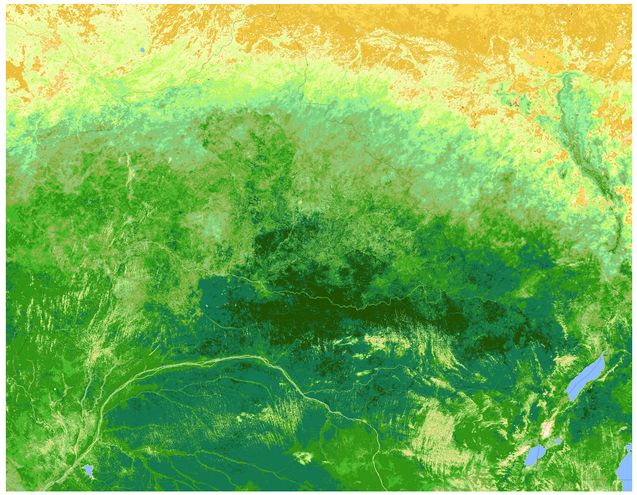
Advanced Data Management (CSCI 640/490)

Data Curation

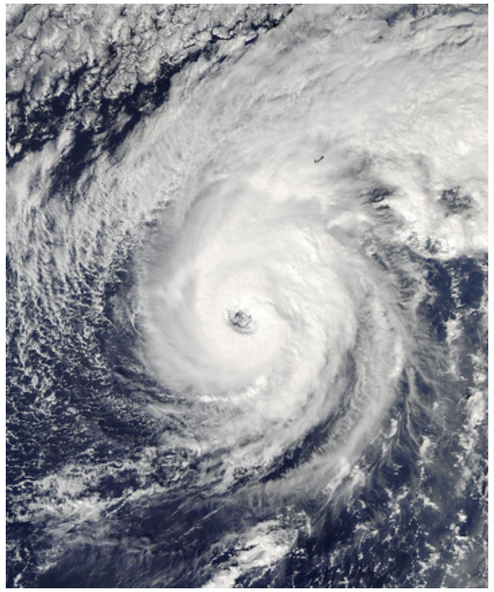
Dr. David Koop

Spatial Data

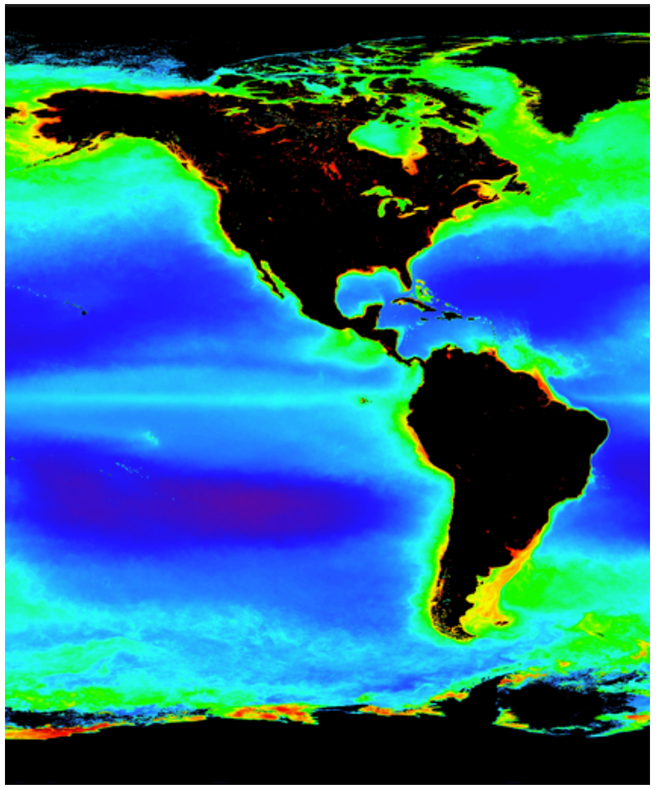
Measure vegetation density



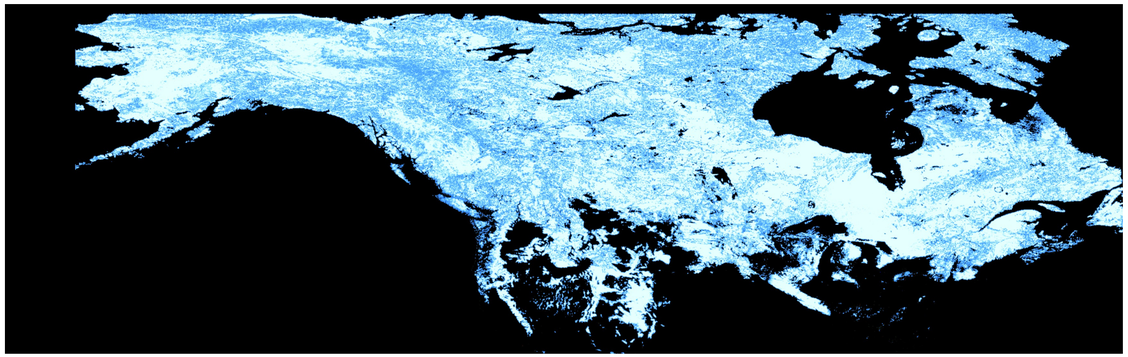
Track hurricanes



Track phytoplankton populations



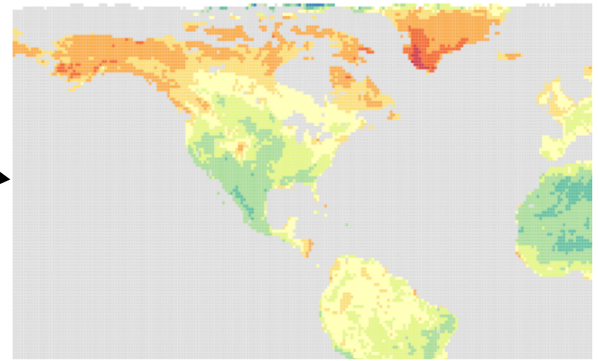
Measure snow melt



[L. Battle, 2017]

Interactive Exploration of Spatial Data

```
SELECT lat, lng, (b4-b6)/(b4+b6) as ndsi
FROM modis_data
WHERE ndsi >0.7
```



query

Client

Server

result

DBMS

PostgreSQL MySQL VERTICA An HP Company SciDB

[L. Battle, 2017]

Interactive Exploration of Spatial Data

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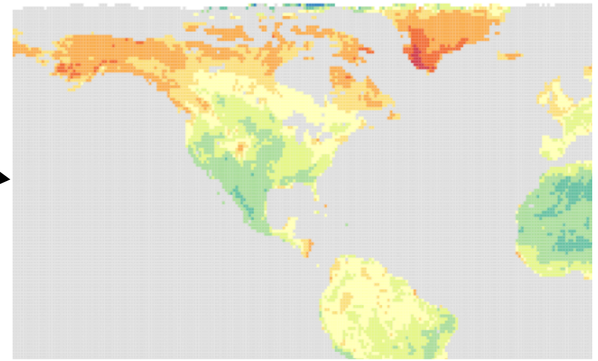


query

Client

Server

result

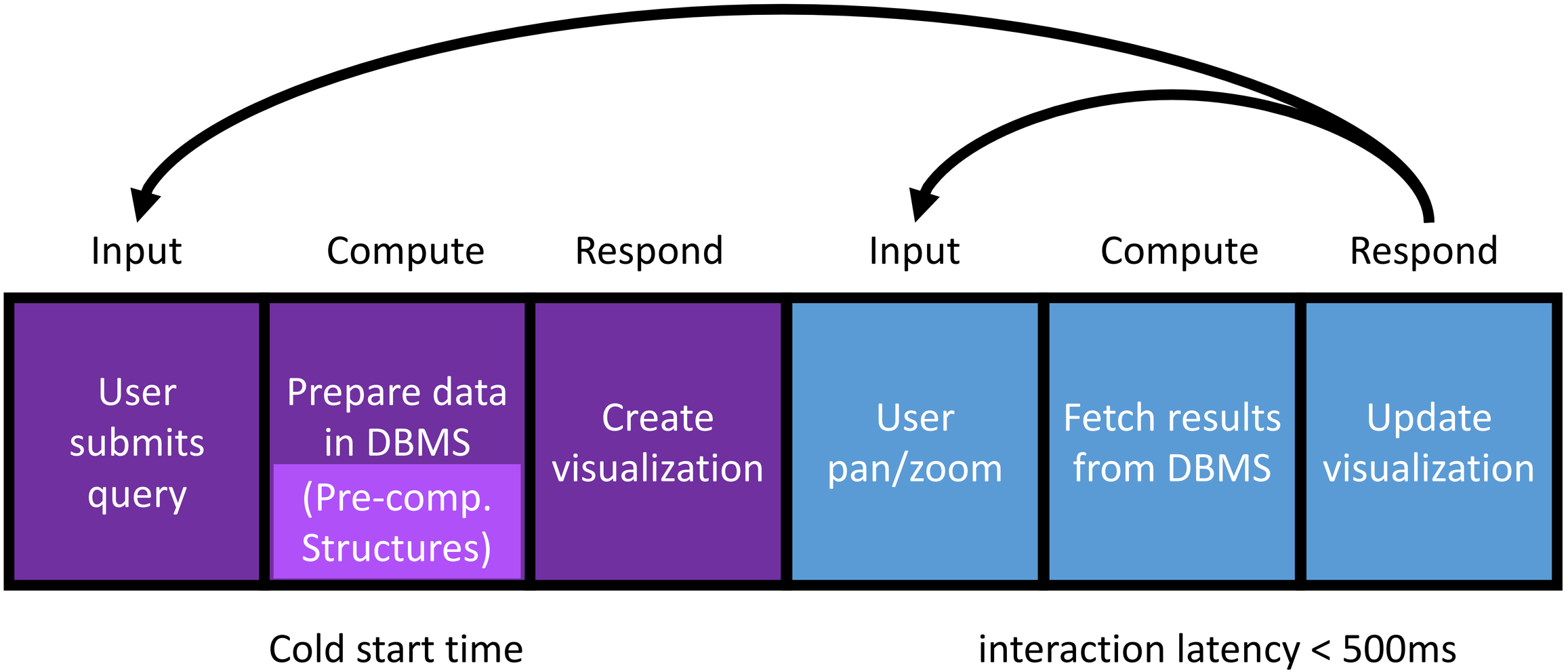
SLOW →

DBMS

PostgreSQL MySQL VERTICA An HP Company SciDB

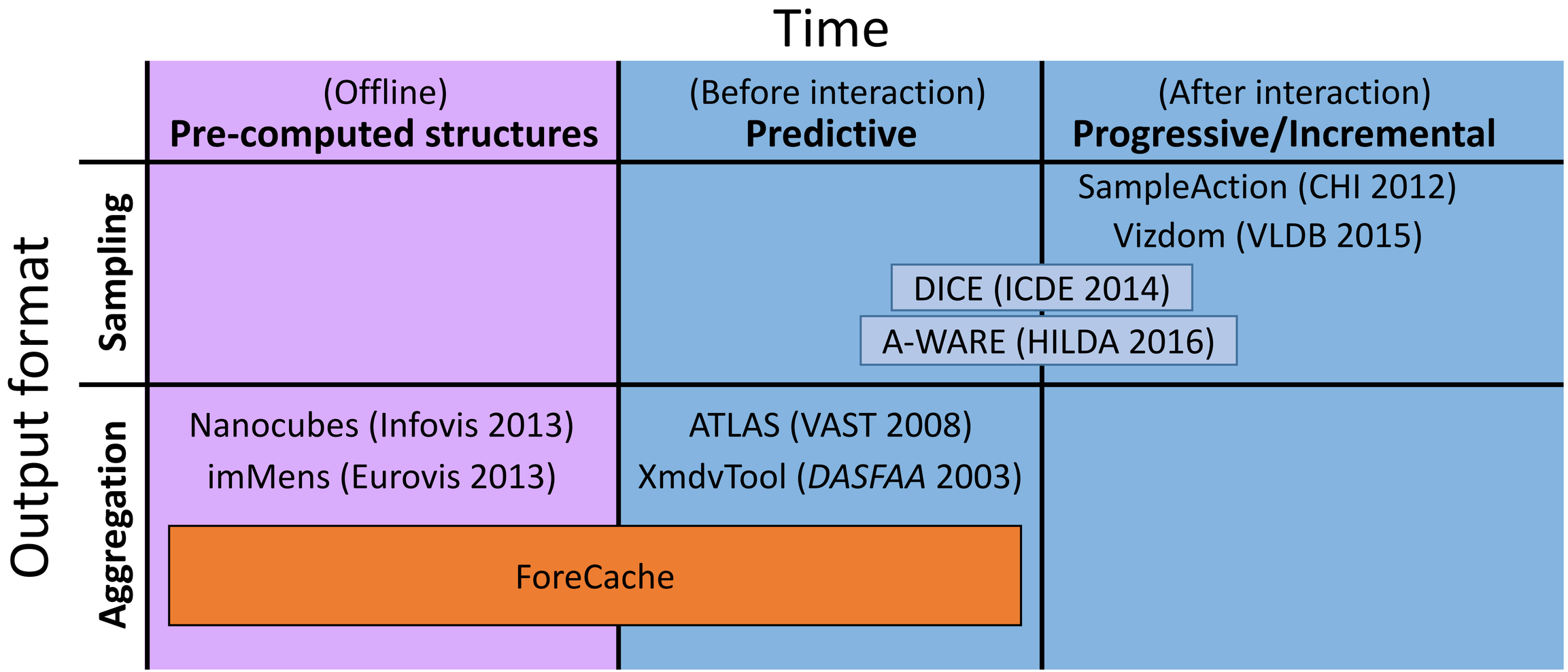
[L. Battle, 2017]

Two Inputs to Exploratory Browsing



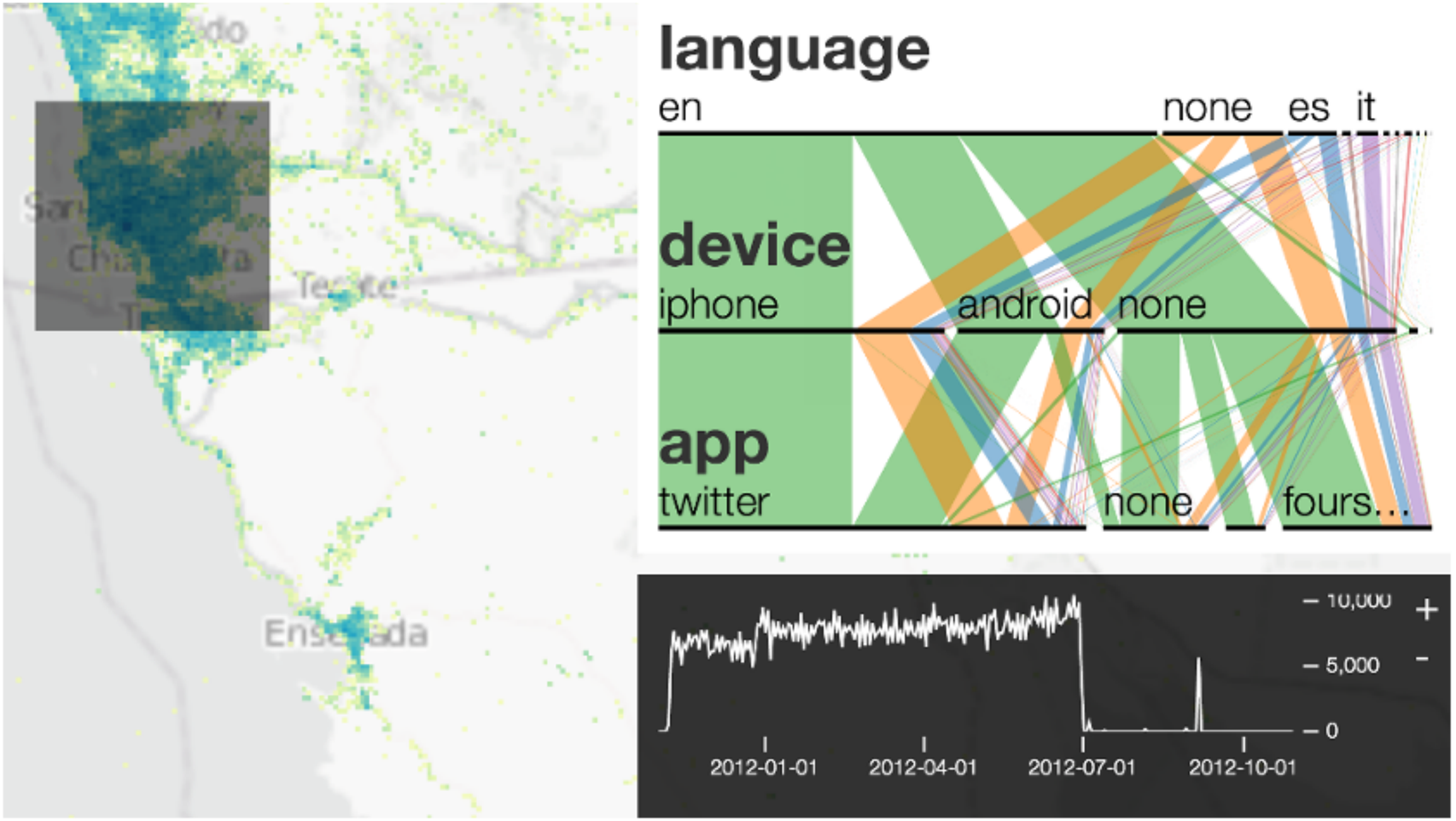
[L. Battle, 2017]

Systems for Interactive Exploration



[L. Battle, 2017]

Nanocubes



Linked view of tweets in San Diego, US

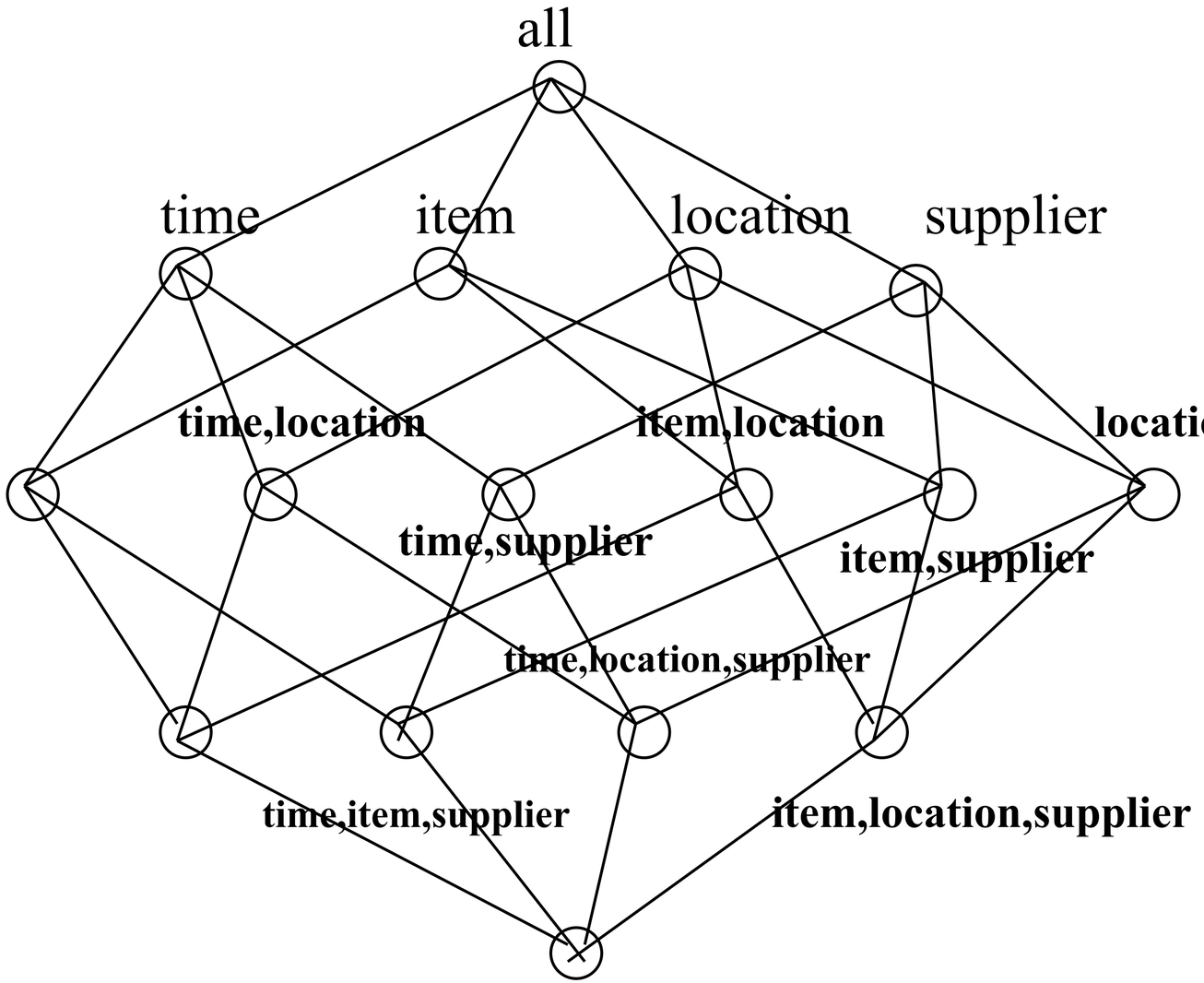
[Lins et. al, 2013]

From Tables and Spreadsheets to Data Cubes

- A **data warehouse** is based on a multidimensional data model which views data in the form of a data cube
- A **data cube**, such as sales, allows data to be modeled and viewed in multiple dimensions
  - **Dimension tables**, such as item (item_name, brand, type), or time(day, week, month, quarter, year)
  - **Fact table** contains **measures** (such as dollars_sold) and keys to each of the related dimension tables
- In data warehousing literature, an n-D base cube is called a **base cuboid**. The top most 0-D cuboid, which holds the highest-level of summarization, is called the **apex cuboid**. The lattice of cuboids forms a **data cube**.

[Han et al., 2011]

Data Cube: A Lattice of Cuboids



0−D (*apex*) cuboid

1−D cuboids

2−D cuboids

3−D cuboids

4−D (*base*) cuboid

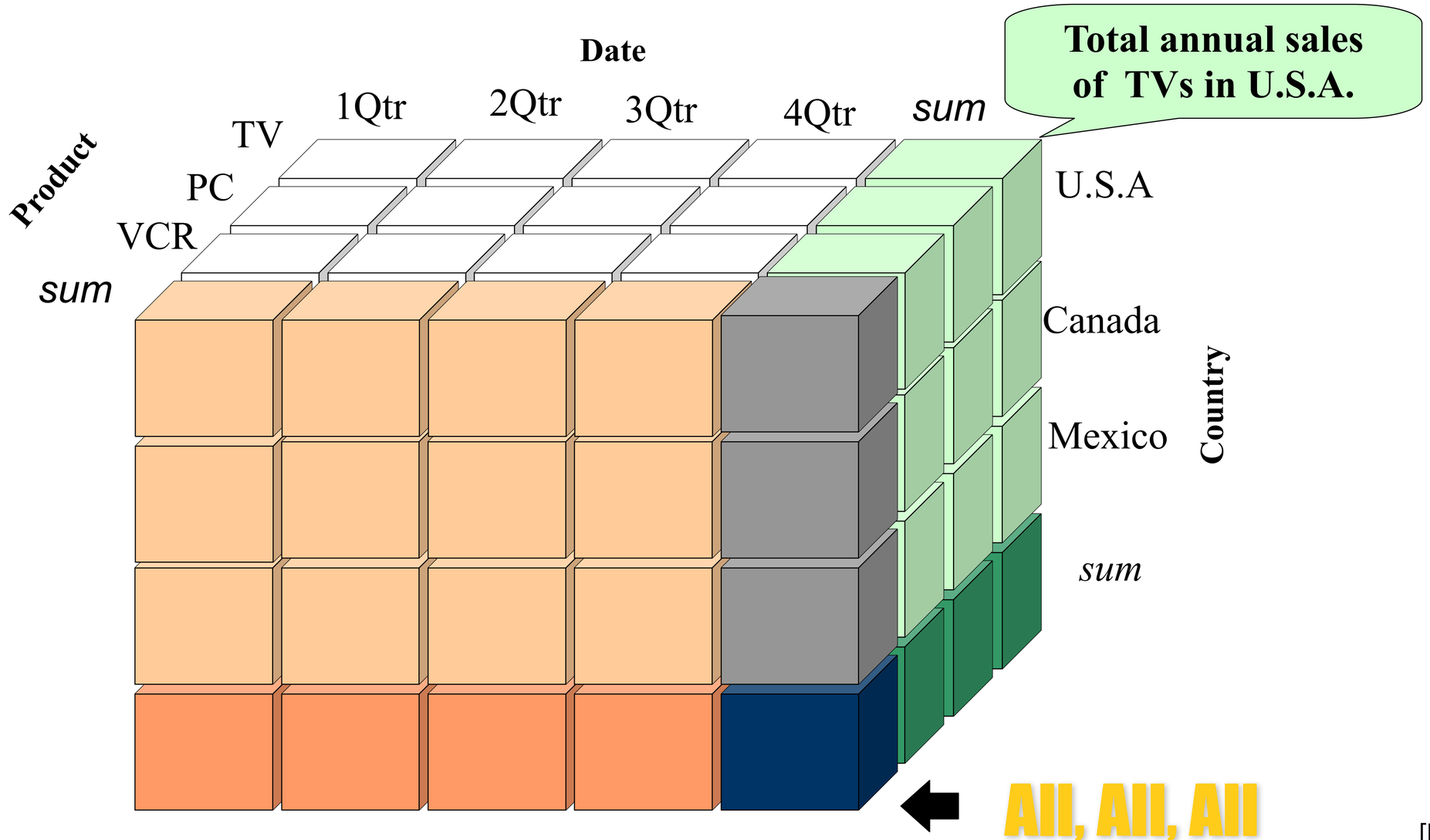
[Han et al., 2011]

Data Cube Measures: Three Categories

- **Distributive**: if the result derived by applying the function to n aggregate values is the same as that derived by applying the function on all the data without partitioning
  - E.g., `count(), sum(), min(), max()`
- **Algebraic**: if it can be computed by an algebraic function with M arguments (where M is a bounded integer), each of which is obtained by applying a distributive aggregate function
  - E.g., `avg(), min_N(), standard_deviation()`
- **Holistic**: if there is no constant bound on the storage size needed to describe a subaggregate.
  - E.g., `median(), mode(), rank()`

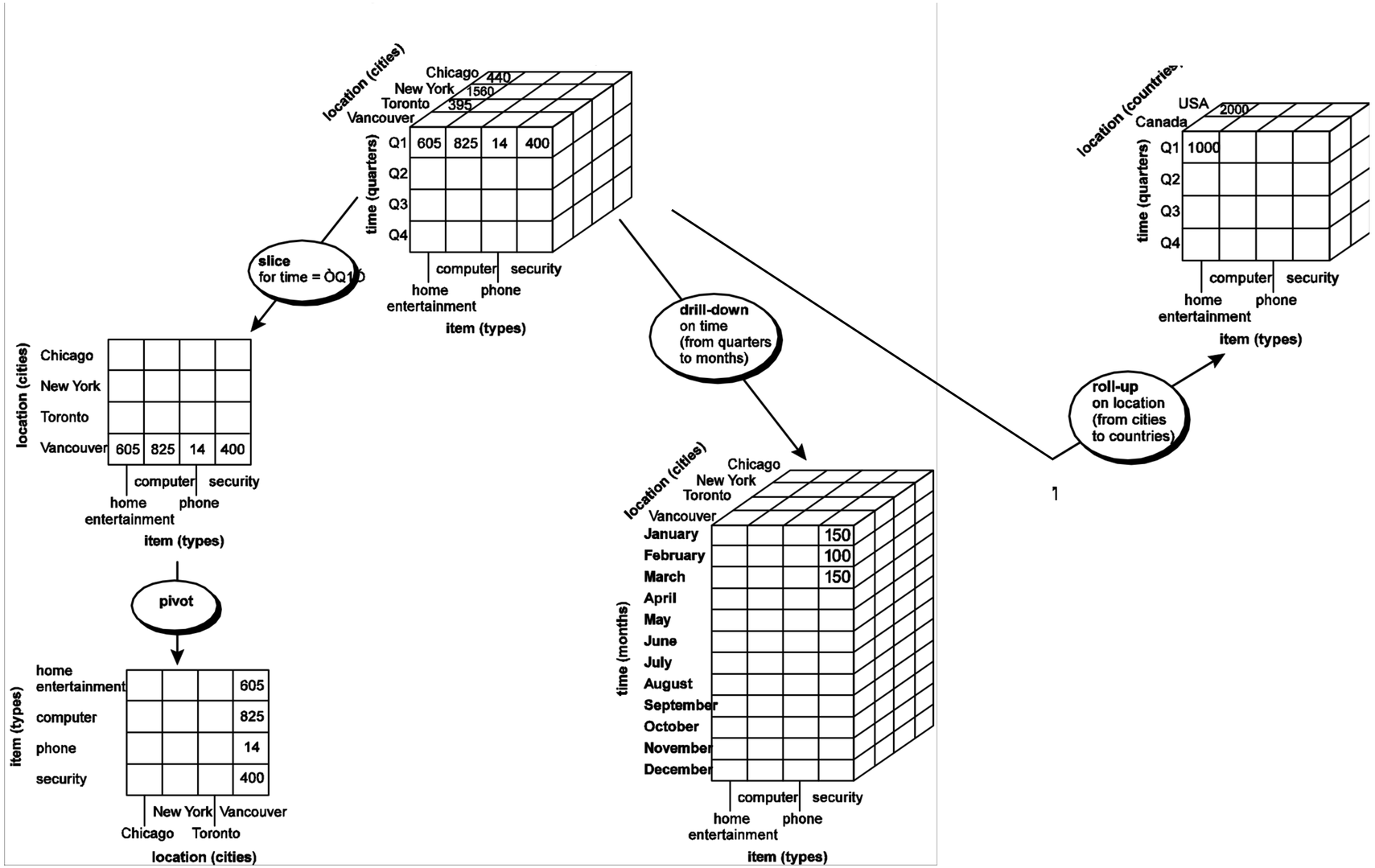
[Han et al., 2011]

A Sample Data Cube



[Han et al., 2011]

OLAP Operations



[Han et al., 2011]

Data Cube Aggregations

Relation A

Country	*Device*	*Language*
US	Android	en
US	iPhone	ru
South Africa	iPhone	en
India	Android	en
Australia	iPhone	en

Aggregation B

Country	*Device*	*Language*	*Count*
All	*All*	*All*	5

Group By on *Device, Language* C

Country	*Device*	*Language*	*Count*
All	Android	en	2
All	iPhone	en	2
All	iPhone	ru	1

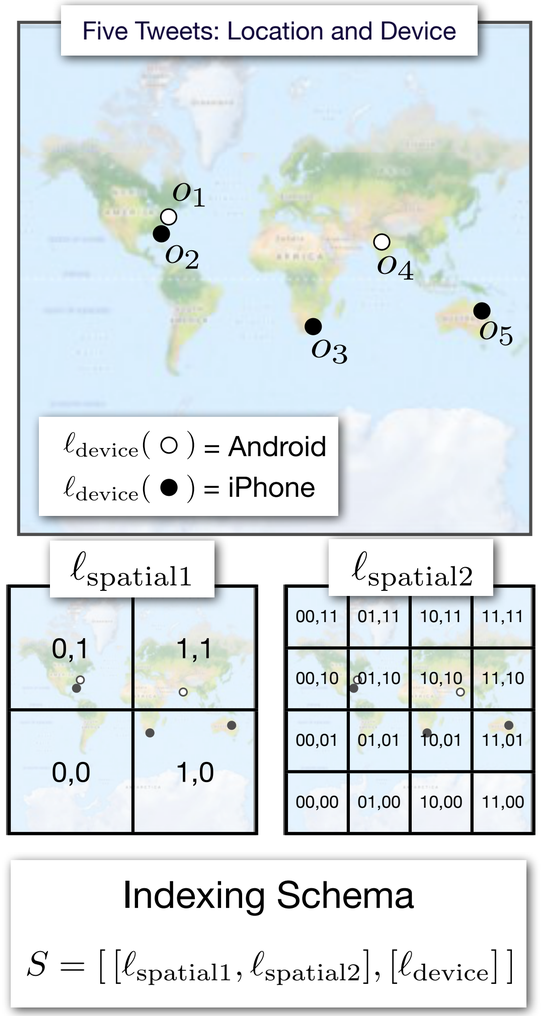
Cube on *Device, Language* D

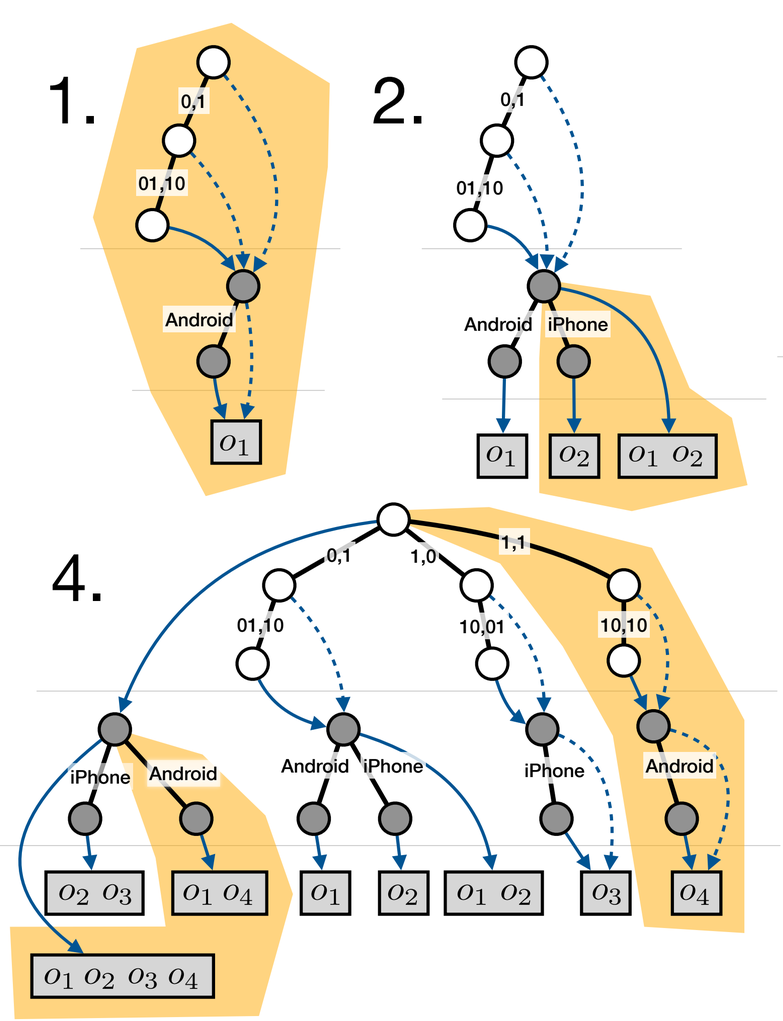
Country	*Device*	*Language*	*Count*
All	*All*	*All*	5
All	Android	*All*	2
All	iPhone	*All*	3
All	*All*	en	4
All	*All*	ru	1
All	iPhone	ru	1
All	Android	en	2
All	iPhone	en	2

Equivalent to Group By on all possible subsets of {*Device, Language*}

[Lins et. al, 2013]

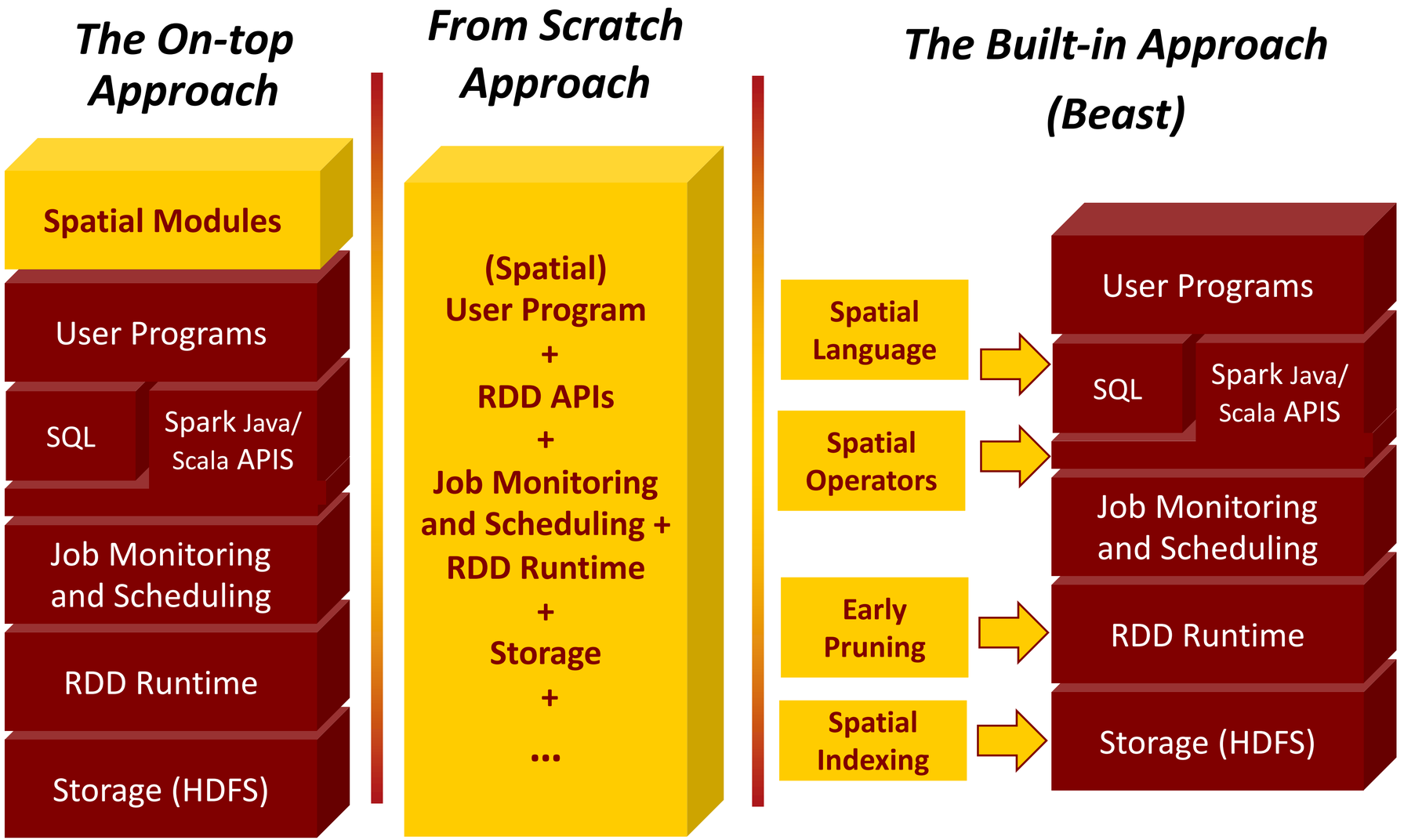
Building a Nanocube





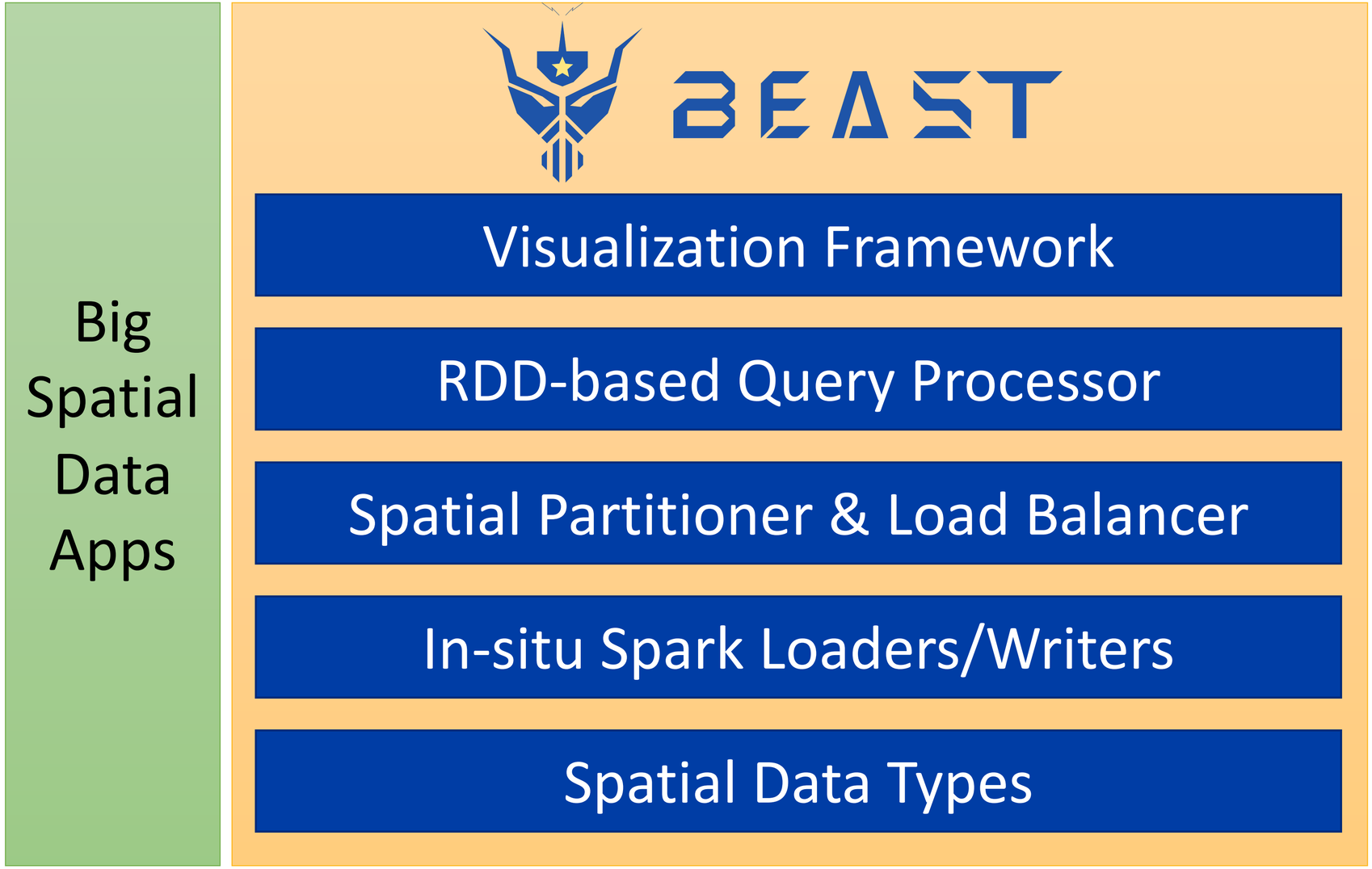
[Lins et. al, 2013]

Beast Architecture



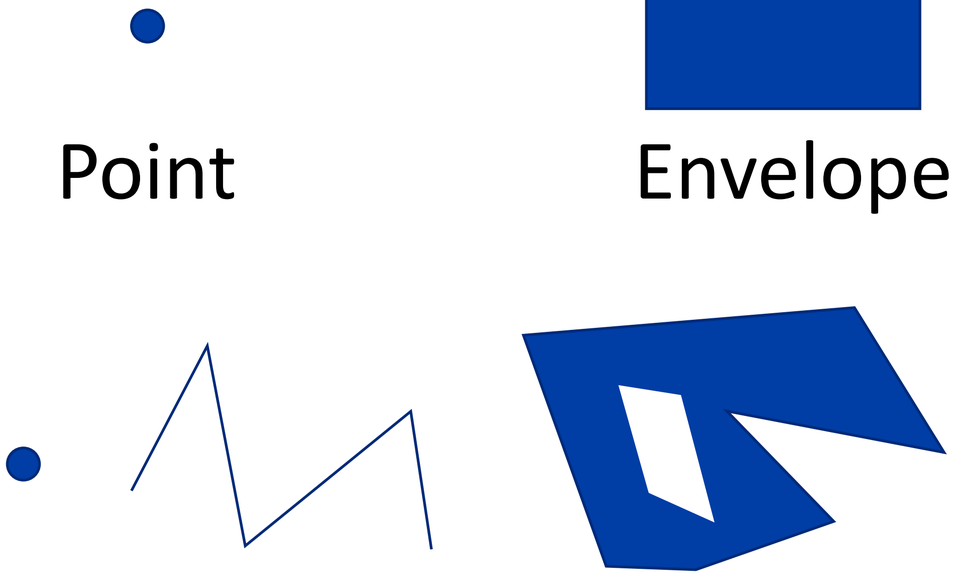
[A. Eldawy, 2021]

Beast Architecture



[A. Eldawy, 2021]

Beast Spatial Data Types



Point

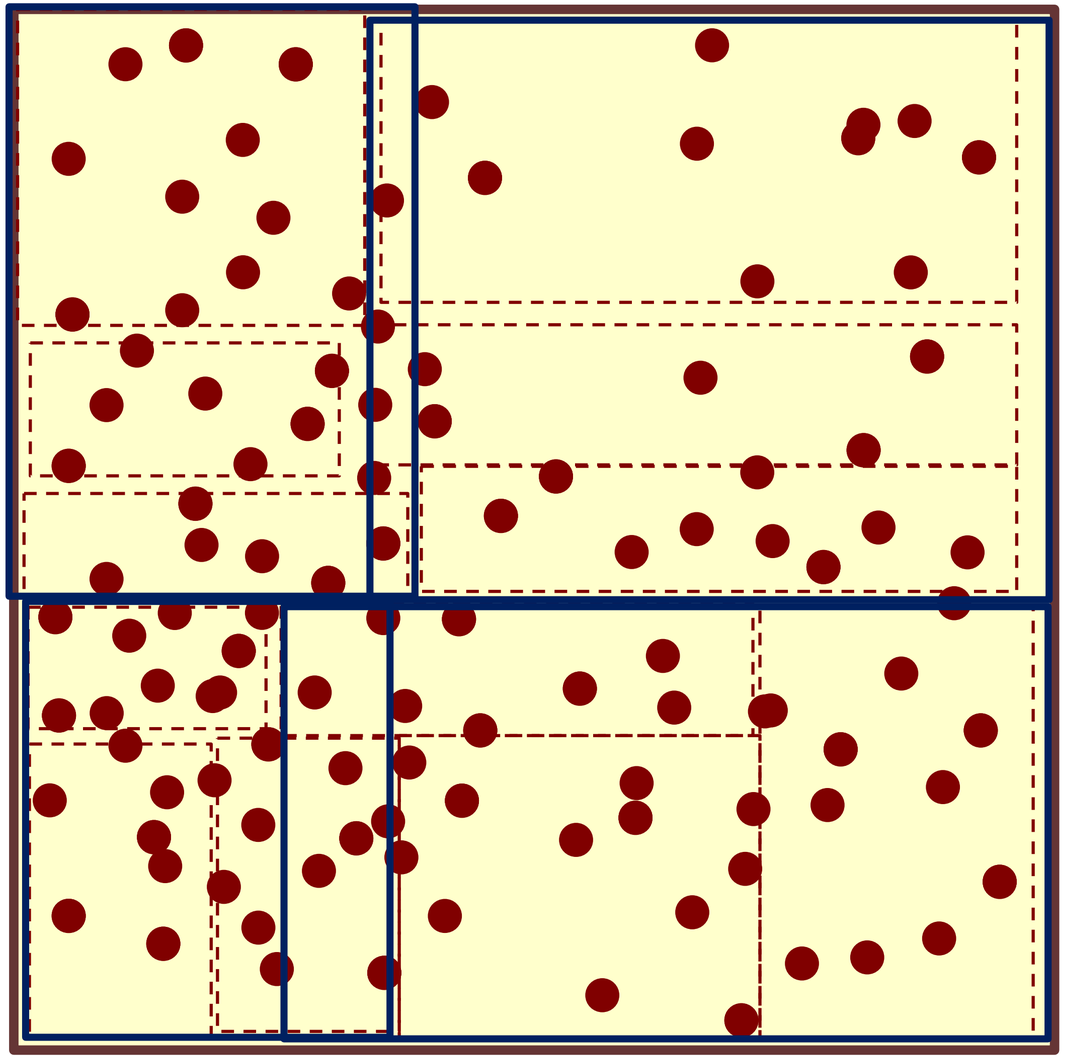
Envelope

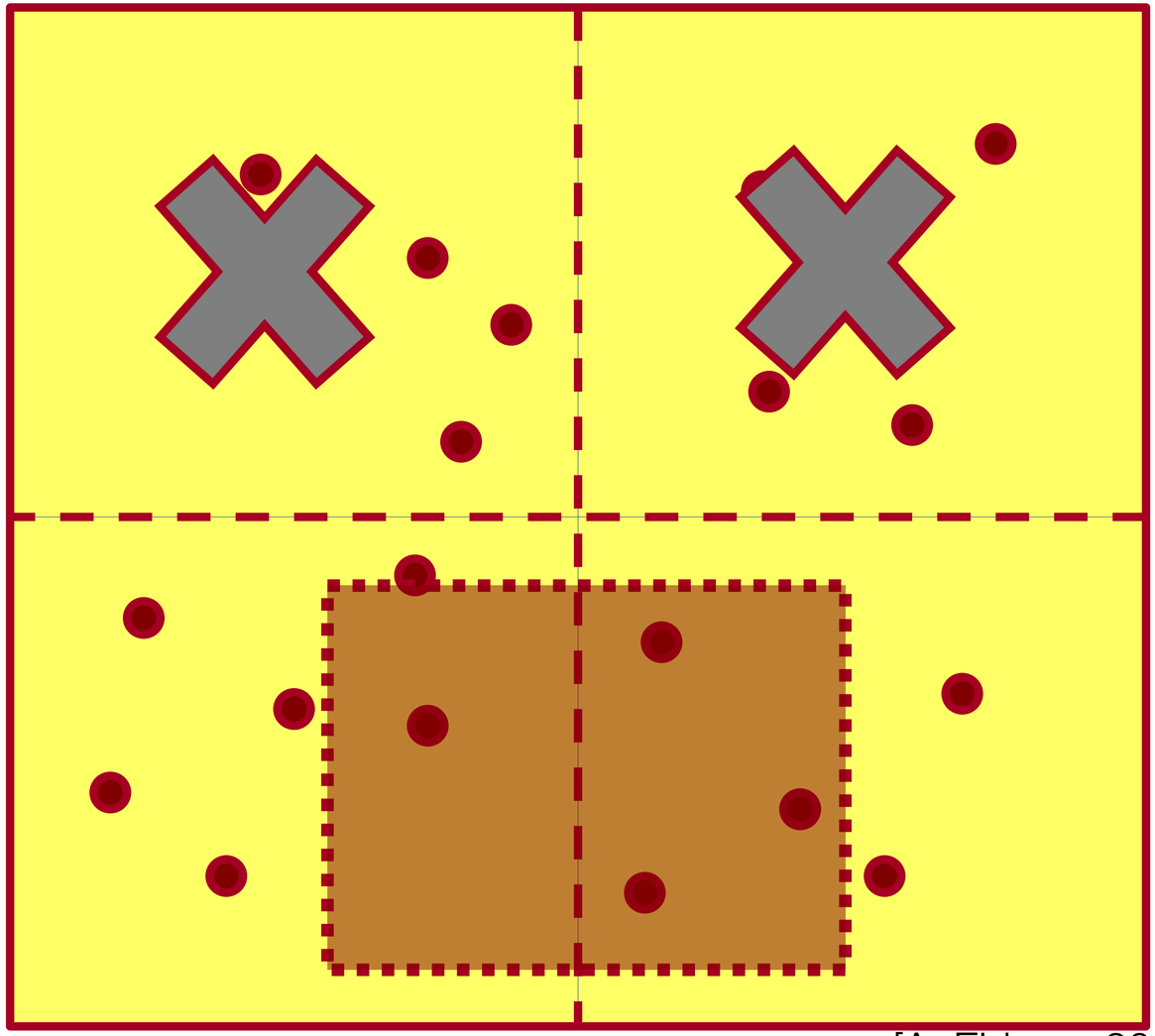
Geometry

Feature

[A. Eldawy, 2021]

Beast Partitioning/Indexing & Range Query

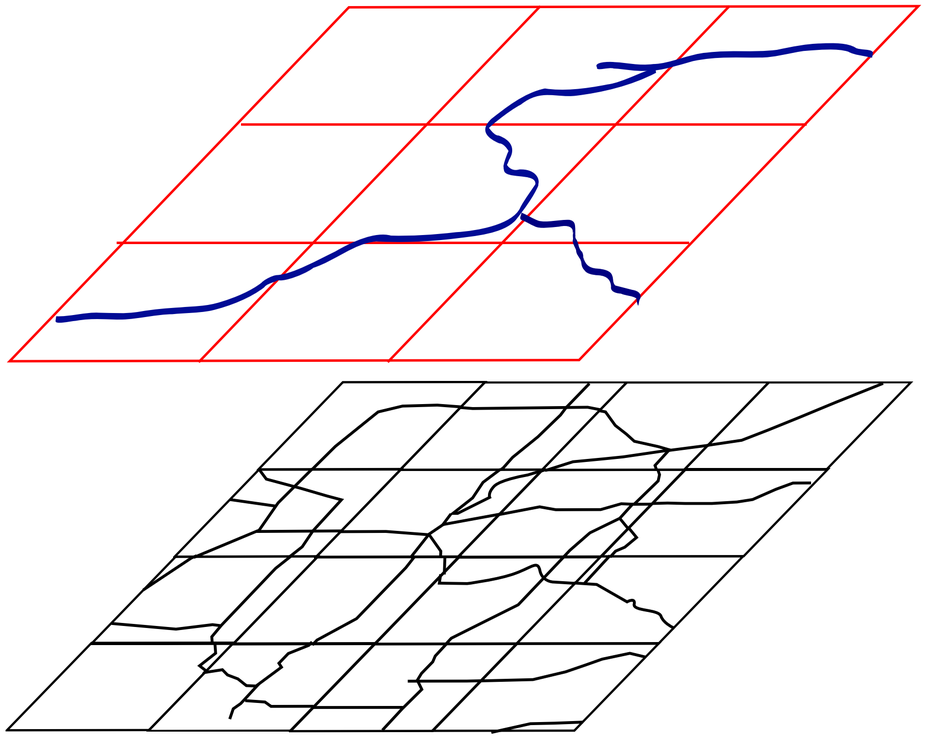




[A. Eldawy, 2021]

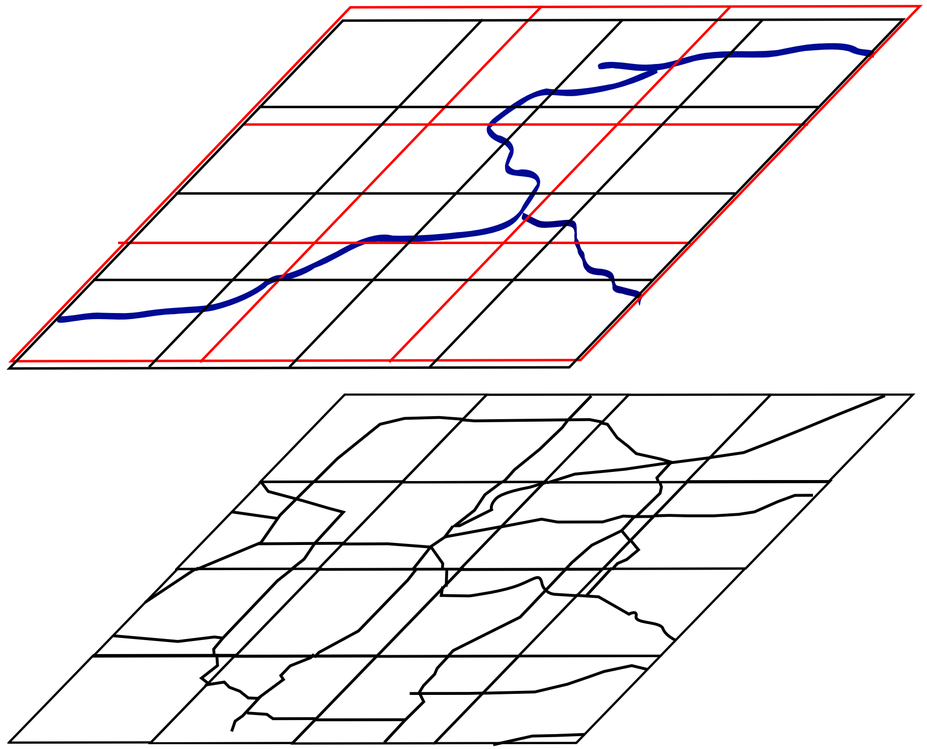
Beast Spatial Join

Join Directly



Total of 36 overlapping pairs

Partition – Join



Only 16 overlapping pairs

[A. Eldawy, 2021]

Assignment 5

- Divvy Bikes Data
- Spatial, Graph, and Temporal Data Processing
- Use pandas, geopandas, neo4j, (modin for extra credit)

Data Curation

Why?

Research Data Infrastructure

C. L. Borgman

What is data and why share it?

- "Data are representations of observations, objects, or other entities used as evidence of phenomena for the purposes of research or scholarship."
  [C. L. Borgman]
- Data can be digital but can also be physical (e.g. sculptures)
- Semantics are important (e.g. temperature to engineer and biologist)
- Grey Data: surveys, student records—think about **privacy**
- Sharing Data
  - Required/encouraged by universities, funding agencies, publishers
  - "Publications are arguments made by authors, and **data are the evidence** used to support the arguments." [C. L. Borgman]

Data attribution and citation

- Publications are counted, authorship is negotiated
- For data:
  - Often compound
  - Ownership is rarely clear
  - Attribution?
  - What about derived data?
- Bibliometrics and Altmetrics

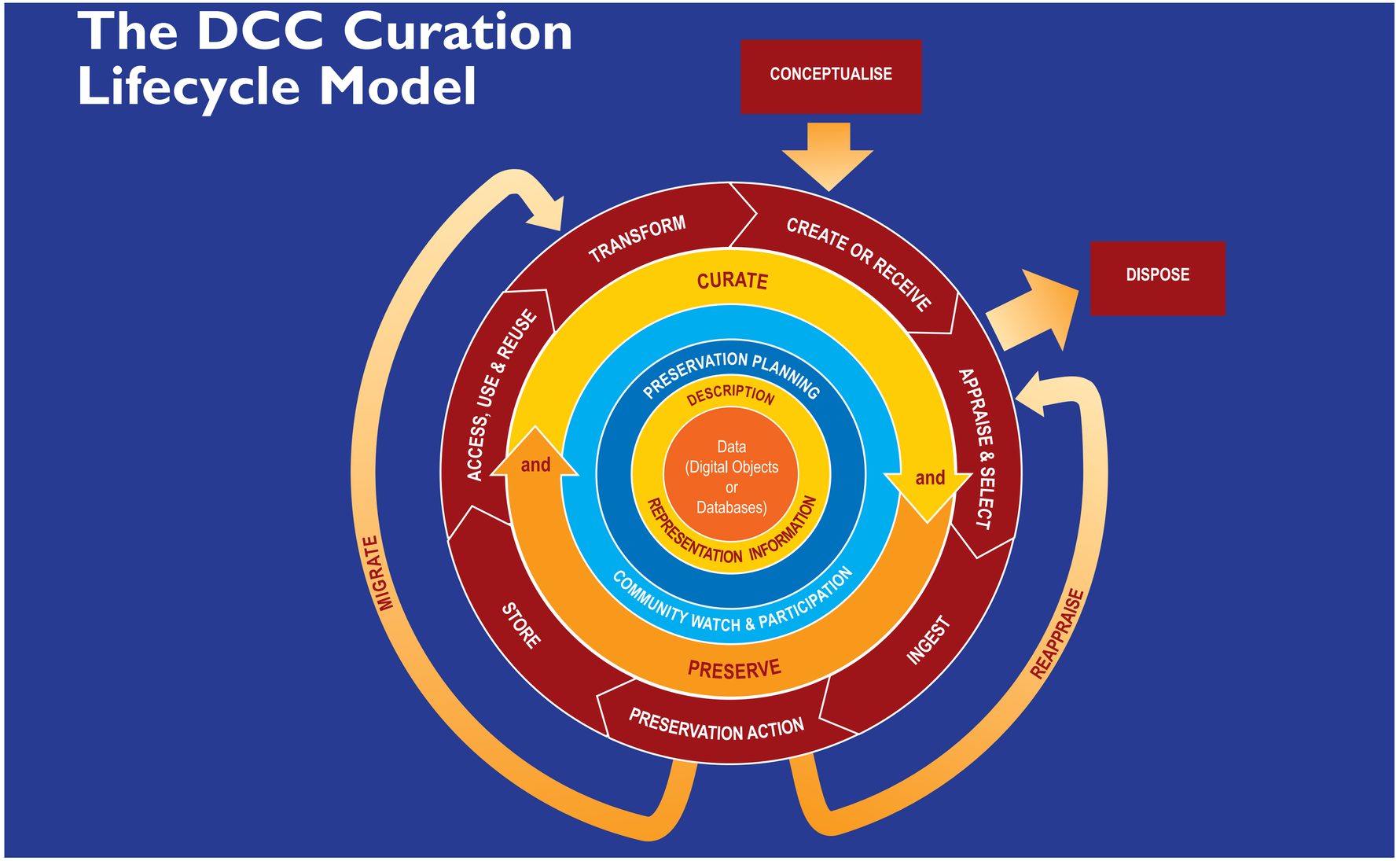
Data Identity

- Identifiers: DOIs, URIs
- Naming and namespaces: ORCID, KEGG Identifier
- Description: Metadata, Self-describing

Data Persistence

- How long should this data be kept?
  - Perishable
  - Long-lived
  - Permanent
- Who is responsible for keeping the data?
  - Scientists/investigators?
  - Publishers?
  - Librarians?
- Privacy should be considered from the beginning

Data Curation Lifecycle



[DCC]

Data (Digital Objects or Databases)

- Data, any information in binary digital form, is at the centre of the Curation Lifecycle. This includes:
  - **Digital Objects**
    - Simple Digital Objects are discrete digital items; such as textual files, images or sound files, along with their related identifiers and metadata.
    - Complex Digital Objects are discrete digital objects, made by combining a number of other digital objects, such as websites.
  - **Databases**: Structured collections of records or data stored in a computer system.

[DCC]

Full Lifecycle Actions

- Description and Representation Information: Assign metadata, using appropriate standards, to ensure adequate description and control
- Preservation Planning: Plan for preservation throughout the curation lifecycle of digital material
- Community Watch and Participation: Watch standards, tools, software.
- Curate and Preserve: Promote curation and preservation throughout the curation lifecycle

[DCC]

Sequential Actions

- Conceptualize: Plan creation of data—capture method and storage options.
- Create or Receive: Create/receive data and make sure metadata exists
- Appraise and Select: Evaluate data and select for long-term curation and preservation
- Ingest: Transfer data to an archive, repository, data centre or other custodian
- Preservation Action: Data cleaning, validation (ensure that data remains authentic, reliable and usable)
- Store: Store the data in a secure manner adhering to relevant standards Access, Use and Reuse: Make sure is accessible to users and reusers
- Transform: Create new data from the original (migrate formats, subsets, etc.)

[DCC]

Occasional Actions

- Dispose: Transfer to another archive or perhaps destroy data
- Reappraise: Return data which fails validation procedures for further appraisal and reelection
- Migrate: Migrate data to a different format—ensure the data's immunity from hardware or software obsolescence

[DCC]

The FAIR Guiding Principles for Scientific Data Management and Stewardship

M. D. Wilkinson et al.

Who and Why?

- Who: People from academia, industry, funding agencies, & scholarly publishers
- Why?
  - Data management leads to knowledge discovery, innovation, and reuse
  - Existing digital ecosystem **prevents** maximum benefit
  - Need to specify what "good" data management/curation/stewardship is
  - Enhance the ability of machines to automatically find and use the data
  - Principles should also apply to **tools**

[M. D. Wilkinson et al., 2016]

FAIR Principles

- Findable: Metadata and data should be easy to find for both humans and computers
- Accessible: Users need to know how data can be accessed, possibly including authentication and authorization
- Interoperable: Can be integrated with other data, and can interoperate with applications or workflows for analysis, storage, and processing
- Reusable: Optimize the reuse of data. Metadata and data should be well-described so they can be replicated and/or combined in different settings

[GO FAIR]

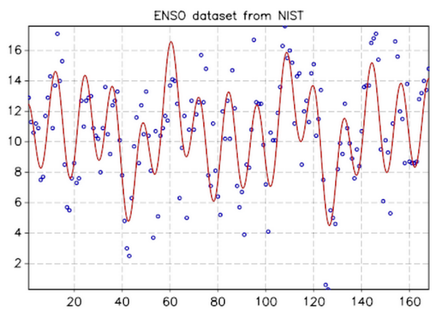
To be Findable

- F1. (Meta)data are assigned a **globally unique and persistent identifier**
- F2. Data are described with **rich metadata** (defined by R1)
- F3. Metadata clearly and explicitly include the **identifier** of the data it describes
- F4. (Meta)data are **registered or indexed** in a searchable resource

[M. D. Wilkinson et al., 2016]

DataCite Workflow

1. Take a dataset



2. Describe it

- Title
- Authors
- Year
- Description
- And others…

3. Assign a DOI

10.1234/exampledata

4. Reuse and reference!

ATLAS Collaboration, "Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC: $H \to \gamma\gamma$,"
http://doi.org/10.7484/INSPIREHEP.DATA.A78C.HK44

☑ Unique ☑ Persistent

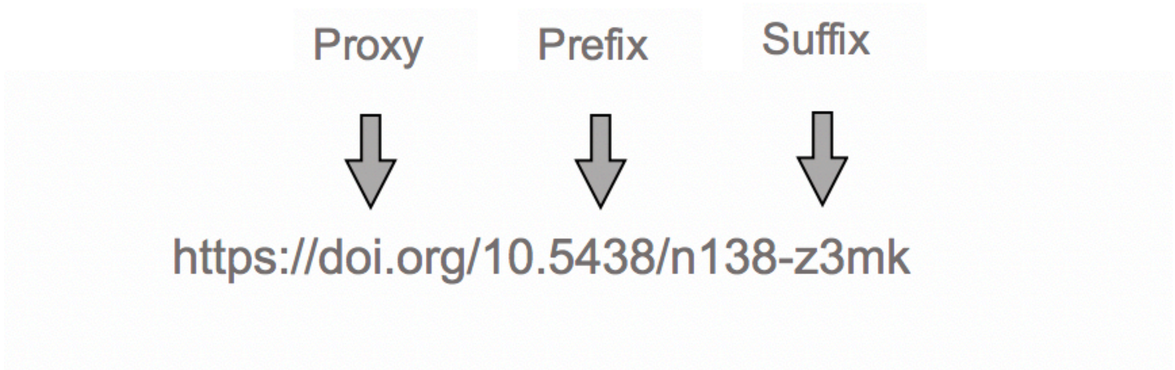
5. Enjoy the benefits

- Findability
- Track citations
- Reusability
- Measure impact

[DataCite]

Digital Object Identifier

- Name: Proxy + Prefix + Suffix



- Metadata: description of the object
- URL: resolves to a digital location, which contains object's details

[DataCite]

DataCite Metadata

Mandatory Properties	Details
Identifier	with mandatory type sub-property
Creator	with optional name identifier and affiliation sub-properties
Title	with optional type sub-properties
Publisher	
PublicationYear	
ResourceType	with mandatory general type description sub-property

Recommended Properties	Details
Subject	with scheme sub-property
Contributor	with type, name identifier, and affiliation sub-properties
Date	with type sub-property
RelatedIdentifier	with type and relation type sub-properties
Description	with type sub-property
GeoLocation	with point, box, and polygon sub-properties

Optional Properties
Language
AlternateIdentifier
Size
Format
Version
Rights
FundingReference

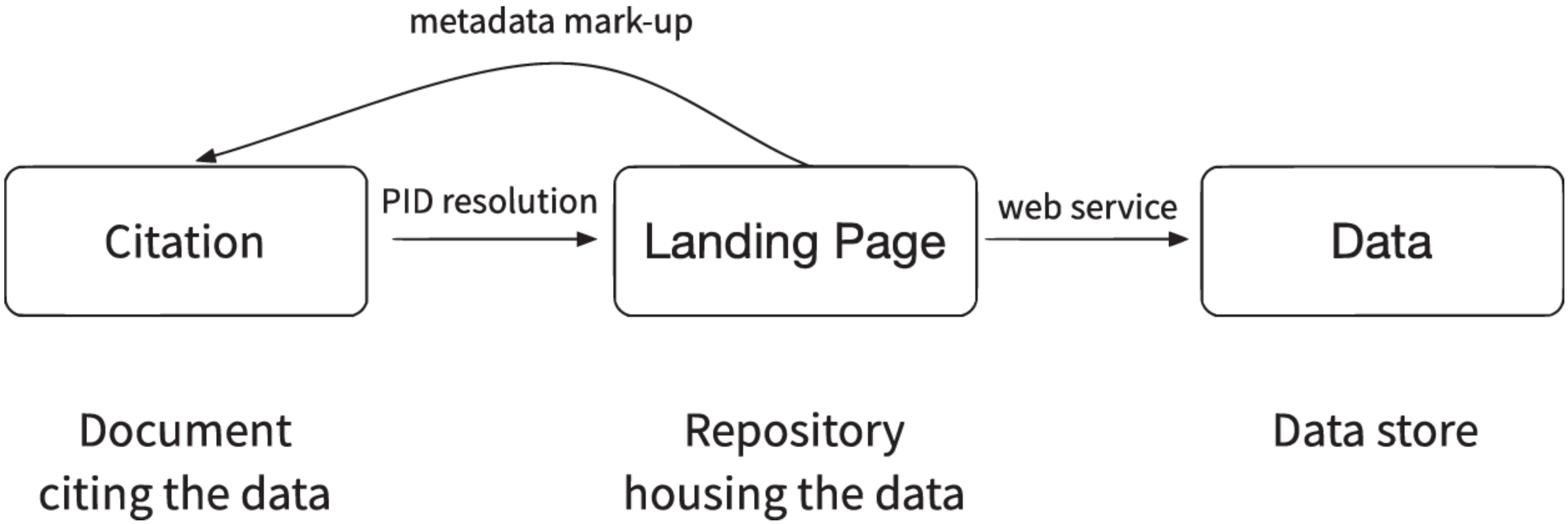
[DataCite]

To be Accessible

- A1. (Meta)data are **retrievable** by their identifier using a standardized communications protocol
  - A1.1. The protocol is **open**, free, and universally implementable
  - A1.2. The protocol allows for an **authentication** and authorization procedure, where necessary
- A2. Metadata are accessible, even when the data are **no longer available**

[M. D. Wilkinson et al., 2016]

How data accessibility might work within publications



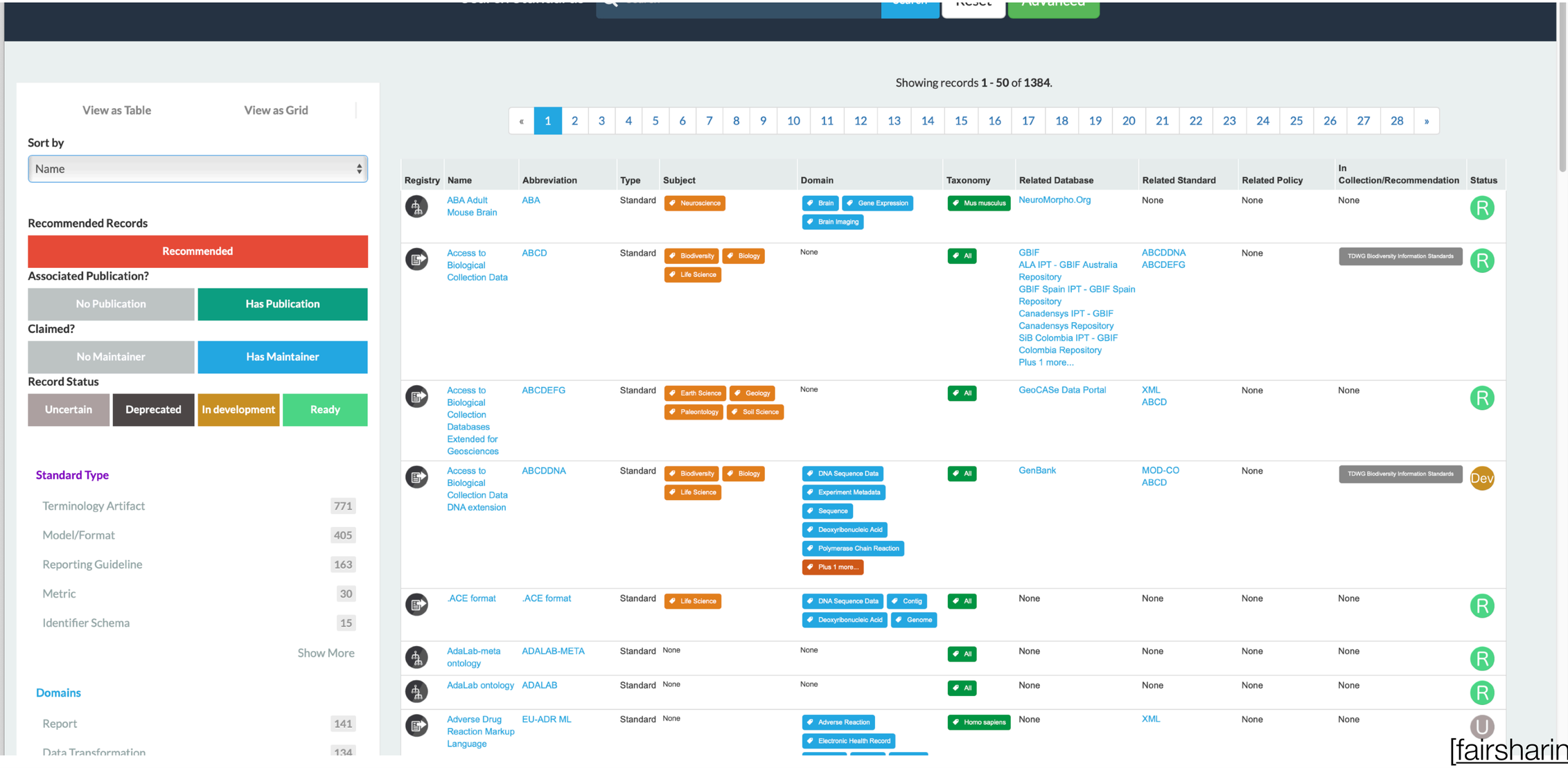
[M. Fenner et al., 2019]

To be Interoperable

- I1. (Meta)data use a formal, accessible, shared, and broadly applicable **language** for knowledge representation.
- I2. (Meta)data use **vocabularies** that follow FAIR principles
- I3. (Meta)data include **qualified references** to other (meta)data

[M. D. Wilkinson et al., 2016]

Standard vocabularies



[fairsharing.org]

To be Reusable

- R1. (Meta)data are richly described with a plurality of accurate and relevant attributes
  - R1.1. (Meta)data are released with a clear and accessible data usage **license**
  - R1.2. (Meta)data are associated with detailed **provenance**
  - R1.3. (Meta)data meet domain-relevant **community standards**

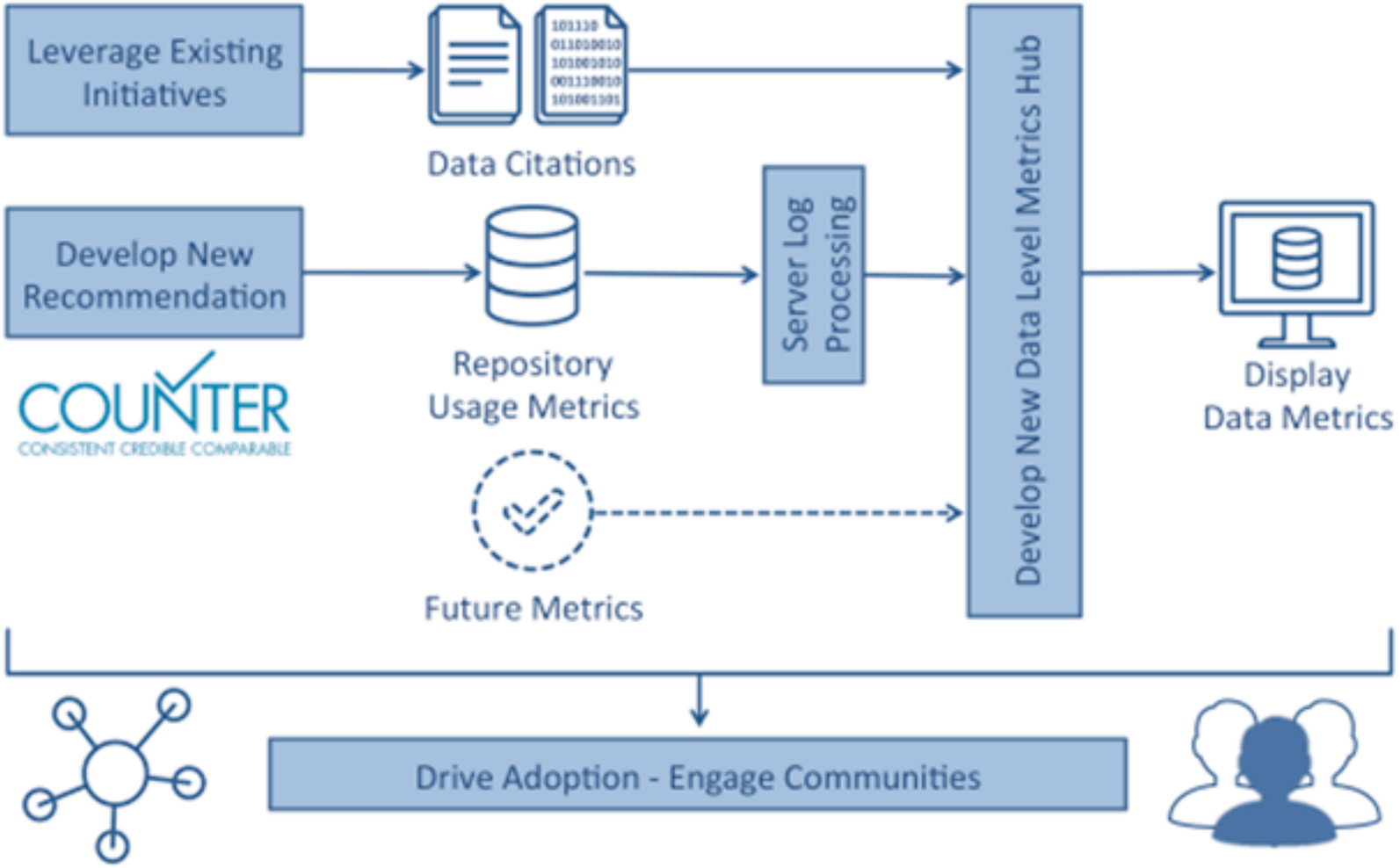
[M. D. Wilkinson et al., 2016]

Licensing

- Citation of a dataset is expected as a scholarly norm, not by law
- CC0:
  - "I hereby waive all copyright and related or neighboring rights together with all associated claims and causes of action with respect to this work to the extent possible under the law"
- CC BY: license, not a waiver as CC0
  - "You must give appropriate credit, provide a link to the license, and indicate if changes were made."
- Data Use Agreements (DUA): Used when data are restricted due to proprietary or privacy concerns.

[M. Crosas]

Make Data Count



[H. Cousijn et al., 2019]