INL Idaho National Laboratory — 70 Years of Science & Innovation

Lawrence Livermore National Laboratory

Los Alamos National Laboratory — EST. 1943

Nevada National Security Site — Managed and operated by Mission Support and Test Services

Oak Ridge National Laboratory

Pacific Northwest National Laboratory

PPPL Princeton Plasma Physics Laboratory

Sandia National Laboratories

SRNL Savannah River National Laboratory

National Nuclear Security Administration

Consortium for Enabling Technologies & Innovation

OSTI NFC 1.1 (897 Authors, 1275 edges, 560 edge budget)

Method Name	TP	FP	TN	FN	Precision	Recall	F1-Score
AToMSv2_pa_he	0	560	-	155	0.0000	0.0000	0.0000
AToMSv2_aa_he	16	544	-	139	0.0286	0.1032	0.0448
AToMSv2_jc_he	**20**	540	-	**135**	**0.0357**	**0.1290**	**0.0559**
AToMSv2_ra_he	17	543	-	138	0.0304	0.1097	0.0476
AToMSv2_cn_he	15	545	-	140	0.0268	0.0968	0.0420
AToMSv2_jc_co	15	545	-	140	0.0268	0.0968	0.0420
PA	1	559	-	154	0.0018	0.0065	0.0028
AA	15	545	-	140	0.0268	0.0968	0.0420
JC	16	544	-	139	0.0286	0.1032	0.0448
RA	16	544	-	139	0.0286	0.1032	0.0448
CN	15	545	-	140	0.0268	0.0968	0.0420
GD2	4	**152**	-	151	0.0256	0.0258	0.0257