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Efficient Multidimensional Blocking for Link Discovery without losing Recall

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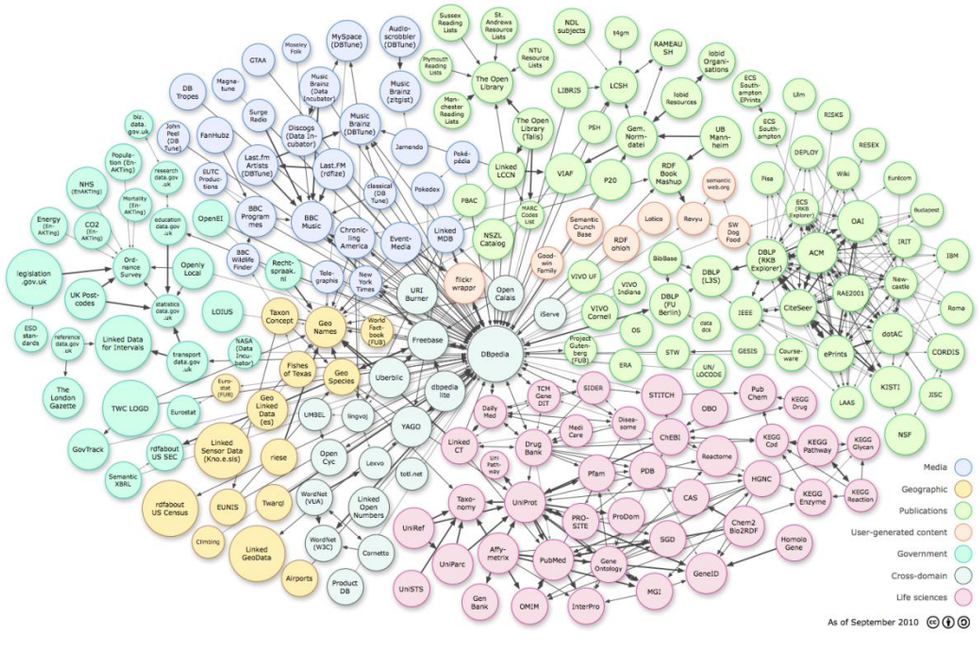
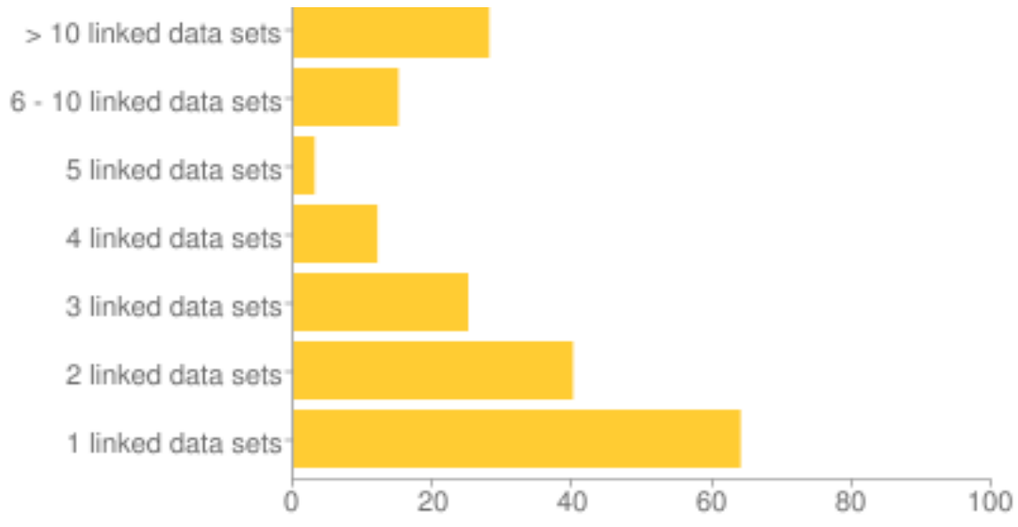
Outline

- Problem Statement
- MultiBlock
- Silk Link Discovery Framework
- Evaluation

Problem

- The Web of Data is a single global data space because data sources are connected by links
- 28 billion triples published as Linked Open Data and growing
- <u>But:</u>
  - Less than 400 million links
  - Most publishers only link to one other dataset





http://lod-cloud.net/state/

Interlinking Data Sources

- **Tools enable data publishers to set links**
- **Most tools generate links based on user-defined link specifications**
- **A link specification typically aggregates several different similarity measures.**
- **Naive solution: Evaluate the link specification for the complete cartesian product**
  - Not feasable for large datasets
- **<u>Idea:</u> Dismiss definitive non-matches prior to comparison**

Requirements

- Linked Data is heterogenous and uses a variety of datatypes

  ⇨ **Should be flexible**

- We don‘t want to lose recall

  ⇨ **No false dismissals**

- Some similarity measures are no metrics (e.g. Jaro-Winkler)

  ⇨ **Support non-metric similarity measures**

- Linked Data application architectures usually want to integrate a incoming stream of entities (e.g. Silk Server)

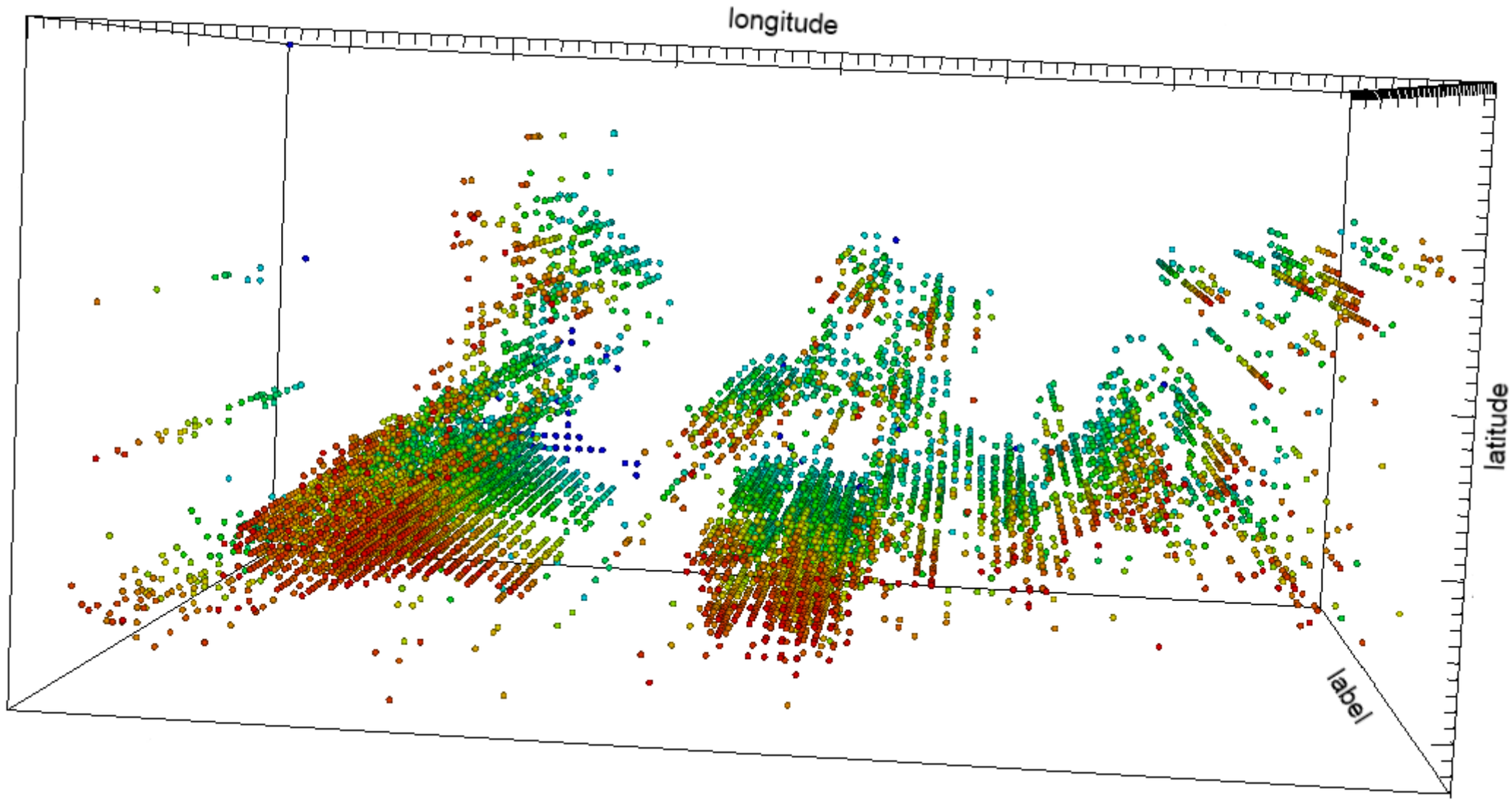
  ⇨ **Should not require any pre- or postprocessing**

Comparison

Method	Lossless	Non-Metrics	Online
Traditional Blocking	No	Yes	Yes
Sorted-Neighborhood	No	Yes	No
Sorted Blocks	No	Yes	No
FastMap	No	No	No
MetricMap	No	No	No
SparseMap	No	No	No
StringMap	No	No	No
Modified SparseMap	Yes	No	No
MultiBlock	**Yes**	**Yes**	**Yes**

MultiBlock

- Map all entities to a multidimensional space preserving the distances of the entities



Approach

1. General framework

- Defines the workflow of the indexing
- Does not define a specific similarity measure or aggregation
- Instead: Defines the properties a similarity measure/aggregation must adhere to

2. Specific similarity measures and aggregations

- Can be plugged into the general framework

Indexing Workflow

Index Generation

- Build an index for each similarity measure in the link specification
- Idea: Preserve the distances of the entities

Index Aggregation

- Aggregate all indexes into one compound multidimensional index

Comparison Pair Generation

- Generate a comparison pair for each two entities which share an index

Index Generation

- Generate an (multidimensional) index for each similarity measure
- Basic function of a similarity measure:

$$sim_s : \ A \times B \rightarrow [0, 1]$$

- Indexing function:

$$index_s : \ (A \cup B) \times [0, 1] \rightarrow \mathcal{P}(\mathbb{N}^n)$$

- All similarity measures must adhere to:

$$sim_s(e_1, e_2) \leq \theta \iff index_s(e_1) \cap index_s(e_2) \neq \emptyset$$

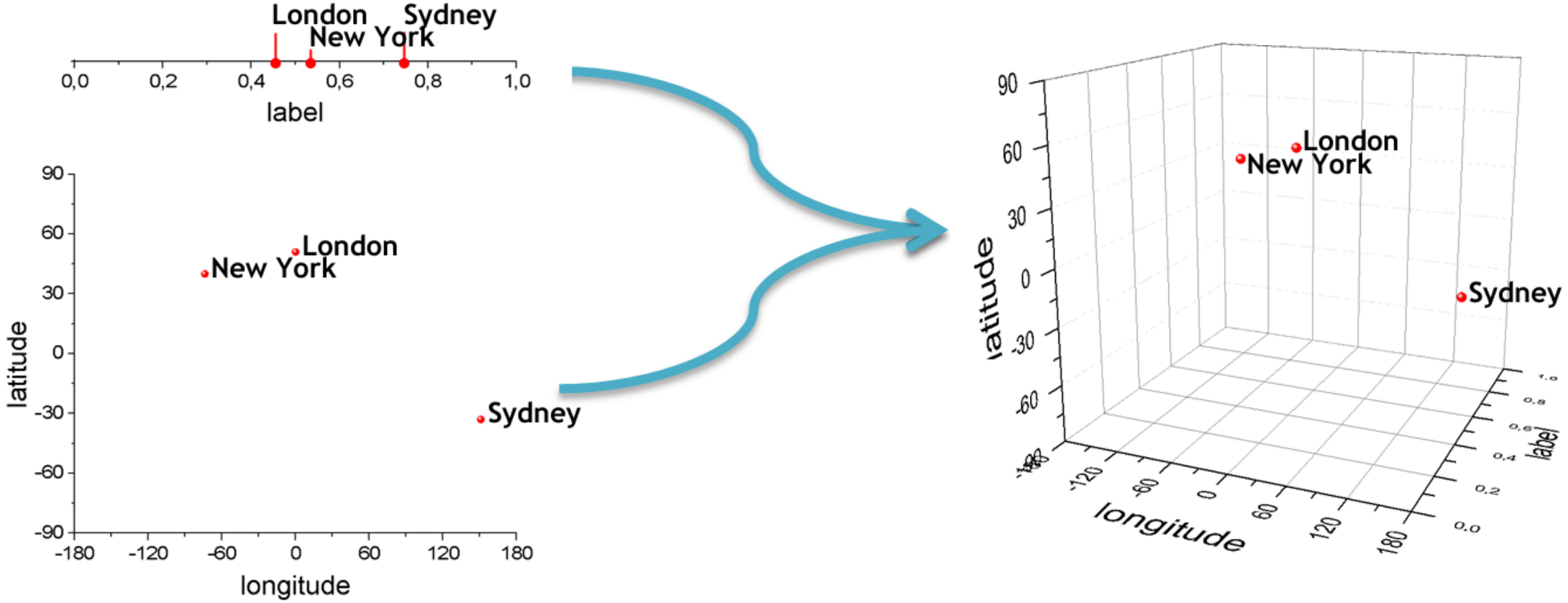
(For all entities e_1, e_2 and a threshold θ)

Index aggregation

- **Aggregate all indices into a single compound index**

$$aggIndex_a : \ \mathcal{P}(\mathbb{N}^n) \times \mathcal{P}(\mathbb{N}^n) \rightarrow \mathcal{P}(\mathbb{N}^n)$$

- **<u>Example:</u>**



Comparison pair generation

- Generate pairs based on overlapping blocks
- Two entities which share the same block will be compared:

$$\{(a,b);\ i_a = i_b, i_a \in index(a), i_b \in index(b), a \in A, b \in B\}$$

The Silk Link Discovery Framework

- Open source link discovery framework, running on all major platforms
- Flexible, declarative language for specifying link conditions
- Scalability and high performance through efficient data handling
  - Reduction of network load by caching and reusing of SPARQL result sets
  - Multi-threaded computation of the data item comparisons
  - Blocking of data items using MultiBlock

Link Conditions

- **Specify which conditions two entities must fulfill in order to be interlinked.**
- **A link condition is expressed as a combination of:**

RDF paths

- Similar to SPARQL 1.1 Property Paths
- Examples:
  - ?movie/dbpedia:director/rdfs:label
  - ?person/label[@lang='en']

Transformations

- Transforms the result set of an RDF paths
- Variety of built-in transformations
- Examples:
  - LowerCase
  - RegexReplace
  - Stem

Similarity Metrics

- Similarity of two inputs based on a user-defined metric.
- Examples:
  - Various string similarity metrics
  - Geographic similarity
  - Date similarity

Aggregations

- Aggregates multiple similarity metrics
- Examples:
  - Min, Max, Average
  - Quadratic Mean
  - Geometric Mean

Silk – Linking Specification

```
<LinkCondition>
  <Aggregate type="average">
    <Compare metric="levenshtein" >
      <Input path="?a/rdfs:label[@lang='en']"/>
      <Input path="?b/rdfs:label[@lang='en']"/>
      <Param name="maxDistance" value="10"/>
    </Compare>
    <Compare metric="wgs84" required="true">
      <Input path="?a/wgs84:geometry"/>
      <Input path="?b/wgs84:geometry"/>
      <Param name="unit" value="km"/>
      <Param name="threshold" value="50"/>
    </Compare>
  </Aggregate>
</LinkCondition>
```

Compare city names

Aggregate results

Compare coordinates

Silk Versions

- **Silk Single Machine**
  - Generate links on a single machine
  - Local or remote data sets
- **Silk MapReduce (from Silk 2.2)**
  - Generate RDF links using a cluster of multiple machines
  - Based on Hadoop (Can be run on Amazon Elastic MapReduce)
- **Silk Server (from Silk 2.1)**
  - Provides an HTTP API for matching instances from an incoming stream of RDF data while keeping track of known entities
  - Can be used as an identity resolution component within applications that consume Linked Data from the Web
  - Can be used for instance together with a Linked Data crawler to populate a local duplicate-free cache with data from the Web

Silk Linking Engine

Loading

- Loads the data from the configured data sources
- Supported sources: SPARQL endpoints. Planned: RDF dumps

MultiBlock

- Indexes the instances. Only instances with the same index will be matched.
- This avoids matching the complete Cartesian product.

Matching

- Computes a similarity value for each pair of instances from the same cluster.
- The similarity value is based on a user-defined link condition.

Filtering

- Removes all links with a lower confidence than the user-defined threshold
- Only a limited number of links from the same subject are yielded

Output

- Writes the generated links to a user-defined destination
- Supported formats: N-Triples, OAEI Alignments, Planned: EDOAL Alignments

Performance Evaluation

- Interlinking 204,109 settlements from DBpedia and 530,606 settlements from LinkedGeoData
- Compared MultiBlock with traditional blocking by labels with an overlapping factor of 0.2

* 3GHz Intel(R) Core i7 CPU with 4 core and 8GB of RAM.

Method	Comparisons	Runtime (*)	Links
Full Evaluation	108,301,460,054	305,188s	70,037
Blocking, 100 blocks	3,349,755,846	22,453s	69,403
Blocking, 1000 blocks	1,049,015,356	7,909s	60,025
MultiBlock	37,667,462	420s	70,037

- MultiBlock reduces the number of comparisons by a factor of 2,875 and is over 700 times faster than the full evaluation

Conclusion

- MultiBlock uses a multidimensional index to increase its efficiency significantly
- It guarantees that no false dismissals can occur
- It does not require the similarity space to form a metric space
- MultiBlock has been implemented as part of the Silk Link Discovery Framework
- Speedup factor of several 100 for large datasets compared to the full evaluation without losing recall

Thanks!

Get Silk from: http://www4.wiwiss.fu-berlin.de/bizer/silk

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