On the Effect of Geometries Simplification on Geo-spatial Link Discovery

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Outline

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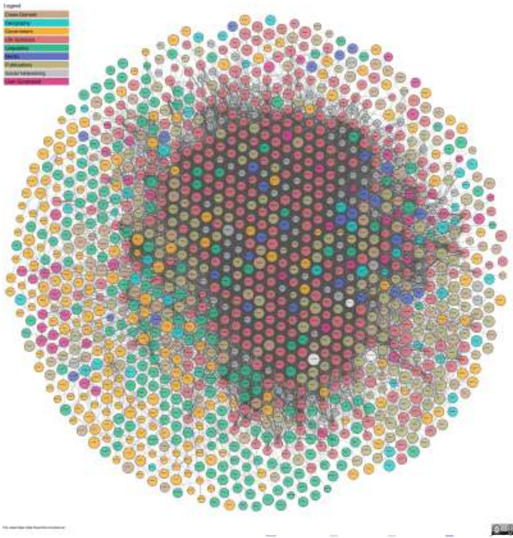
Motivation

Link Discovery among RDF geospatial data

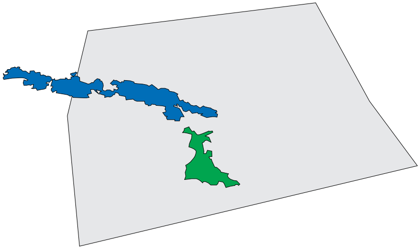
- Linked Data Cloud
  - `http://stats.lod2.eu`
  - 150+ billion triples
  - 46+ million links
  - Mostly `owl:sameAs`
- Large geospatial datasets
  - *LinkedGeoData* contains 20+ billion triples
  - *CLC* consists of 2+ million resources
  - *NUTS* contains up to 1500 points/resources



Motivation

Why is linking geospatial resources difficult?

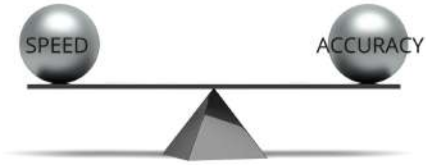
- Link Discovery
  - Given two knowledge bases S and T, find links of type $\mathcal{R}$ between S and T
  - Formally find $M = \{(s, t) \in S \times T : \mathcal{R}(s, t)\}$
  - Naïve computation of M requires quadratic time complexity
- Geo-spatial resources available on the LOD
  - Described using polygons
  - Large in number
  - Demands the computation of
    1. Topological relations
    2. point-set distance



Motivation

Why is linking of simplified geospatial data important?

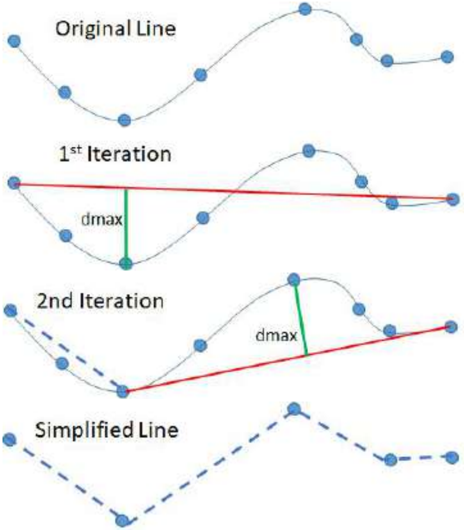
- Real-time applications
  - Structured machine learning
  - Cross-ontology QA
  - Reasoning
  - Federated Queries
  - ...
- The trade-off between
  - Runtime and
  - Accuracy



http://www.thepinsta.com

- **Input:** Polygonized curve with n vertices
- **Goal:** Find an approximating polygonized curve with m vertices, where $m < n$
- **Idea:** Approximate a line with a defined error tolerance $\epsilon > 0$
- Many algorithms exist
  - *Douglas-Peucker*
  - *Visvalingam-Whyatt*
  - ...

- Constract a line segment from the first point to the last point
- Find the point with farthest distance *dmax* from the line segment
- If ϵ *tolerance* $<$ *dmax* , the approximation is accepted
- otherwise, keep recursion



- Standard to describe the topological relations in 2D space.
- DE-9IM is based on the intersection matrix:

$$DE9IM(a,b)\begin{bmatrix} dim(I(g_1)\cap I(g_2)) & dim(I(g_1)\cap B(g_2)) & dim(I(g_1)\cap E(g_2)) \\ dim(B(g_1)\cap I(g_2)) & dim(B(g_1)\cap B(g_2)) & dim(B(g_1)\cap E(g_2)) \\ dim(E(g_1)\cap I(g_2)) & dim(E(g_1)\cap B(g_2)) & dim(E(g_1)\cap E(g_2)) \end{bmatrix}$$

- At least one shared point for a relation to be hold
- For the `disjoint` relation $\Rightarrow$ inverse of the `intersects` relation
- Accelerates the computation of any topological relation

- **Input** Two resources with input geometries g_s and g_t
- Compute the *orthodromic distance* $\delta(s_i, t_j)$ between pairwise point of g_s and g_t

$$\delta(s_i, t_j) = R\cos^{-1}\sin(\varphi_{s_i})\sin(\varphi_{t_j}) + \cos(\varphi_{s_i})\cos(\varphi_{t_j})\cos(\lambda_{s_i} - \lambda_{t_j}),$$

  p_i is a point on the surface (φ_i, λ_i), latitude φ_i and longitude λ_i,
- Many methods exist to compute the (g_s, g_t) point-set distance
  - Hausdorff

$$D_{Hausdorff}(g_s, g_t) = \max_{s_i \in g_s}\left\{\min_{t_j \in g_t}\left\{\delta(s_i, t_j)\right\}\right\}$$

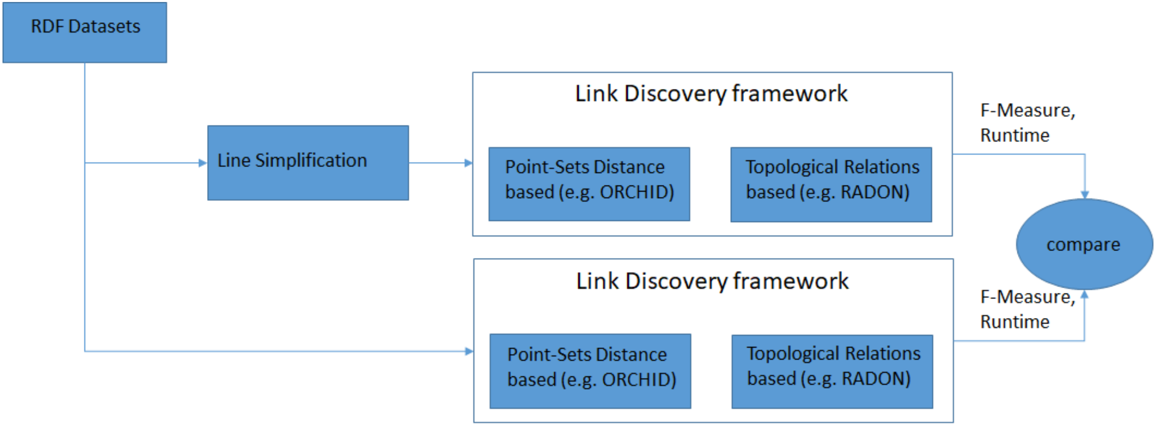
  - Mean

$$D_{mean}(g_s, g_t) = \delta\left(\frac{1}{n}\sum_{s_i \in g_s} s_i, \frac{1}{m}\sum_{t_j \in g_t} t_j\right)$$

- Line Simplification is independent from Link Discovery framework
- Stat of the art:
  - RADON for topological relation extraction
  - ORCHID for point set distance
- Topological relations:
  - `within`, `touches`, `overlaps`, `intersects`, `equals`, `crosses` and `covers`
- Point-sets distance:
  - `Hausdorff`, `Mean`, `Link`, `Min`, and `Sumofmin`

Evaluation

Overview



- Hardware
  - Oculus a cluster machine running OpenJDK 64-Bit 1.8.0161 on *Ubuntu* 16.04.3 LTS
  - Assigned 16 CPU (2.6 GHz Intel Xeon "Sandy Bridge") and 200 GB of RAM with timeout limit of 4 hours for each job
- Datasets
  - NUTS
  - CORINE Land Cover (CLC)

Q_1

How much performance (i.e., F-measure) each of the geospatial LD approaches loses, when to deal with the simplified geometries vs. when to deal with the original ones?

- The first set of experiments setup
  - RADON for discovering topological relations
  - *Douglas-Peucker* with simplification factors of $0.05, 0.09, 0.10$ and 0.2
  - NUTS dataset as a source and CLC dataset as a target

Relation/Factor	0.05	0.09	0.10	0.20	Average
Equals	1.00	1.00	1.00	1.00	1.00 ± 0.00
Intersects	0.99	0.97	0.97	0.94	0.97 ± 0.02
Contains	0.99	0.97	0.97	0.93	0.97 ± 0.03
Within	0.99	0.97	0.97	0.93	0.97 ± 0.03
Covers	0.99	0.97	0.97	0.93	0.97 ± 0.03
Coveredby	0.99	0.97	0.97	0.93	0.97 ± 0.03
Crosses	1.00	1.00	1.00	1.00	1.00 ± 0.00
Touches	1.00	1.00	1.00	1.00	1.00 ± 0.00
Overlaps	0.80	0.52	0.47	0.28	0.52 ± 0.21
Average	0.97 ± 0.07	0.94 ± 0.16	0.93 ± 0.17	0.90 ± 0.23	0.94 ± 0.03

F-measures results of applying RADON against geometries generated using the *Douglas-Peucker* line simplification algorithm.

Q_1

How much performance (i.e., F-measure) each of the geospatial LD approaches loses, when to deal with the simplified geometries vs. when to deal with the original ones?

- The second set of experiments setup:
  - ORCHID for measuring the distance between point-sets
  - *Douglas-Peucker* with simplification factors of $0.05, 0.09, 0.10$ and 0.2
  - NUTS dataset dedublicated to compute F-measure
  - NUTS dataset as a source and as a target (deduplication)

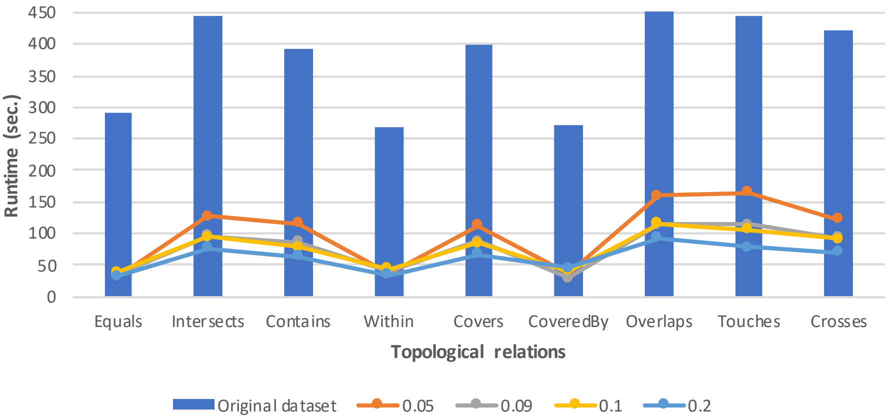
Measure/Factor	0.05	0.9	0.1	0.2	0.3	Average	$F_{original}$
Hausdorff	0.90	0.91	0.91	0.91	0.91	0.91 ± 0.00	0.88
Mean	0.94	0.94	0.94	0.94	0.94	0.94 ± 0.00	0.94
Min	0.14	0.16	0.16	0.21	0.25	0.18 ± 0.04	0.13
Link	0.95	0.95	0.94	0.94	0.94	0.94 ± 0.00	0.94
SumOfMin	0.95	0.95	0.94	0.94	0.94	0.94 ± 0.00	0.94
avarege	0.77 ± 0.36	0.78 ± 0.35	0.78 ± 0.35	0.79 ± 0.32	0.80 ± 0.31		0.77 ± 0.36

F-measures results of the point-set distance measures implementations in ORCHID using the *Douglas-Peucker* line simplification algorithm.

Q_2

How well each of the geospatial LD approaches scale (i.e., runtime speedup), and when to deal with the simplified geometries?

- The third sets of experiments setup:
  - Same setting as in the first sets of experiments
    - RADON for discovering topological relations
    - *Douglas-Peucker* with simplification factors of $0.05, 0.09, 0.10$ and 0.2
    - NUTS dataset as a source and CLC dataset as a target



Runtimes of RADON's implementation of topological relations LD using the *Douglas-Peucker* algorithm

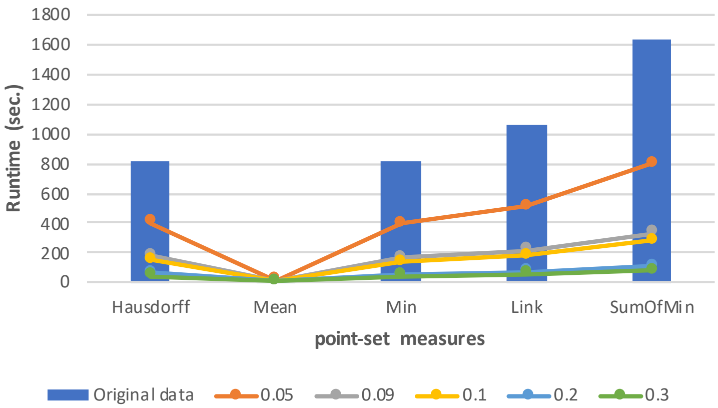
Q_2

How well each of the geospatial LD approaches scale (i.e., runtime speedup), and when to deal with the simplified geometries?

- The fourth set of experiments:
  - Same setting in the second sets of experiments
    - ORCHID for measuring the distance between point-sets
    - *Douglas-Peucker* with simplification factors of $0.05, 0.09, 0.10$ and 0.2
    - NUTS dataset dedublicated to compute F-measure
    - NUTS dataset as a source and as a target (deduplication)

Evaluation

Runtime Analysis



Runtimes of ORCHID's implementation of set-points distance measure LD using the *Douglas-Peucker* algorithm

Q_3

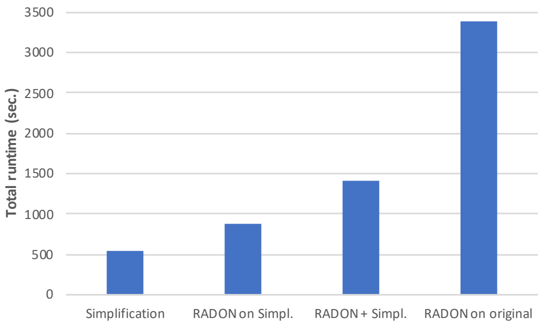
Which relation is the most/least affected by the simplification process?

- Same setting in the first and second sets of experiments
- The relation `overlaps` has the most affected F-measure when using *Douglas-Peucker* algorithm, (see Table 14)
- The `equals`,`crosses` and `touches` are not affected at all by any simplification (see Tables 14
- In the case of point-set measures, the F-measure of `min` measure is the most affected, (see Table 16)

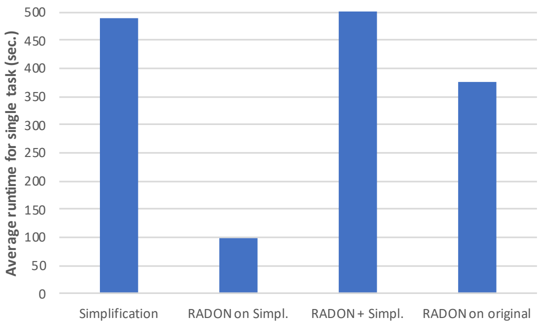
Q_4

What is the run time cost of simplification?

- Same setting in the third and fourth sets of experiments



Total Runtime for all topological relations.



Average Runtime of a single topological relation.

Runtime of RADON on the original data vs. simplified data using the *Douglas-Peucker* algorithm.

Conclusion & Future Work

- Conclusion
  - Studied the usage of line simplification as a preprocessing step of LD approaches over geospatial RDF knowledge bases
  - Studied the behaviour of two categories of geospatial linking approaches (i.e., the topological relations and point-set distances)
  - On average, F-measure of 0.94 using the *Douglas-Peucker* algorithm and 0.69 using the *Visvalingam-Whyatt* algorithm has been achieved.
  - Gain up to 19.8$\times$ speedup using *Douglas-Peucker* algorithm and up to 67.3$\times$ using the *Visvalingam-Whyatt*
- Future Work
  - Guarantee the minimum F-measure loss
  - Determine fittest line simplification algorithm and its best parameter to achieve a better trad-off between F-measure and Runtime

Thank you for your Attention!

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`https://github.com/dice-group/Orchid`

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