Metadata Analytics: Workflows and Applications

Jian Qin

School of Information Studies

Syracuse University

Metadata analytics

What is it?

- The (very brief) history
- The motivation
- The perspective

- Theories
- Methodologies
- Applications

What is (big) metadata?

An earlier definition

"…the structured, semi-structured, or unstructured descriptions of scientific data stored in repositories" (Bratt et al., 2017)

An updated brief version

The structured or semi-structured descriptions of information and/or data objects.

An updated long version

The structured or semi-structured descriptions of information and/or data objects in the forms of library catalogs, indexing databases, and metadata repositories.

The (very brief) history

Price, Derek J. de Solla, 1922-1983.

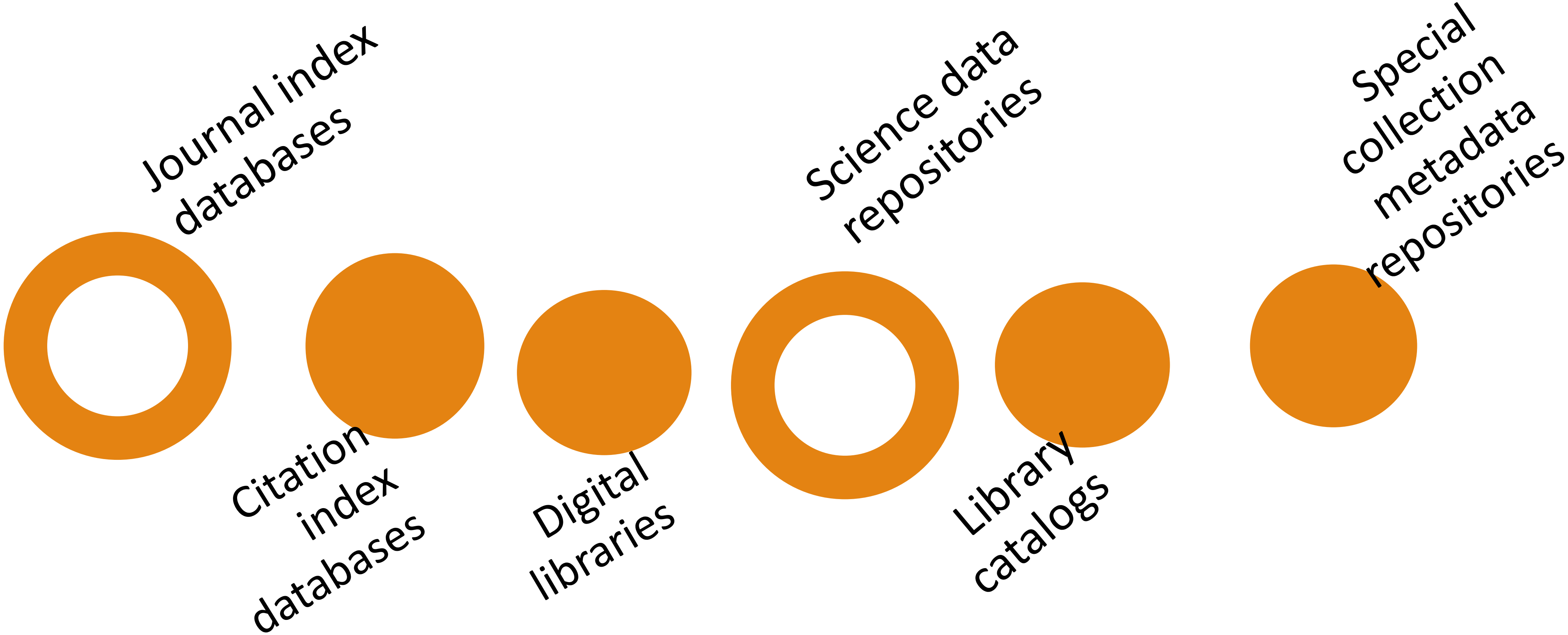
- Price’s model: Preferential attachment process
- Power law distribution of citation network, first example of scale-free network
- Price’s law: square root law for relationships between authors and publications
- Exponential growth of science and half-life of science literature

Eugene Eli Garfield, 1925-2017

- Science citation index (which inspired the PageRank algorithm by Google co-founders)
- Journal impact factor

Bibliometrics, Scientometrics:
Theories (laws) built on math
Quantitative methods
Macro- and micro-scale
Authors, publications, citations

The changing landscape of metadata…



Journal index databases

Citation index databases

Digital libraries

Science data repositories

Library catalogs

Special collection metadata repositories

Old issues, great challenges

- The perpetual ambiguous author names → Name disambiguation
- Metadata is never readily usable for analysis → Constant data cleaning and processing
- Difficult to reuse code and workflows → Reinventing the wheel
- Limitations of current metadata structures → Linked data

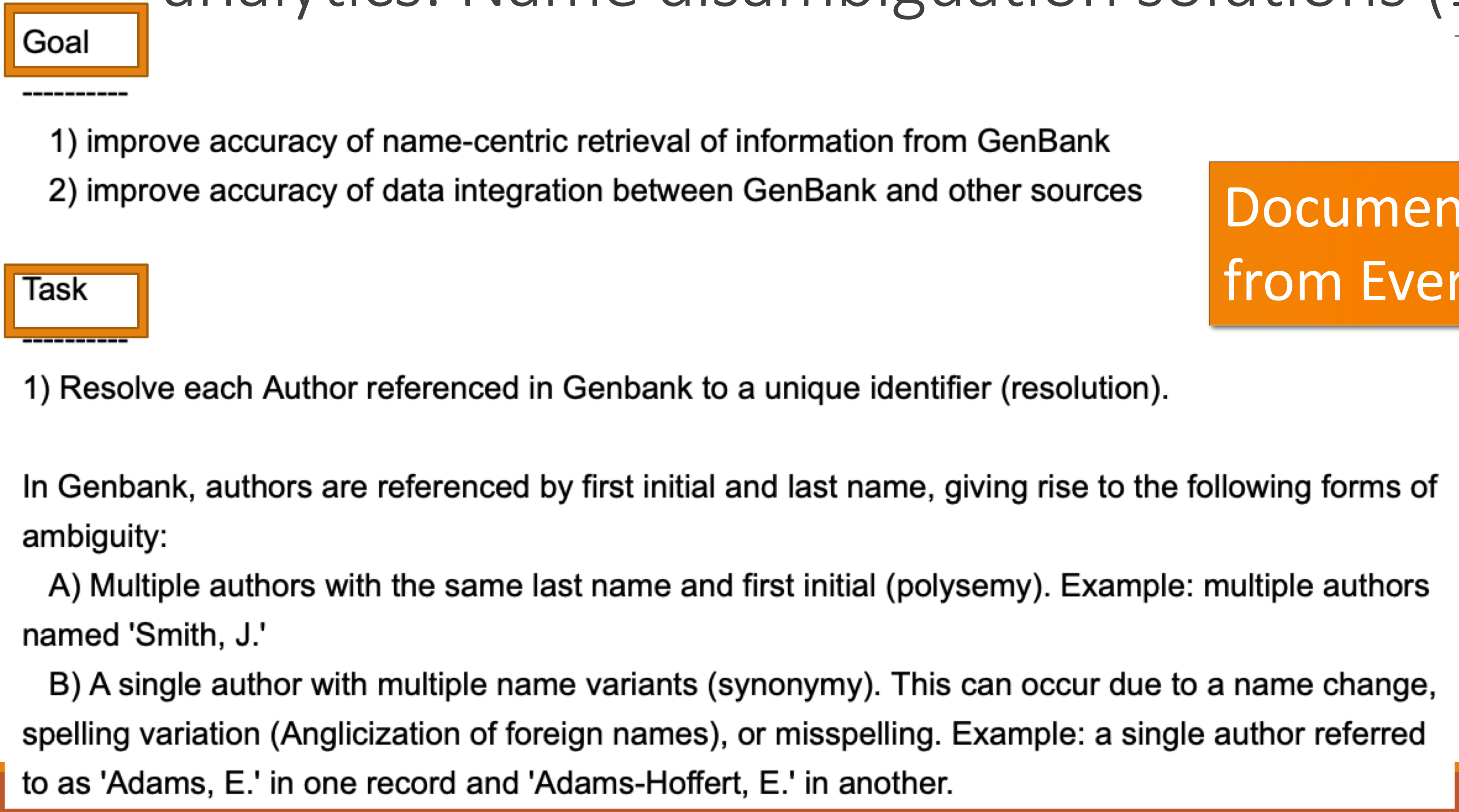
Very large volume of data and very complex structures require careful planning for metadata analytics to avoid reinventing the wheel and/or waste of time and efforts.

Workflows are a method for ensuring effectiveness and quality of metadata analytics.

What is a workflow?

- 💡 What is a workflow?
- 💡 "the activity of defining the sequence of tasks needed to manage a business or computational science or engineering process" with four broad aspects:
  - composition,
  - mapping,
  - execution, and
  - Provenance." (Deelman et al., 2009, p. 529).

An example of conceptual workflow in metadata analytics: Name disambiguation solutions (1)



Goal

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1) improve accuracy of name-centric retrieval of information from GenBank

2) improve accuracy of data integration between GenBank and other sources

Task

----

1) Resolve each Author referenced in Genbank to a unique identifier (resolution).

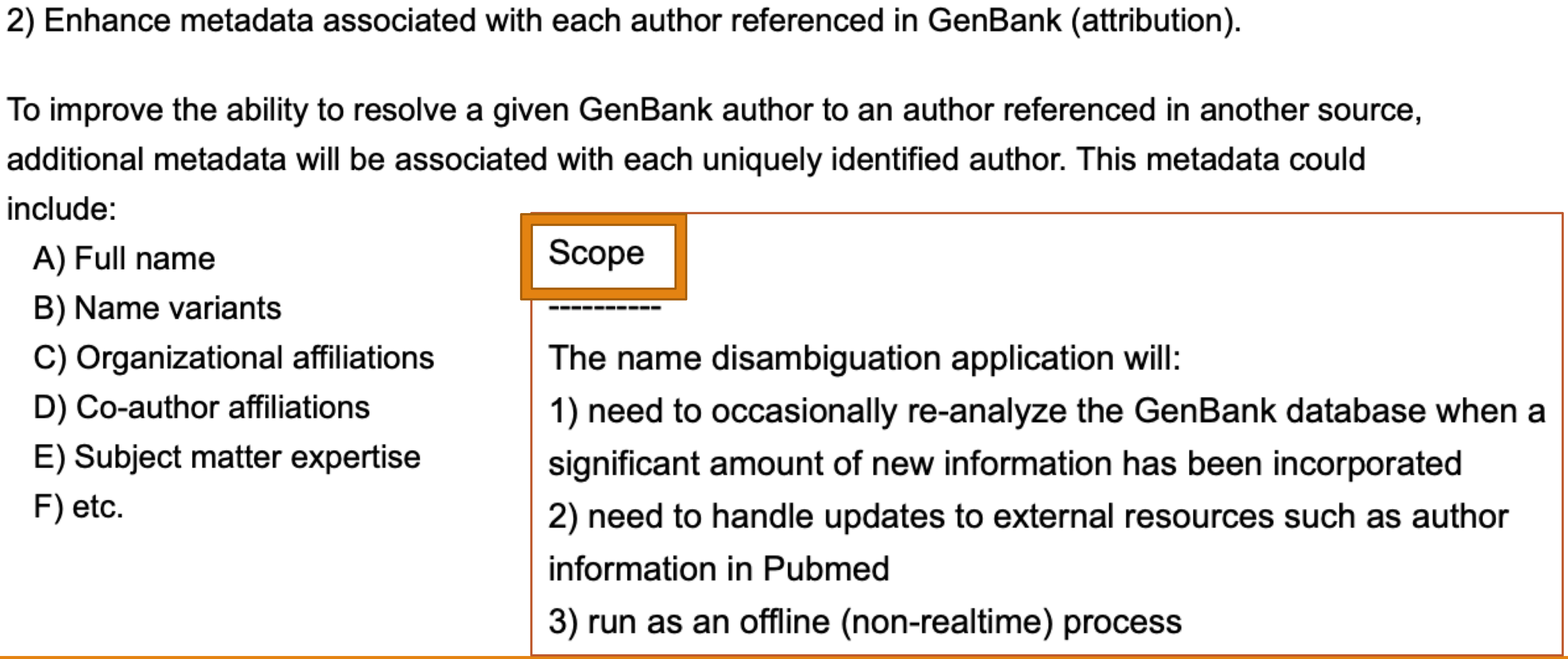
In Genbank, authors are referenced by first initial and last name, giving rise to the following forms of ambiguity:

A) Multiple authors with the same last name and first initial (polysemy). Example: multiple authors named 'Smith, J.'

B) A single author with multiple name variants (synonymy). This can occur due to a name change, spelling variation (Anglicization of foreign names), or misspelling. Example: a single author referred to as 'Adams, E.' in one record and 'Adams-Hoffert, E.' in another.

Documentation from Evernote

An example of conceptual workflow in metadata analytics: Name disambiguation solutions (2)



2) Enhance metadata associated with each author referenced in GenBank (attribution).

To improve the ability to resolve a given GenBank author to an author referenced in another source, additional metadata will be associated with each uniquely identified author. This metadata could include:

A) Full name
B) Name variants
C) Organizational affiliations
D) Co-author affiliations
E) Subject matter expertise
F) etc.

Scope

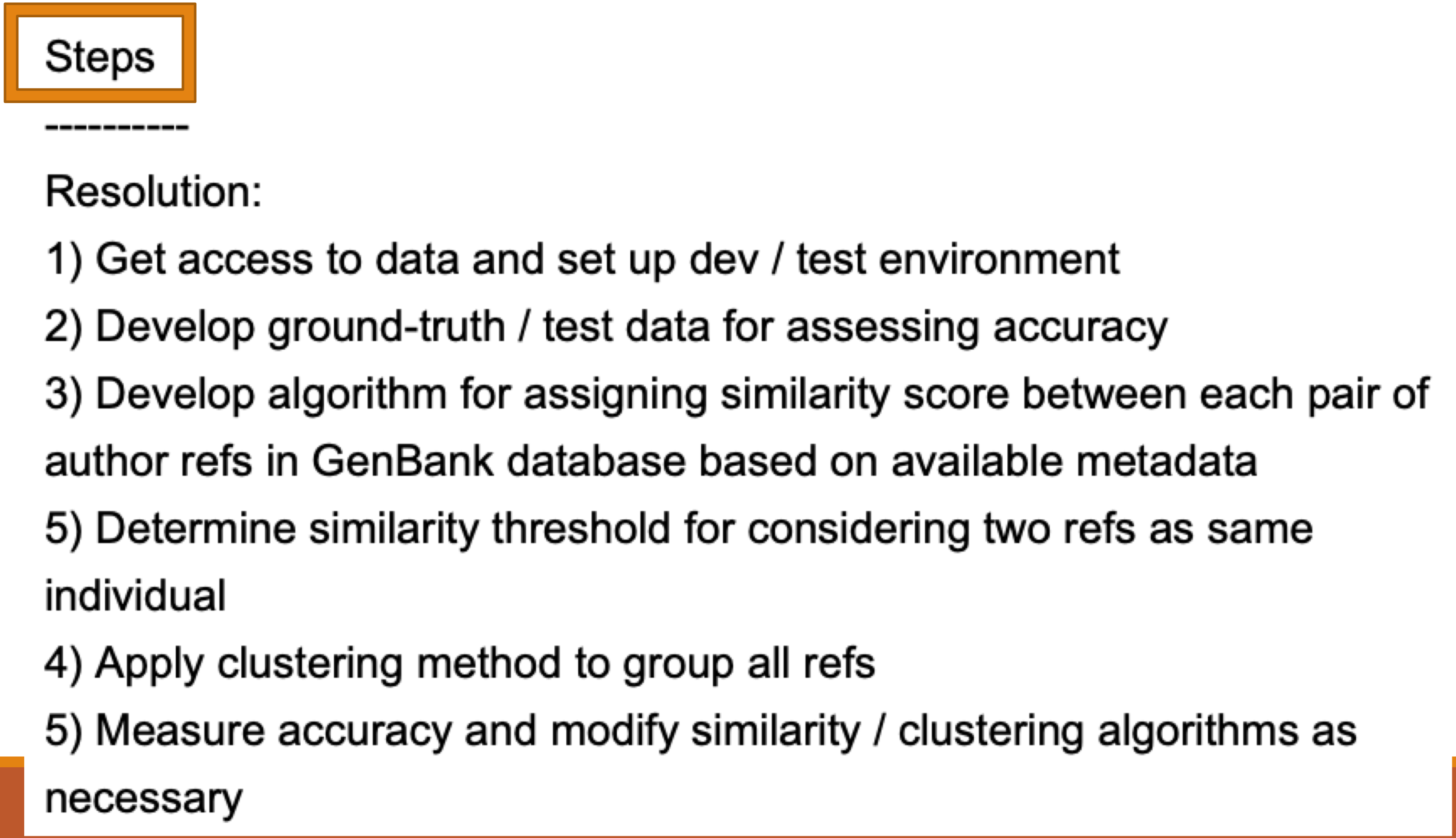
The name disambiguation application will:

1) need to occasionally re-analyze the GenBank database when a significant amount of new information has been incorporated

2) need to handle updates to external resources such as author information in Pubmed

3) run as an offline (non-realtime) process

An example of conceptual workflow in metadata analytics: Name disambiguation solutions (3)



Steps

Resolution:

1) Get access to data and set up dev / test environment

2) Develop ground-truth / test data for assessing accuracy

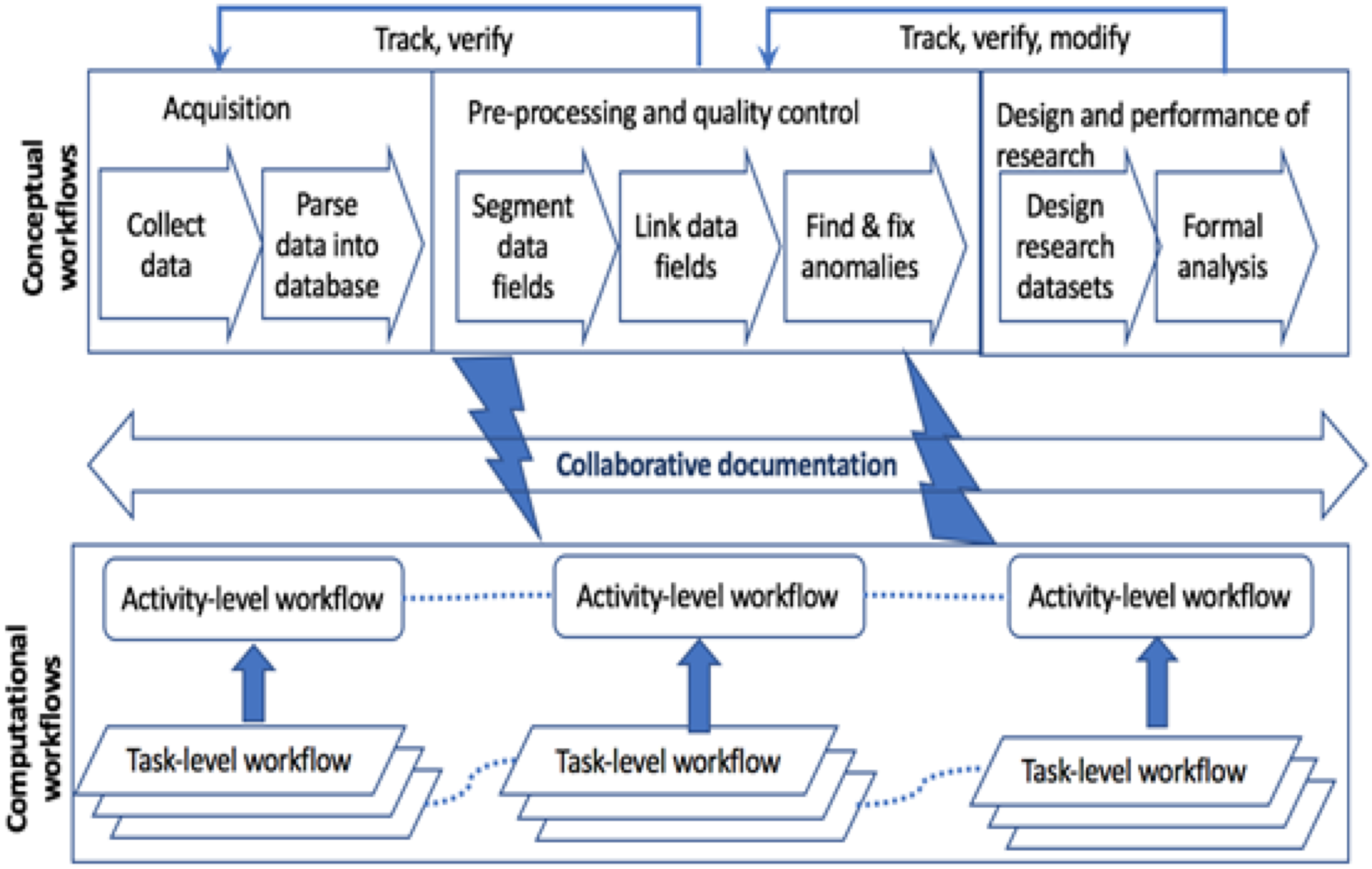
3) Develop algorithm for assigning similarity score between each pair of author refs in GenBank database based on available metadata

5) Determine similarity threshold for considering two refs as same individual

4) Apply clustering method to group all refs

5) Measure accuracy and modify similarity / clustering algorithms as necessary

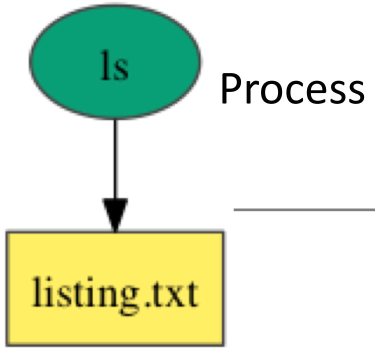
Workflows in (big) metadata analytics (Bratt, Hemsley, Qin, 2017)



Why do we need workflows in metadata analytics?

- Align your data collection, processing, and analysis with your research goals
  - make sure the data you collected are you needed for answering your research question
- Make a feasible plan step by step to keep your data and research stay on track
- Establish provenance for your research project to assure the reproducibility and replicability of your research

Tools for (computational) workflow management



https://pegasus.isi.edu/

Pegasus Workflow Management System

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<!--  generated by: gideon  -->
<!--  generator: python  -->
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http://pegasus.isi.edu/schema/dax-3.4.xsd" version="3.4"
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    transfer="true"/>
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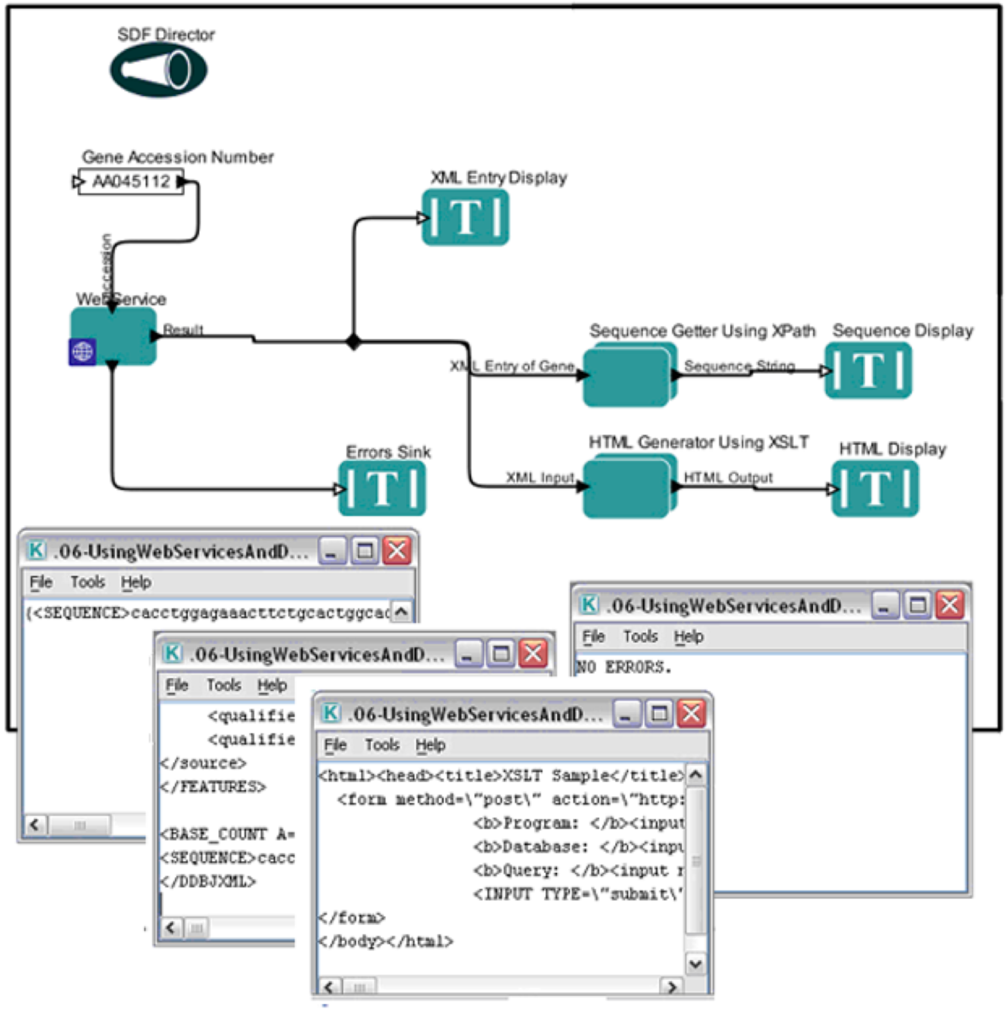

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Kepler Workflow Management System

https://kepler-project.org/

Now we have conceptual and computational workflows, what comes next?

Linked data

- Available on the web
- Available as structured data readable by machine
- Available in a non-proprietary format
- Expressed using open World Wide Web Consortium (W3C) standards
- Linked to other data on the web

What implications are there to the fields of bibliometrics and scientometrics?

Name disambiguation solutions

- Traditional solution: use algorithms to automatically disambiguating author names
  - However, if database producers keep current practice in abbreviating names, the problem will remain unresolved.
- New solution: creating globally unique ID for researchers and authors

ORCID

ResearcherID

VIAF
Virtual International Authority File

LC Linked Data Service
Authorities and Vocabularies

Union List of Artist Names®
Getty Research Institute

Identifying things with globally unique identifiers

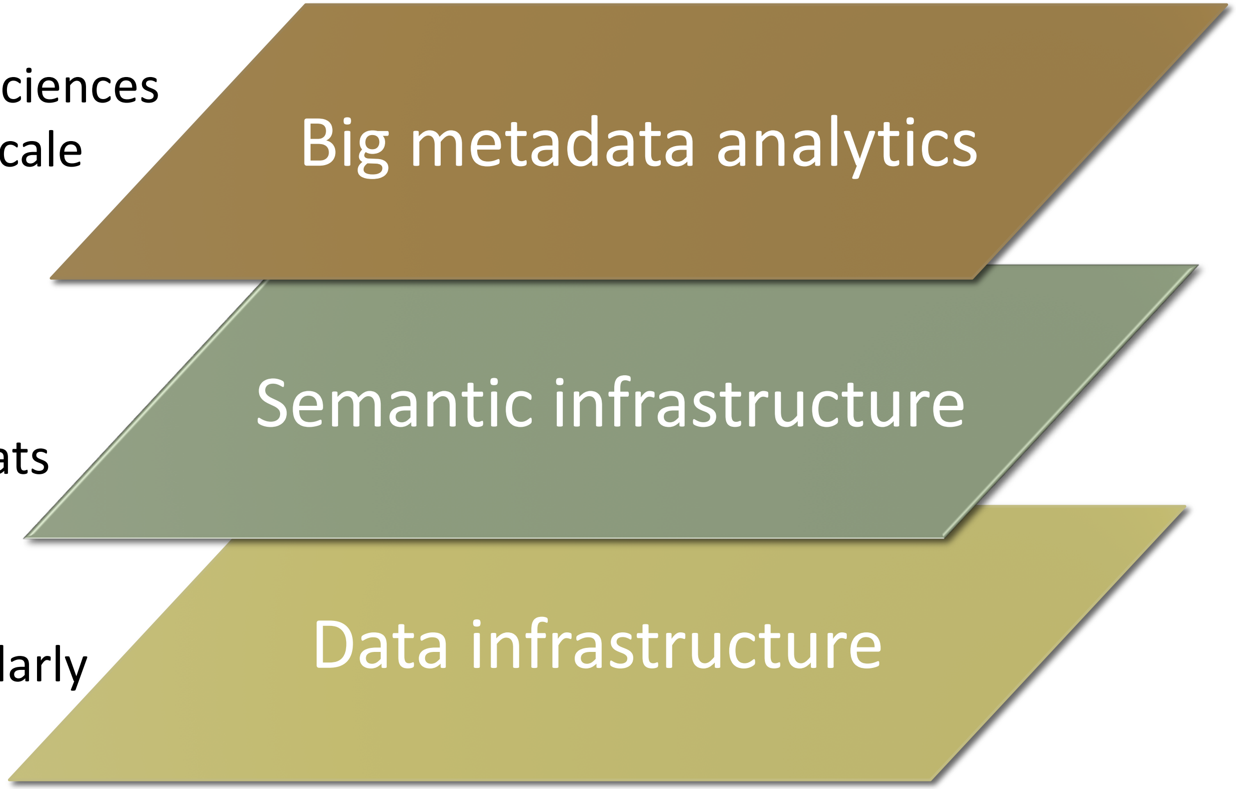
- **Subject terms** in controlled vocabularies
- **Events** (political, cultural, public health, social, …)
- **Publications** (papers, versions of a paper, journals, …)
- **Datasets** (research data, census data, observation data, sensor data…)
- **Cultural objects** (archives, museum objects, digital surrogates of physical objects…)

Metadata is changing to broaden the research horizon

Bibliometrics and scientometrics
Knowledge discovery for humanities and social sciences
Data services to support interdisciplinary large-scale research

Uniquely identified authors, organizations, taxonomic classes, subject terms, datasets, publications, etc. in structured, linkable formats

Index databases; library catalogs; metadata repositories for datasets; digital libraries for scholarly pubs, special collections, and cultural objects

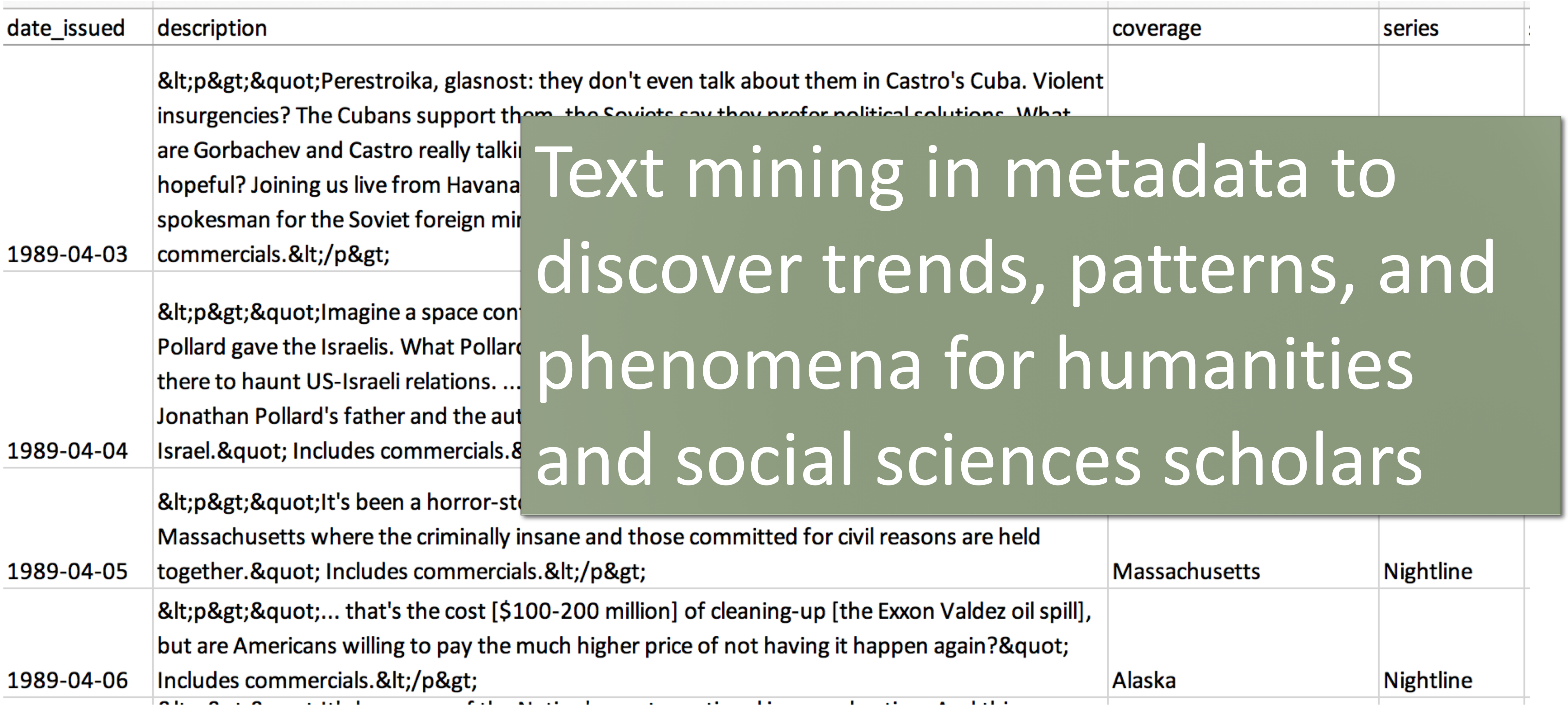


Big metadata analytics

Semantic infrastructure

Data infrastructure

Case: Mining large (meta)datasets for the humanities (1)



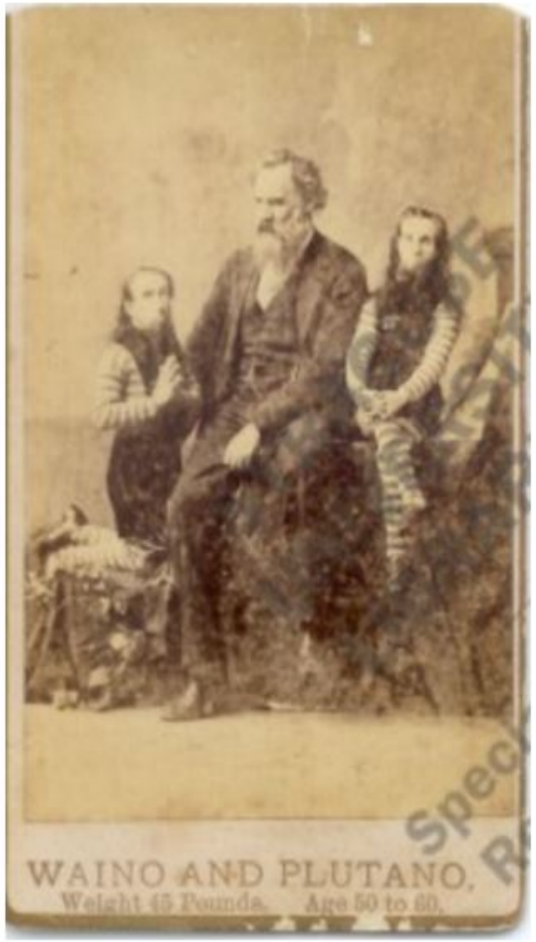
date_issued	description	coverage	series
1989-04-03	&lt;p&gt;&quot;Perestroika, glasnost: they don't even talk about them in Castro's Cuba. Violent insurgencies? The Cubans support them, the Soviets say they prefer political solutions. What are Gorbachev and Castro really talki hopeful? Joining us live from Havana spokesman for the Soviet foreign mi commercials.&lt;/p&gt;		
1989-04-04	&lt;p&gt;&quot;Imagine a space con Pollard gave the Israelis. What Pollar there to haunt US-Israeli relations. ... Jonathan Pollard's father and the aut Israel.&quot; Includes commercials.&		
1989-04-05	&lt;p&gt;&quot;It's been a horror-st Massachusetts where the criminally insane and those committed for civil reasons are held together.&quot; Includes commercials.&lt;/p&gt;	Massachusetts	Nightline
1989-04-06	&lt;p&gt;&quot;... that's the cost [$100-200 million] of cleaning-up [the Exxon Valdez oil spill], but are Americans willing to pay the much higher price of not having it happen again?&quot; Includes commercials.&lt;/p&gt;	Alaska	Nightline

Text mining in metadata to discover trends, patterns, and phenomena for humanities and social sciences scholars

Leonard, Peter. (2014). Mining large datasets for the humanities. IFLA WLIC . http://library.ifla.org/930/1/119-leonard-en.pdf

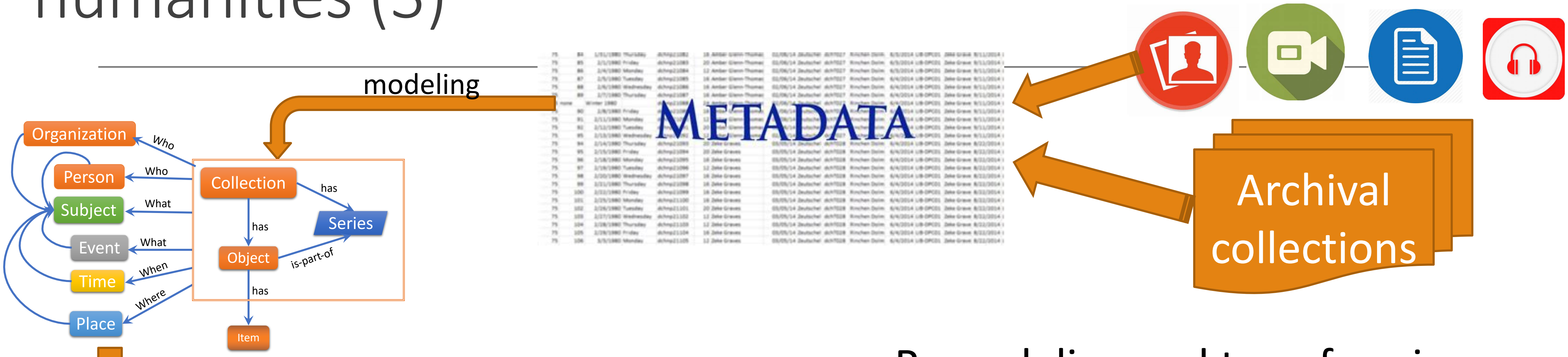
Case: Mining large (meta)datasets for the humanities (2)

- Text analysis for metadata description led to new faceted approach in representing historical visual materials

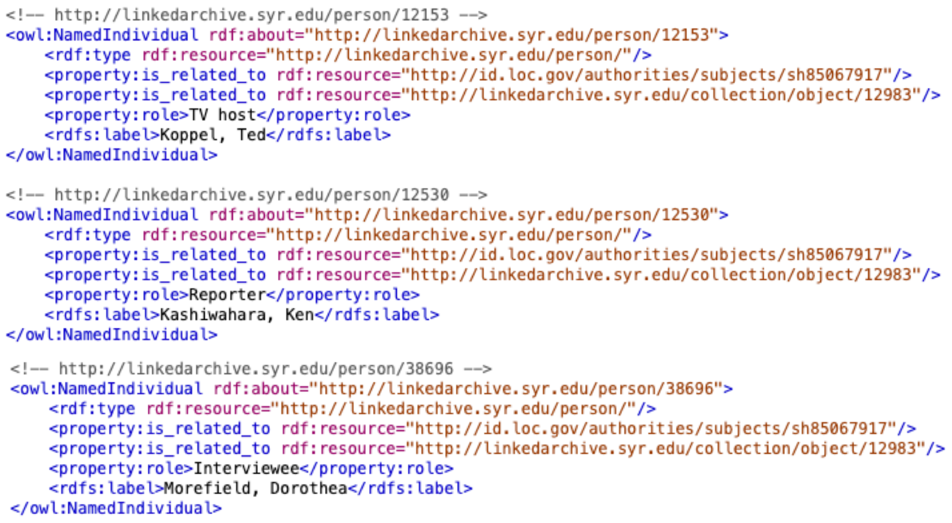


Individual depicted (LCNAF)	Wano, 1825-1905
Individual depicted (LCNAF)	Plutano, 1827-1912
Groups depicted (LCSH)	Circus performers
Groups depicted (LCSH)	Men
Groups depicted (21st century terminology)	Little people
Groups depicted (21st century terminology)	Dwarfs
Groups depicted (19th century terminology)	Midgets
Conditions depicted (MeSH)	Dwarfism
Conditions depicted (SNOMED CT)	Short stature disorder
Relations depicted (LCSH)	Brothers
Nationalities depicted (LCSH)	Americans
Places referenced (19th century terminology)	Borneo
Time period depicted (LCSH)	Nineteenth century

Case: Mining large (meta)datasets for the humanities (3)



Transforming



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Remodeling and transforming special collection metadata to linked archives

Ready for publishing and sharing as well as consuming by machines

Case: GenBank Metadata mining (1)

"From 1982 to the present, the number of bases in GenBank has doubled approximately every 18 months."

-- NCBI. (2017). Growth of GenBank and WGS, http://www.ncbi.nlm.nih.gov/genbank/statistics.

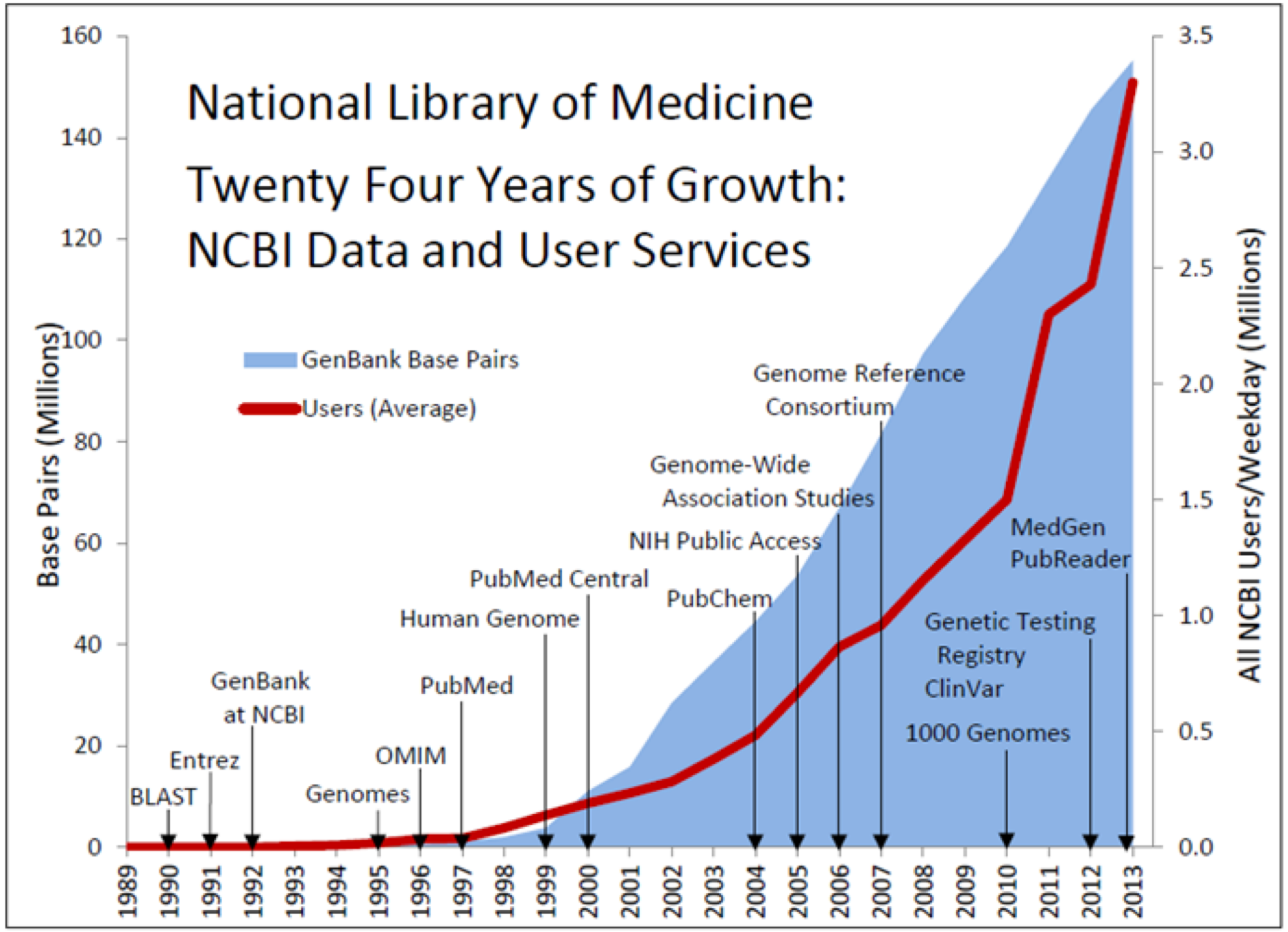
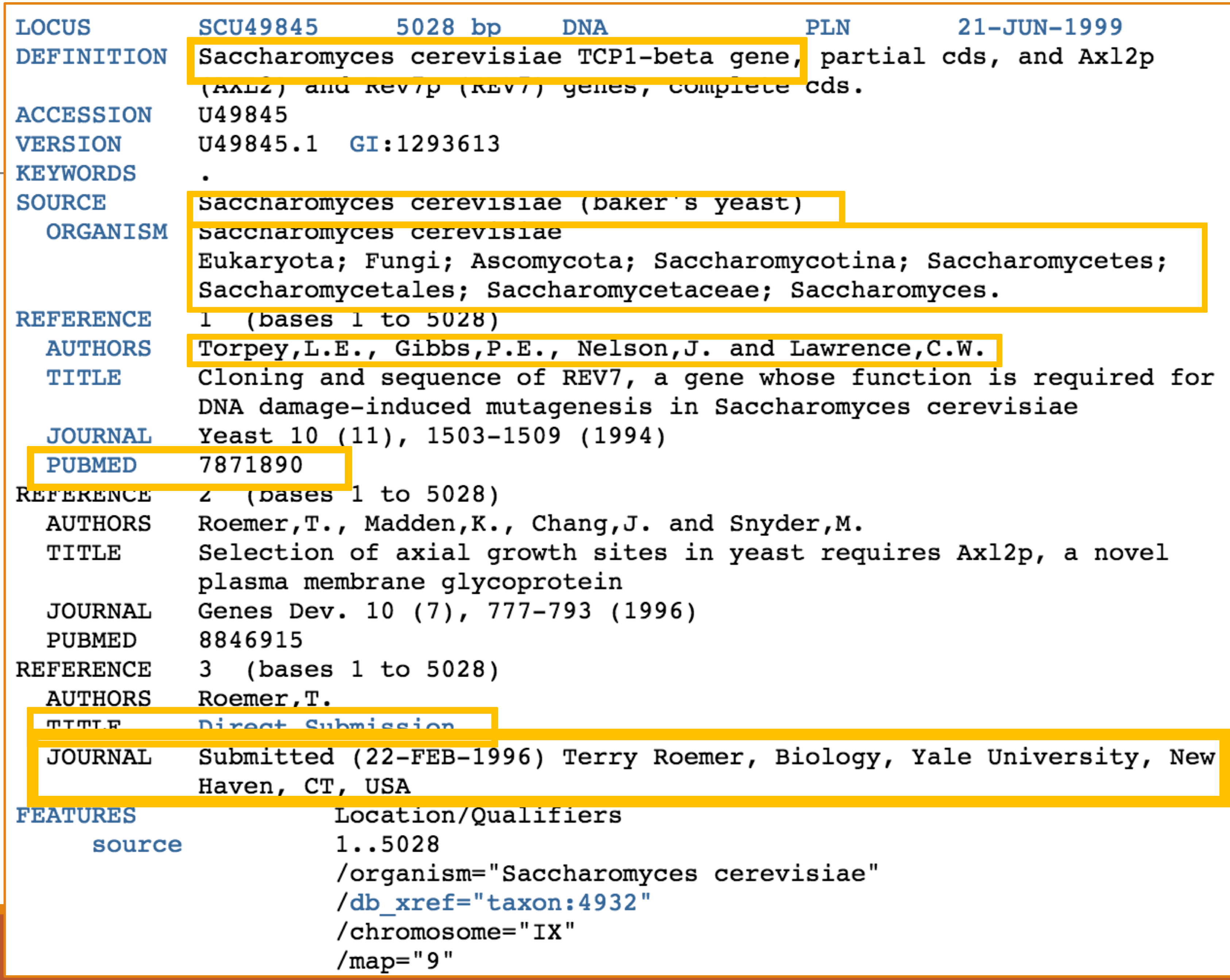


Image credit: https://www.nlm.nih.gov/about/2015CJ.html

Case: GenBank Metadata mining (2)

GenBank's big metadata as a source for quantitative studies of team science



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ACCESSION   U49845
VERSION     U49845.1  GI:1293613
KEYWORDS    .
SOURCE      Saccharomyces cerevisiae (baker's yeast)
  ORGANISM  Saccharomyces cerevisiae
            Eukaryota; Fungi; Ascomycota; Saccharomycotina; Saccharomycetes;
            Saccharomycetales; Saccharomycetaceae; Saccharomyces.
REFERENCE   1  (bases 1 to 5028)
  AUTHORS   Torpey,L.E., Gibbs,P.E., Nelson,J. and Lawrence,C.W.
  TITLE     Cloning and sequence of REV7, a gene whose function is required for
            DNA damage-induced mutagenesis in Saccharomyces cerevisiae
  JOURNAL   Yeast 10 (11), 1503-1509 (1994)
  PUBMED    7871890
REFERENCE   2  (bases 1 to 5028)
  AUTHORS   Roemer,T., Madden,K., Chang,J. and Snyder,M.
  TITLE     Selection of axial growth sites in yeast requires Axl2p, a novel
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  JOURNAL   Genes Dev. 10 (7), 777-793 (1996)
  PUBMED    8846915
REFERENCE   3  (bases 1 to 5028)
  AUTHORS   Roemer,T.
  TITLE     Direct Submission
  JOURNAL   Submitted (22-FEB-1996) Terry Roemer, Biology, Yale University, New
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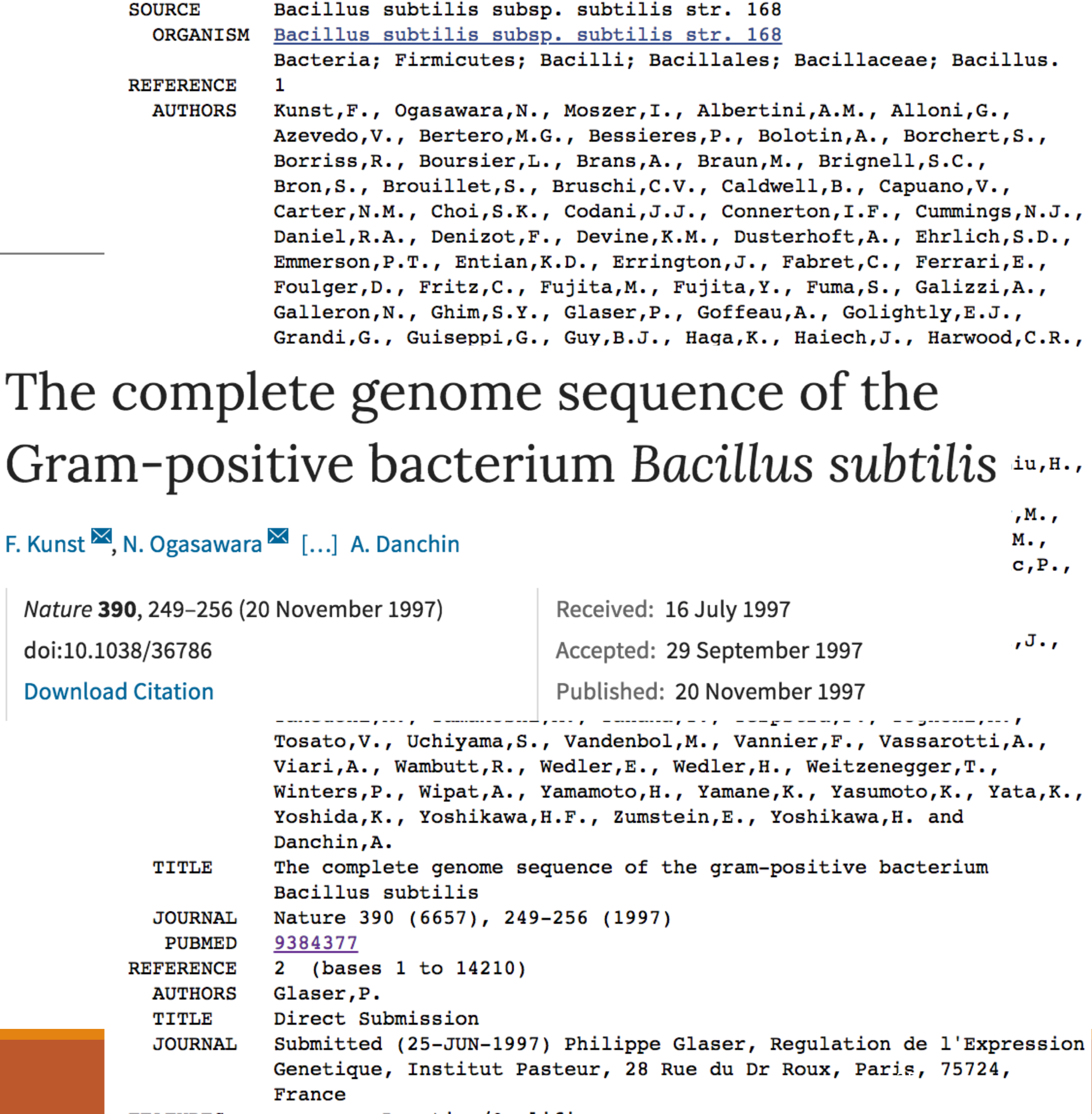
Case: GenBank Metadata mining (3)

Collaboration across countries, labs, and fields

- 💡Big problems, big data (and big metadata), and big teams
- 💡Relations between data production and paper publication
- 💡Large scale studies of collaboration networks to find patterns, structures, and empirical evidence for in-depth exploration



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SOURCE      Bacillus subtilis subsp. subtilis str. 168
  ORGANISM  Bacillus subtilis subsp. subtilis str. 168
            Bacteria; Firmicutes; Bacilli; Bacillales; Bacillaceae; Bacillus.
REFERENCE   1
  AUTHORS   Kunst,F., Ogasawara,N., Moszer,I., Albertini,A.M., Alloni,G.,
            Azevedo,V., Bertero,M.G., Bessieres,P., Bolotin,A., Borchert,S.,
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            Carter,N.M., Choi,S.K., Codani,J.J., Connerton,I.F., Cummings,N.J.,
            Daniel,R.A., Denizot,F., Devine,K.M., Dusterhoft,A., Ehrlich,S.D.,
            Emmerson,P.T., Entian,K.D., Errington,J., Fabret,C., Ferrari,E.,
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            Grandi,G., Guiseppi,G., Guy,B.J., Haga,K., Haiech,J., Harwood,C.R.,
```

The complete genome sequence of the Gram-positive bacterium *Bacillus subtilis*

F. Kunst ✉, N. Ogasawara ✉ […] A. Danchin

Nature **390**, 249–256 (20 November 1997)

doi:10.1038/36786

Download Citation

Received: 16 July 1997

Accepted: 29 September 1997

Published: 20 November 1997

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                                                                   iu,H.,
                                                                   ,M.,
                                                                   M.,
                                                                   c,P.,
                                                                   ,J.,
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  AUTHORS   Glaser,P.
  TITLE     Direct Submission
  JOURNAL   Submitted (25-JUN-1997) Philippe Glaser, Regulation de l'Expression
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            France
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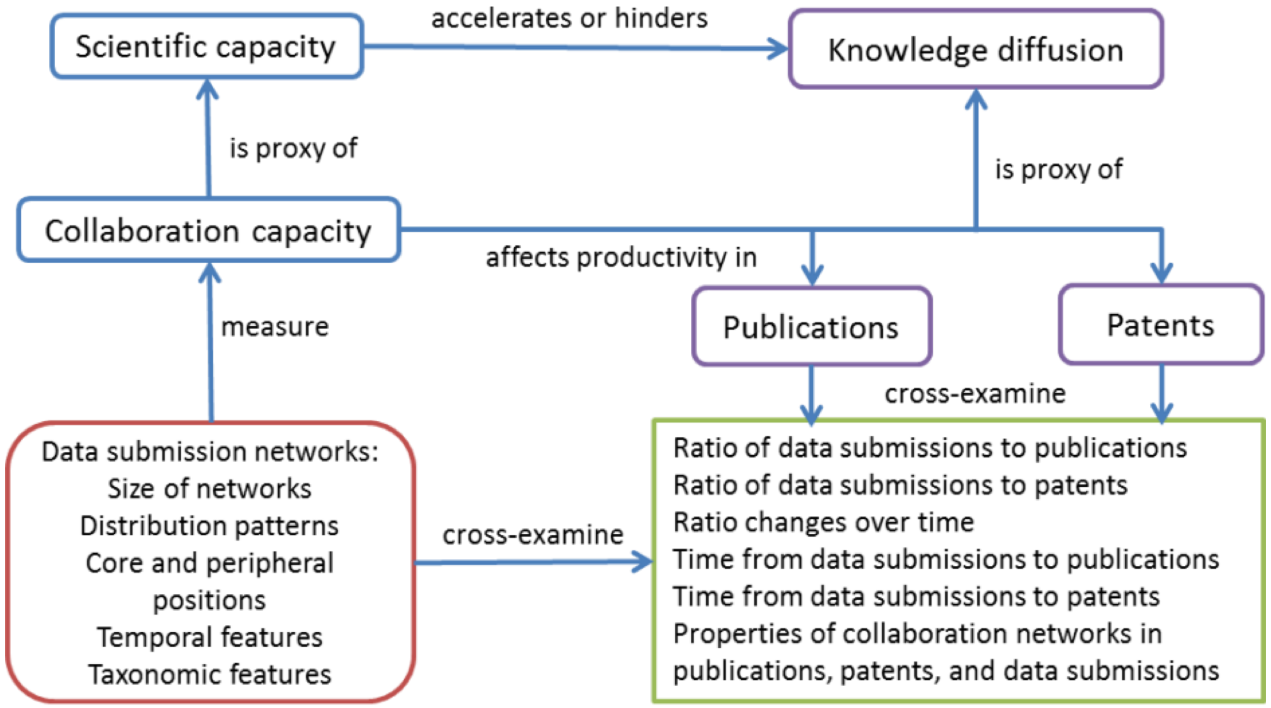
Case: GenBank Metadata mining (4)

The collaboration capacity framework



Scientific capacity

accelerates or hinders

Knowledge diffusion

is proxy of

is proxy of

Collaboration capacity

affects productivity in

Publications

Patents

measure

cross-examine

Data submission networks:
Size of networks
Distribution patterns
Core and peripheral positions
Temporal features
Taxonomic features

cross-examine

Ratio of data submissions to publications
Ratio of data submissions to patents
Ratio changes over time
Time from data submissions to publications
Time from data submissions to patents
Properties of collaboration networks in publications, patents, and data submissions

(Qin et al., 2018)

Collaboration capacity: the ability of an individual researcher or a team of researchers to collaborate throughout the data production and publication lifecycle and sustain a network of collaborators over time.

Assumptions:

- Collaboration capacity is a proxy for studying scientific capacity
- Data, publication, and patent together can be used as a proxy for studying knowledge diffusion
- Collaboration capacity significantly affects the level of research productivity and extent of knowledge diffusion

Case: GenBank Metadata mining (5): Methods

- Source: metadata describing molecular sequences in GenBank

- Exploratory data analysis (EDA)
- Social Network Analysis (SNA)

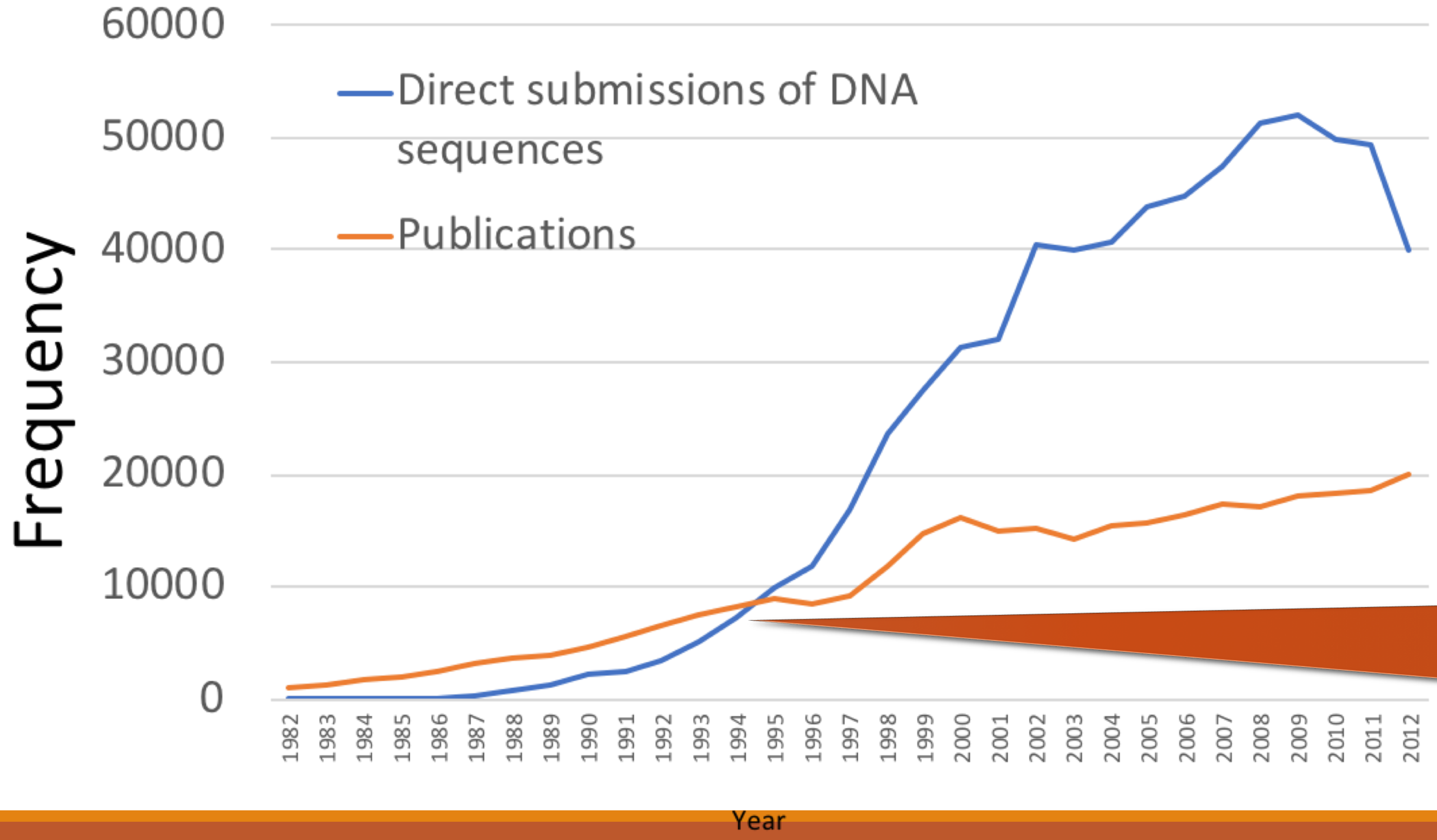
Purpose: using descriptive stats and visualization techniques to look for patterns, structures, and problems

- Based on our framework, datasets generated include:
  - Size of collaboration networks for data submission
  - Extent of knowledge diffusion
  - Rate of knowledge diffusion

Case: GenBank Metadata mining (6): Findings

- Connectedness of collaboration networks
- Ratio of data submissions to publications

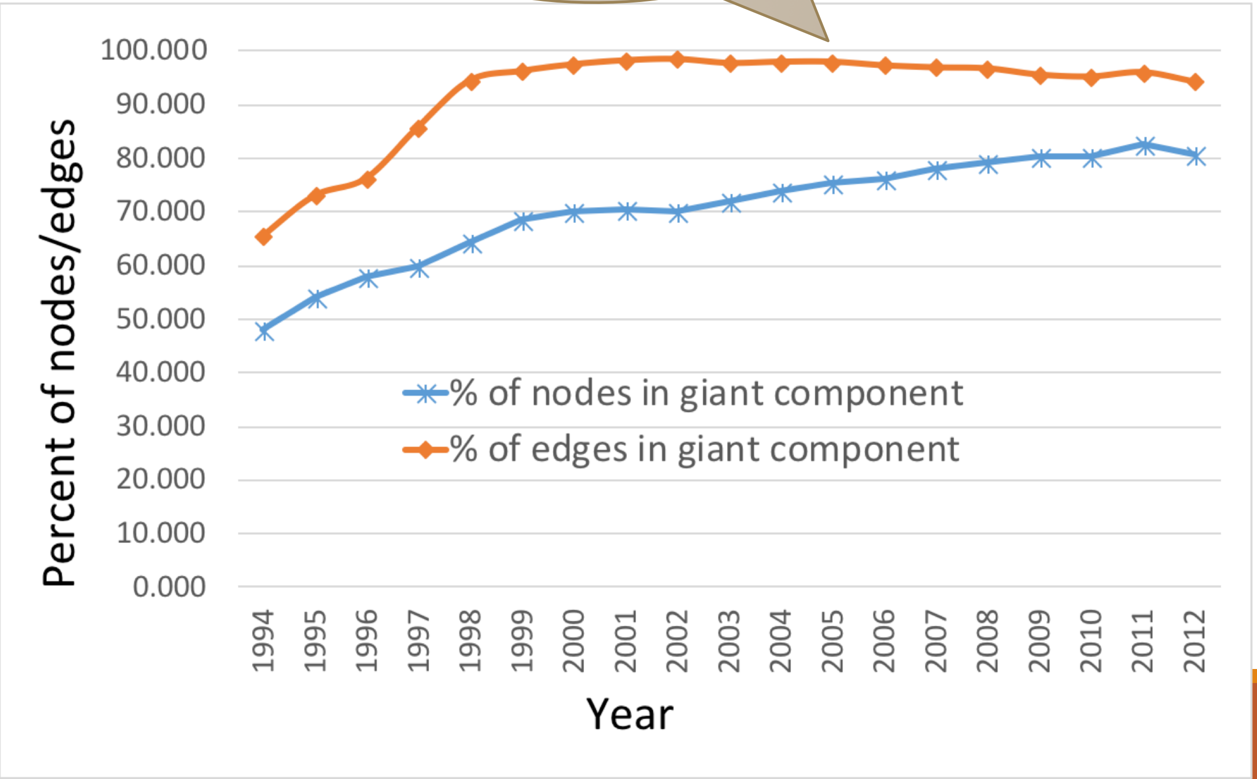
Case: GenBank Metadata mining (7): Data submissions vs. publications



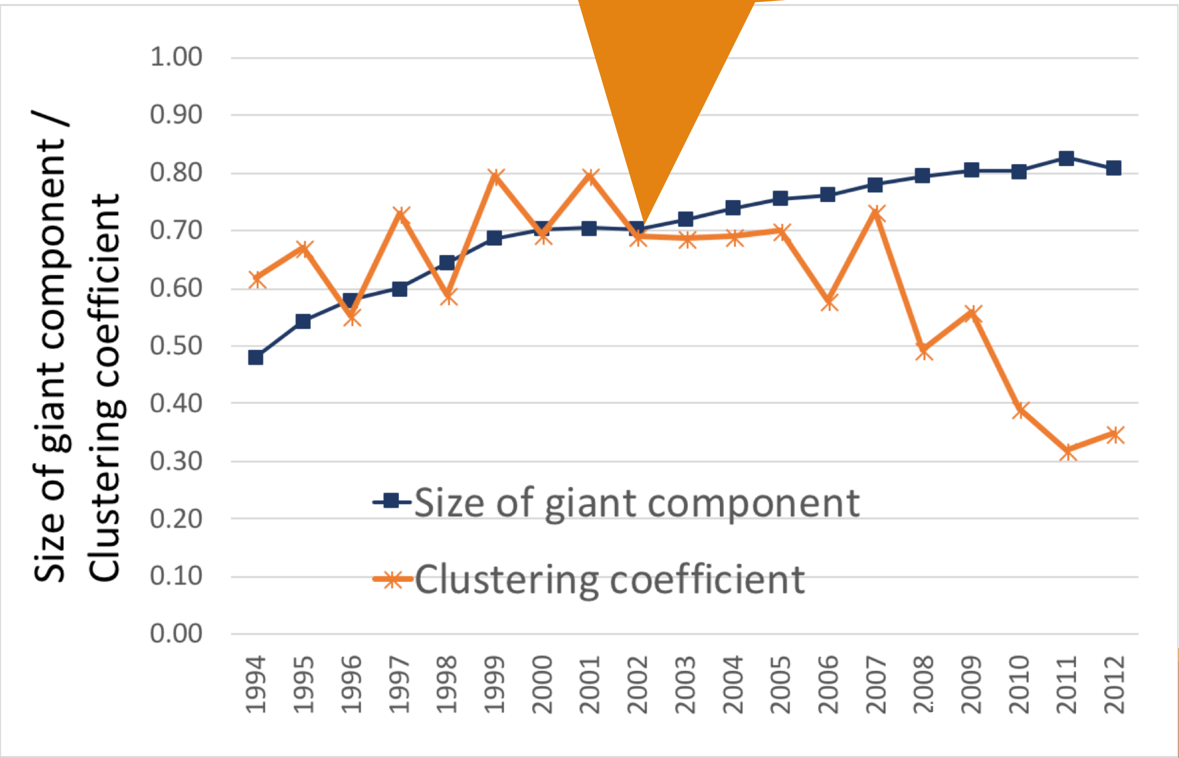
As early as 1994, the number of data submissions surpassed that of publications

Case: GenBank Metadata mining (8): Connectedness vs. distributedness

Authors remain well connected over time



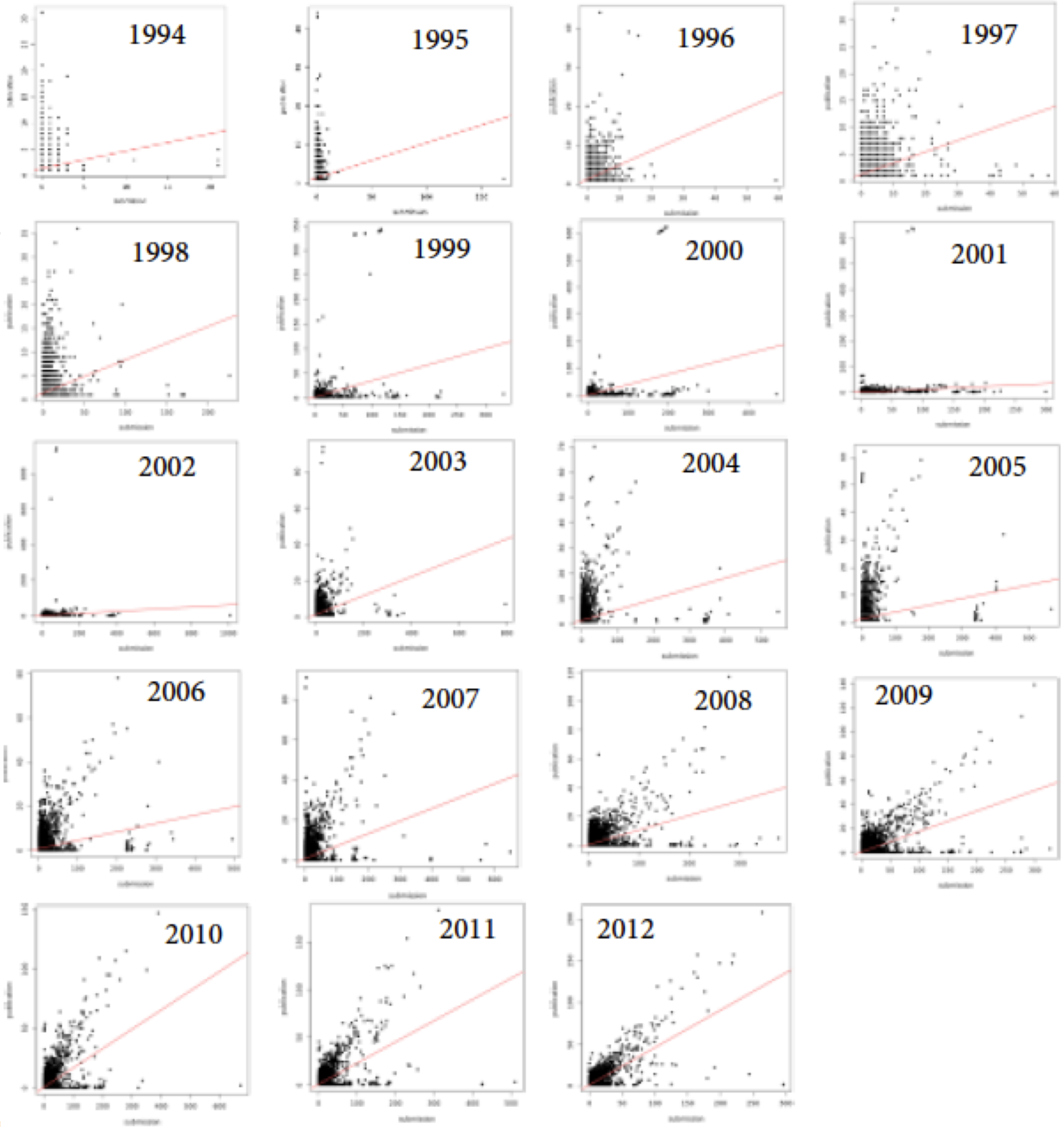
While more clusters of smaller communities emerged



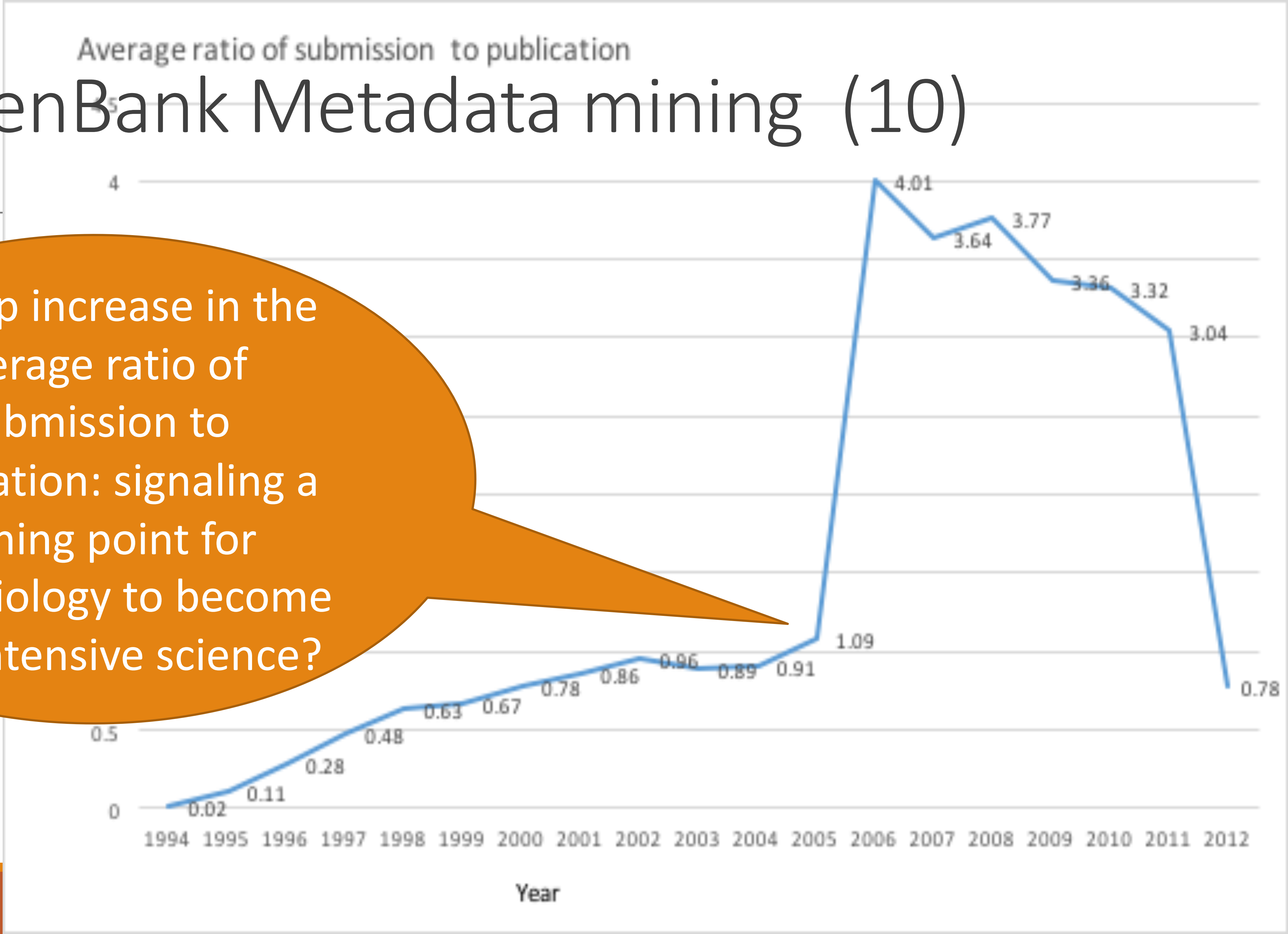
Case: GenBank Metadata mining (9)

Ratio of submissions to publications

- x axis: # of authors who submitted sequence data
- y axis: # of authors who published a paper associated with the data submissions
- After 1998, more authors were involved in data production than those in paper publications
- Significant increment in productivity:
  - Before 1998, majority had a range between 20 publications and 50 data submissions
  - Since 2008, a sizable # of authors had a high productivity in the range of 50~100 publications and 100~300 data submissions



Case: GenBank Metadata mining (10)



A sharp increase in the average ratio of submission to publication: signaling a turning point for microbiology to become data-intensive science?

Conclusion

- (Big) metadata analytics uses metadata as the data source to:
  - Study phenomena, trends, behaviors, and relations
  - Produce semantically precise, linked data for better discovery, access, and management of information resources and datasets
- As an emerging research field, it faces great challenges in
  - Methodologies: workflows, tools, and practices that reduce reinventing the wheel and enhance research reproducibility
  - Data: scattered, in different formats, messy, and over 80% of time spent in getting data ready for analysis

Thank you!

Questions?

References

- Bratt, S., Hemsley, J., Qin, J. & Costa, M. (2017), Big data, big metadata and quantitative study of science: A workflow model for big scientometrics. *Proc. Assoc. Info. Sci. Tech.,* 54: 36–45. doi:10.1002/pra2.2017.14505401005
- Qin, J., J. Hemsley, & S. Bratt. (2018). Collaboration capacity: Measuring the impact of cyberinfrastructure-enabled collaboration networks. Science of Team Science (SCITS) 2018 Conference, Galveston, Texas, May 21-24, 2018.