Mining Citations, Linking Texts

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L'édition critique à l'ère numérique – Genève 2 March 2016

Overview

My PhD

- **Dissertation**:
  - *From Index Locorum to Citation Network: an Approach to the Automatic Extraction of Canonical References and its Applications to the Study of Classical Texts*.
  - `http://hdl.handle.net/11858/00-1780-0000-002A-4537-A`
- Department of Digital Humanities, King's College London
- **supervisors:**
  - Willard McCarty
  - Shalom Lappin

References in Classics

Canonical References

- Vergil, *Aen.* 12, 101-109
- Thuc. I 89, 1
- Hom. *Il.* 7.180

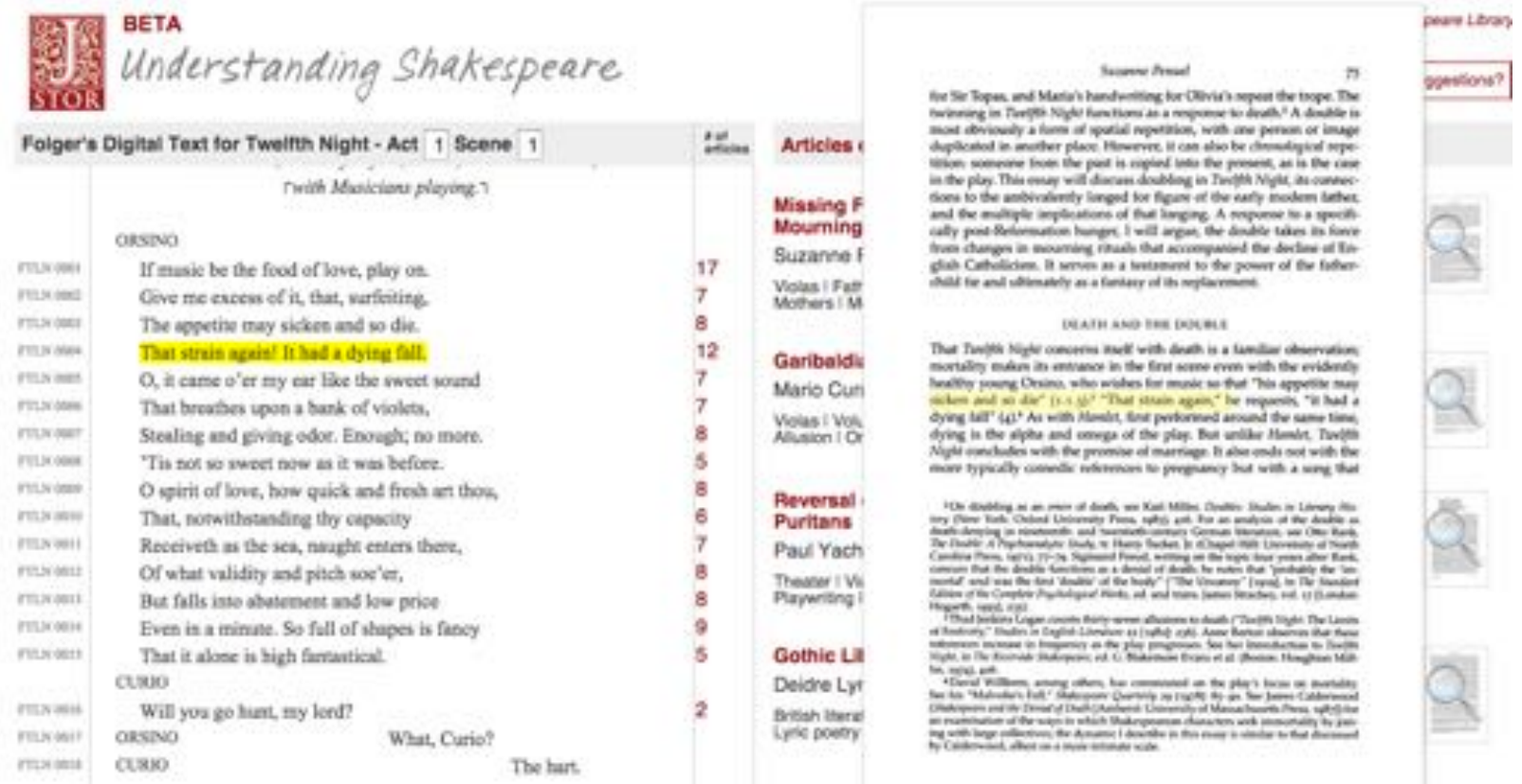
But also references to:

- inscriptions (e.g. CIL 3, 6174; AE 1991, 1405)
- papyri (e.g. PCair. inv. 10750)
- manuscripts (e.g. Vendôme, Bibl. mun. 31)
- fragmentary texts, coins, etc.

Yandle's Line-by-line Bibliography of the *Parzival*

Line-by-line Bibliographical Database of Wolfram von Eschenbach's Parzival, `http://wolfram.lexcoll.com/txts/index.htm`

JSTOR Labs: Understanding Shakespeare



http://labs.jstor.org/shakespeare/

Research questions

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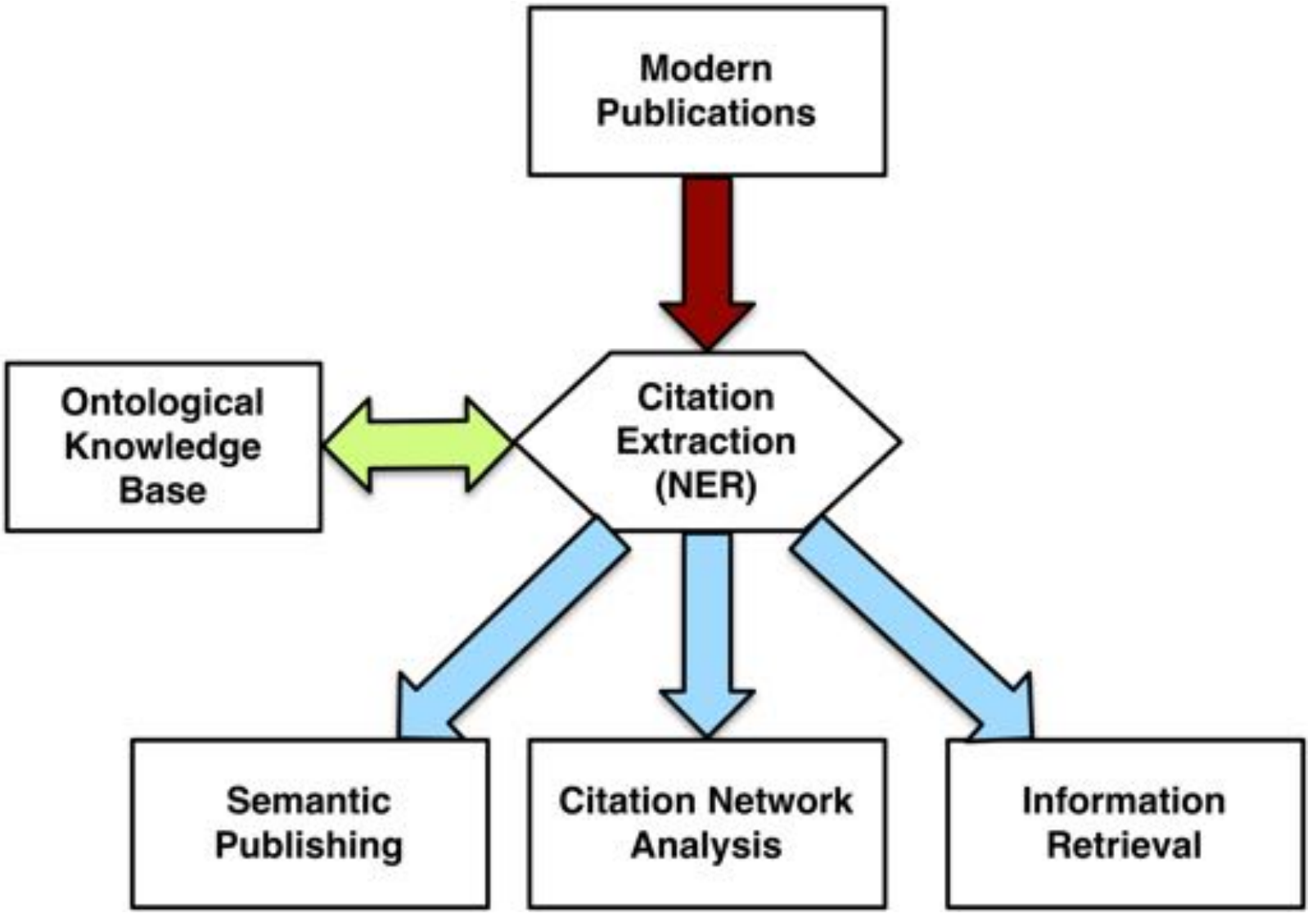
2. With what level of accuracy can this extraction be performed?
3. How can a system be implemented to perform this task?
4. How might the applications enabled by the automatic extraction of canonical references change the way we study classical texts?

The Big Picture



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   - the development of new search tools
   - the analysis of these networks

From *Index Locorum* to Citation Network

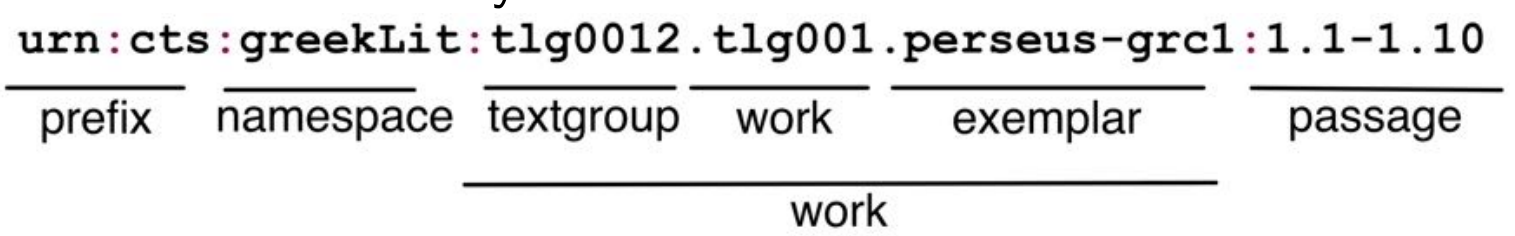
Index locorum.

From Footnotes/References to Links

- *footnotes*: only backwards
- *references*: only outwards
- *links*:
  - future-proof footnotes
  - reverse references
- Pelagios:
  - focus on place names/geographical data
  - common unique identifiers to expresss place references
  - resources referring to same place connected together
- linking texts by mining references/citations
  - but common identifiers are needed...

Canonical Text Services Unique Resource Names (CTS URNs)

A machine-readable syntax for canonical references

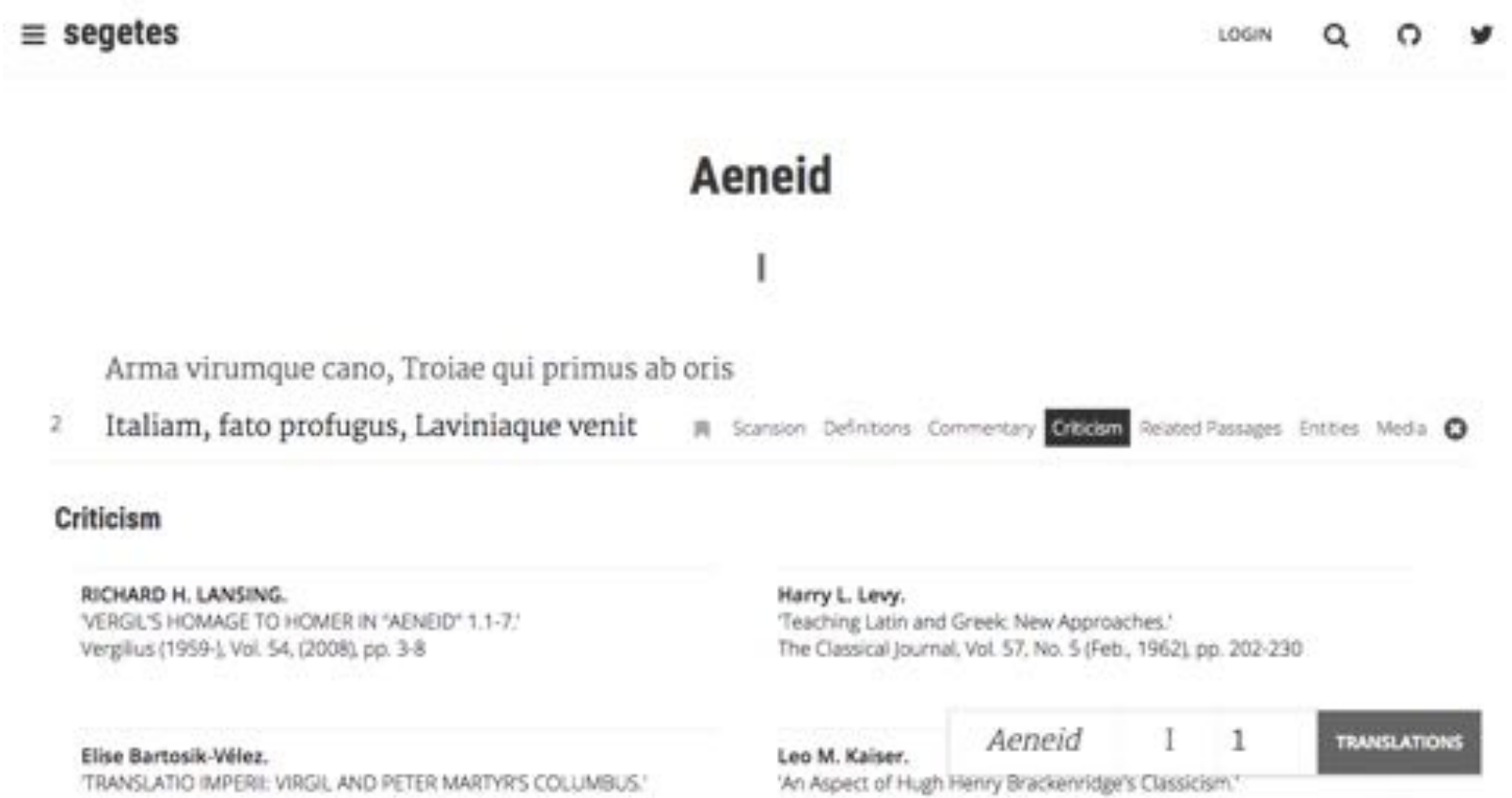


- Homer
  - `urn:cts:greekLit:tlg0012`
- Homer's *Iliad*
  - `urn:cts:greekLit:tlg0012.tlg001`
- Hom., *Il.* 1.1-10
  - `urn:cts:greekLit:tlg0012.tlg001:1.1-1.10`

Enhanced Digital Editions (1)

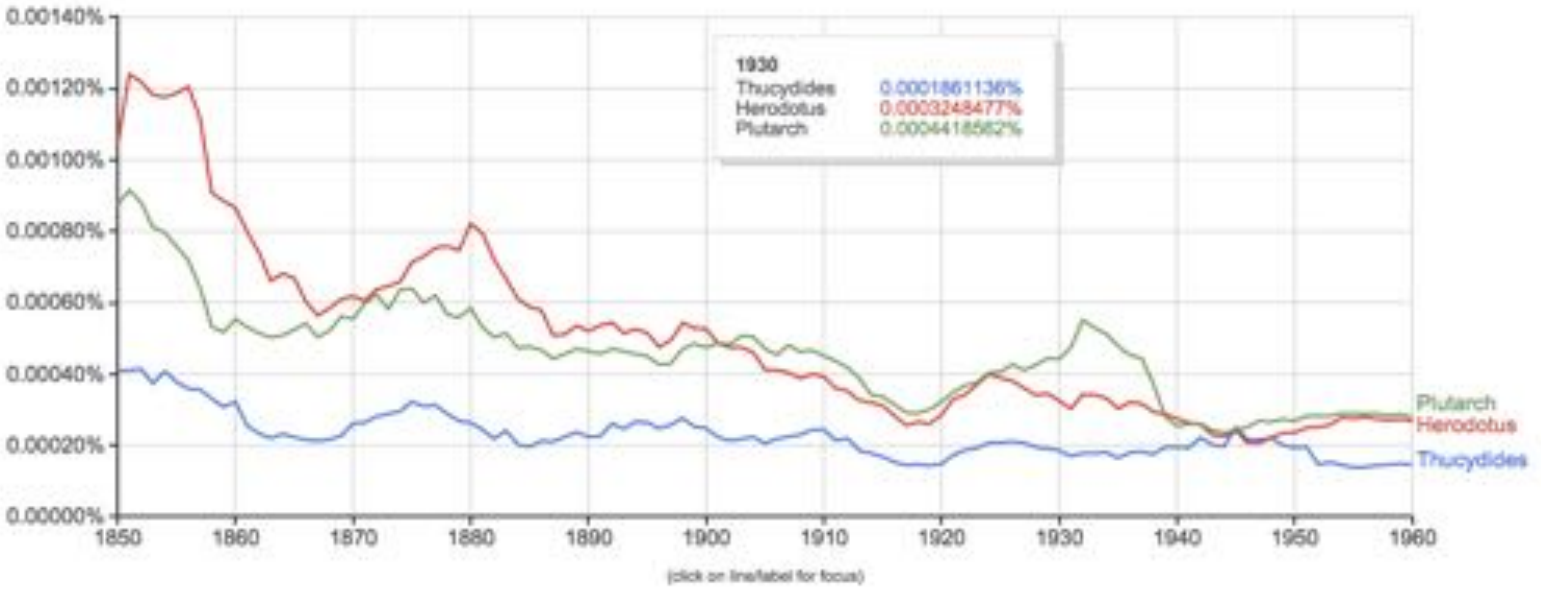
Hellespont Project
`http://gapvis.hellespont.dainst.org/#book/1/read/113/`

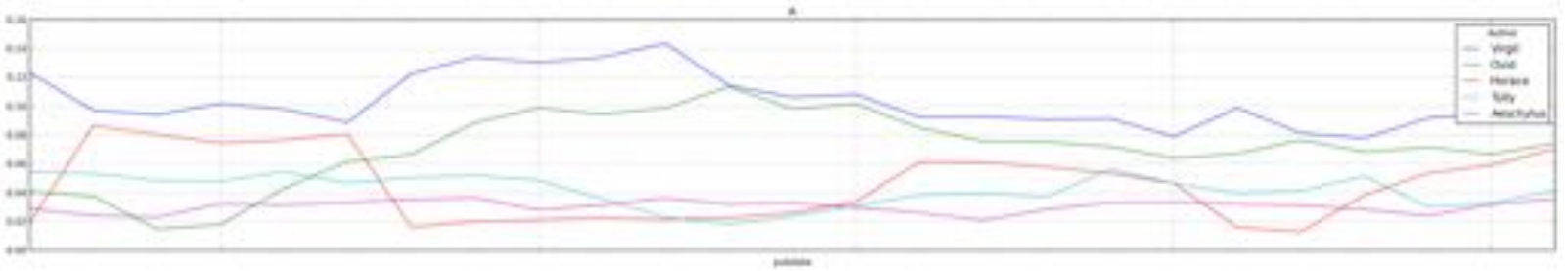
Enhanced Digital Editions (2)

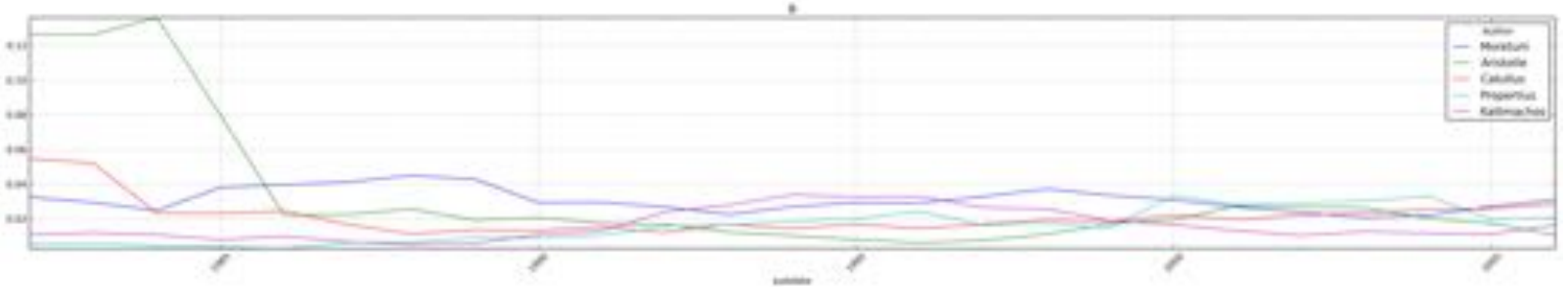


Segetes, `http://segetes.io/aeneid`

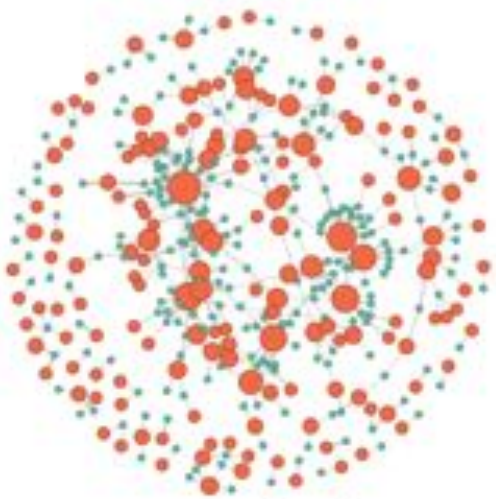
Distant Reading

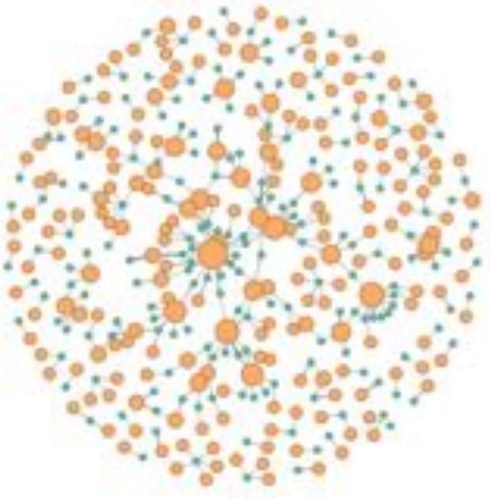






Networks & Information Retrieval





with applications to:

1. search
2. document clustering
3. network analysis and visualisation

Extraction – Approach

Rationale

- beyond string-based search
- references not quotations
- scalable approach:
  - language independent
  - applicable to large amounts of documents
  - easily adaptable to different materials and ways of referencing

Examples:

- In Statius' « Achilleid » (2, 96-102) Achilles describes [...]
- e.g. Vergil, Aen. 12, 101-109 ; Lucan 1, 204-212 ; Statius, Th. 12, 736-740 [...]

Named Entity Recognition

Computer Science > Information Extraction > NER

Question Answering System

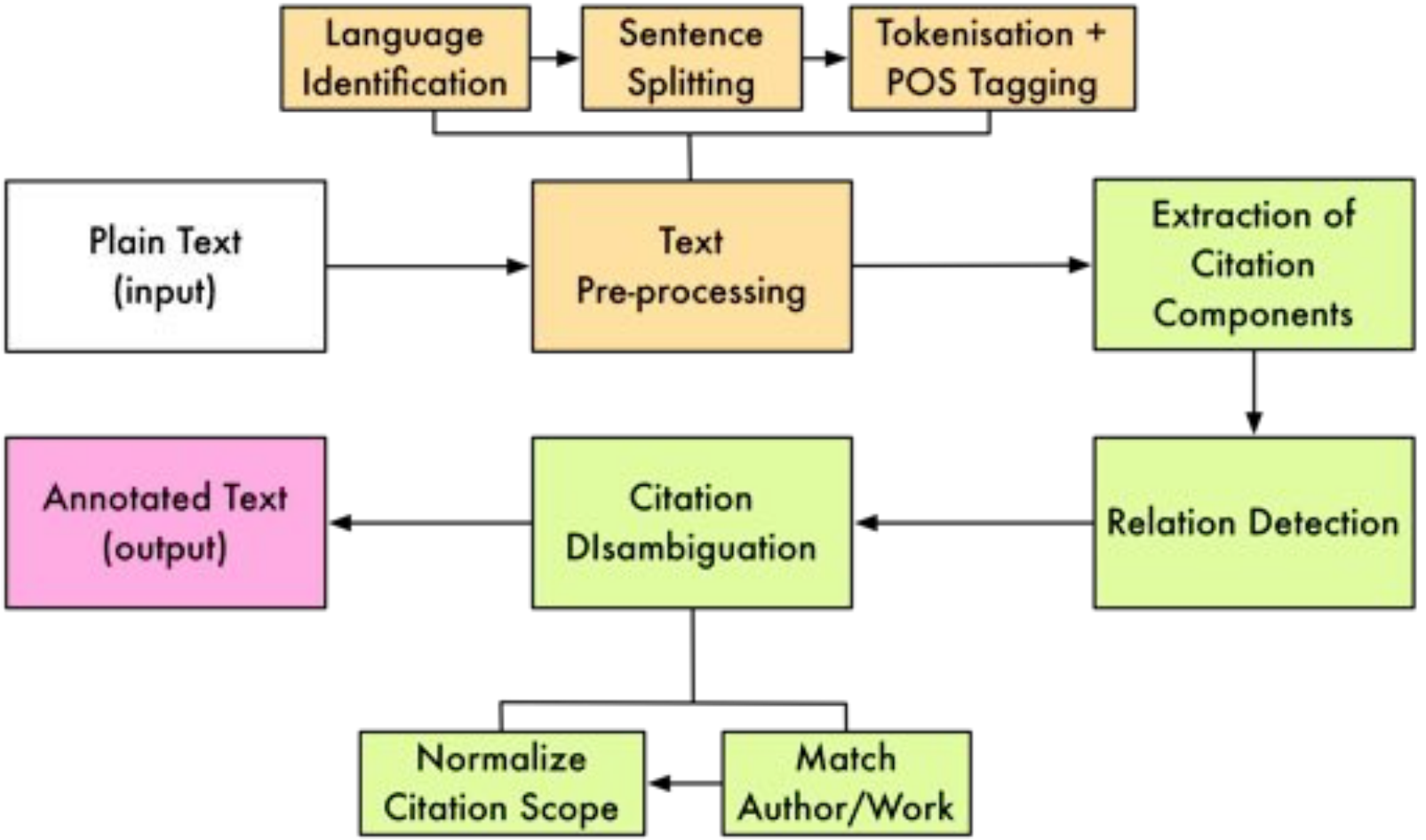
- **Q:** where did Aaron Swartz die?
- **A:** New York

Two days after the prosecution rejected a counter-offer by ***Swartz****,* ***he*** was found dead in *his* ***Brooklyn, New York*** *apartment, where he had hanged himself.*

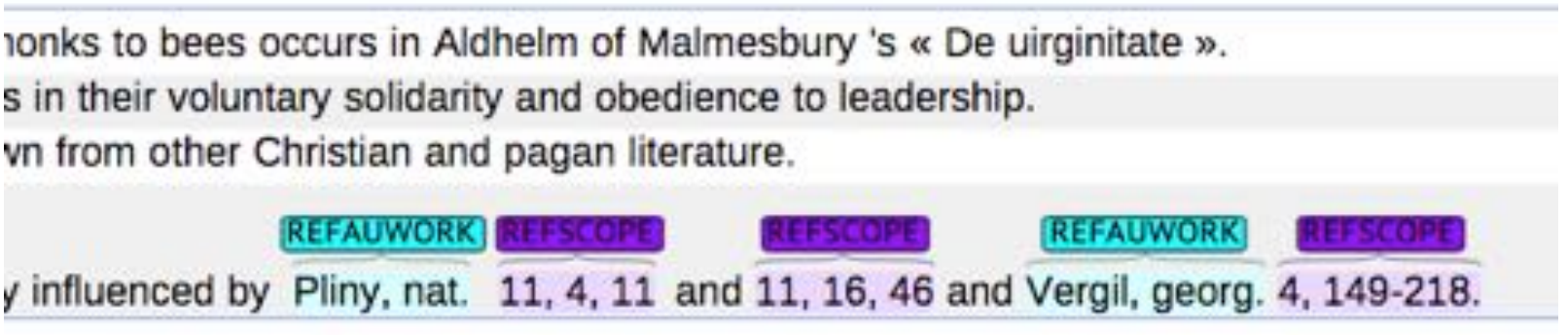
3-step process:

1. Named Entity Recognition and Classification
2. Relation Extraction
3. Named Entity Disambiguation

The Extraction Pipeline



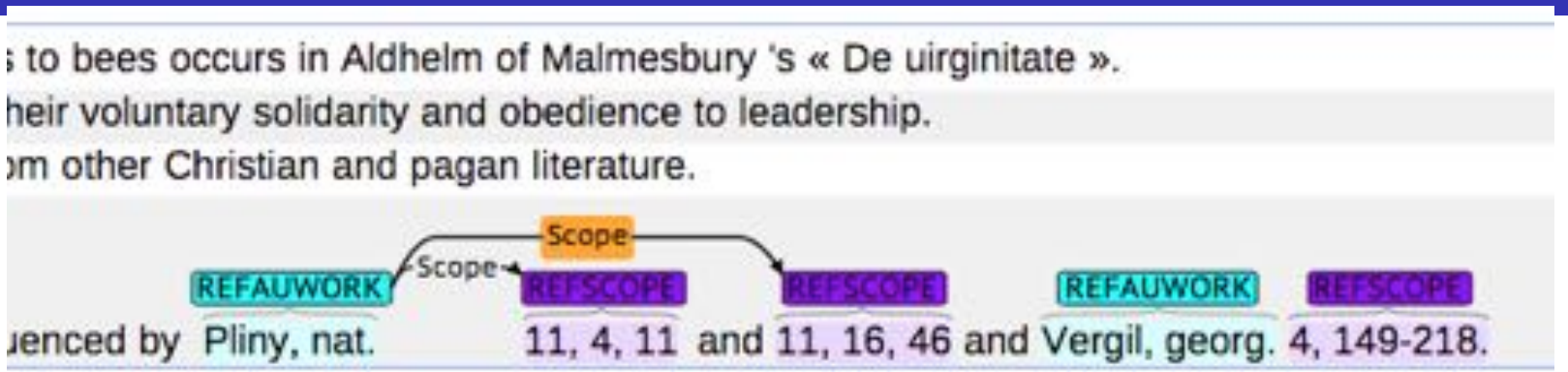
Citation Extraction: Step 1 (NER)



Named Entities (= citation components):

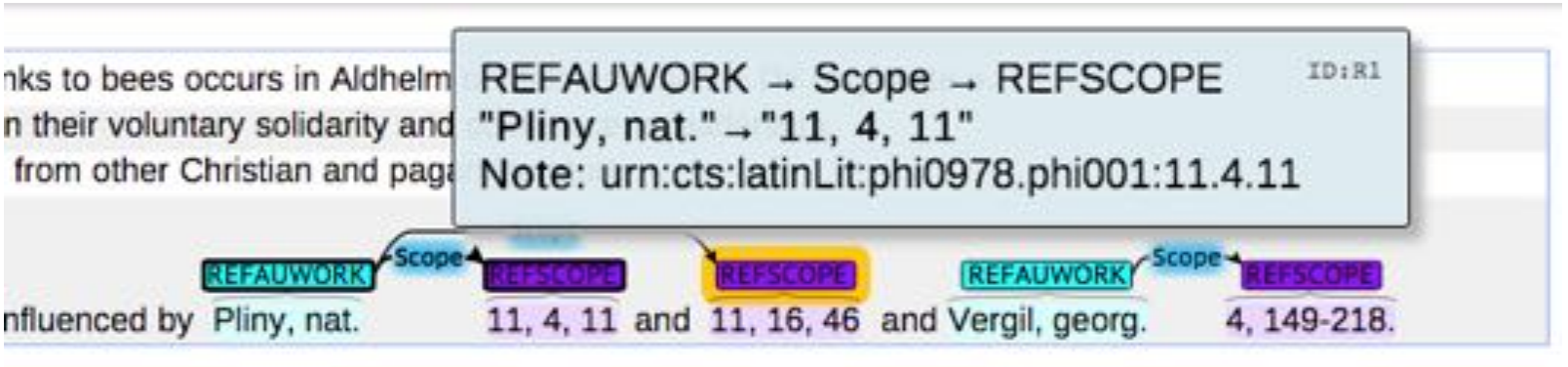
- `AAUTHOR` = ancient author
- `AWORK` = ancient work
- `REFAUWORK` = concise reference to author, work or both ("Pliny, nat.", "Thuc.")
- `REFSCOPE` = indication of the cited passage ("11, 4, 11")

Citation Extraction: Step 2 (Relation Detection)



- reference as *relation* vs. reference as *monolithic entity*
- binary `scope` relation between two entities (arguments)
  - arg1: `aauthor` | `awork` | `refauwork`
  - arg2: `refscope`
- examples:
  - Ammianus (15, 8, 7) {aauthor+refscope}
  - Trabajos 159–173" {awork+refscope}
  - Thuc. 1.89.1 {refauwork+refscope}

Citation Extraction: Step 3 (Disambiguation)



- assign each author/work/canonical reference a unique ID
- IDs are CTS URNs

Extraction – Evaluation

L'Année philologique (APh)

http://www.annee-philologique.com/

APh Example

APh 75-06697 => S. Braund & G. Gilbert. 2004. "An ABC of epic ira: anger, beasts, and cannibalism" *Yale Classical Studies* 32:250-285

> *In Statius ' « Achilleid » (2, 96-102) Achilles describes his diet of wild animals in infancy, which rendered him fearless and may indicate another aspect of his character - a tendency toward aggression and anger.*

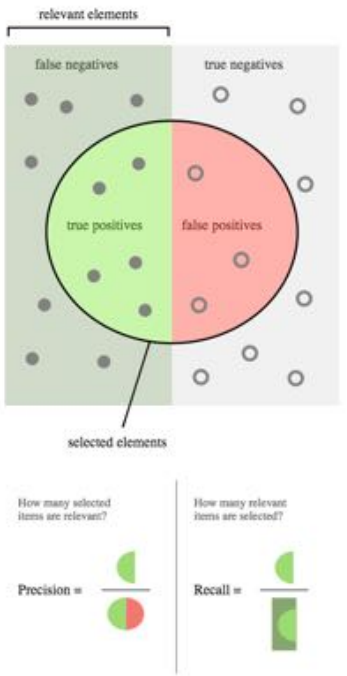
> *The portrayal of angry warriors in Roman epic is effected for the most part not by direct descriptions but indirectly, by similes of wild beasts (e.g. Vergil, Aen. 12, 101-109; Lucan 1, 204-212; Statius, Th. 12, 736-740; Silius 5, 306-315).*

> *These similes may be compared to two passages from Statius (Th. 1, 395-433 and 8, 383-394) that portray the onset of anger in direct narrative. Analysis of these passages demonstrates that the concept of « ira » in epic takes its moral aspect from the context.*

The Data

- **APh**
  - analytical reviews (en, de, fr, es, it)
  - 80 volumes (1924-)
  - autom. processed vol. 75 (2004)
    - 6,694 abstracts (total = 6,946; errors = 252)
    - 350k tokens
    - 3k citations
  - man. corrected ~8 % of vol. 75
    - 366 abstracts
    - 26k tokens
    - 380 citations

Precision, Recall and F1 Score



https://commons.wikimedia.org/wiki/File:Precisionrecall.svg

By Walber (Own work) [CC BY-SA 4.0]

Evaluation Summary

Task	Precision	Recall	F_1 Score
NER	79.24%	69.62%	73.88%
RelEx	93.33%	91.87%	92.60%
NED	61.04%	90.94%	73.05%

- methods:
  - NER: machine learning-based
  - RelEx: rule-based
  - NED: rule-based + knowledge base

NER: Method

1. Linguistic Features (PoS Tag, neighbouring words)
2. Word-level Features:
   - punctuation
     - final_dot, quotation_mark, has_hyphen, bracket
   - case
     - mixed_caps, all_caps, init_caps, all_lower
   - number
     - roman, year, range, mixed_alphanum
   - patterns
     - "Avien." –> "Aaaaa-" (expanded)
     - "Avien." –> "Aa-" (compressed)
3. Semantic Features (matches against dictionaries)

NER: Evaluation

Task: extraction of entities `aauthor`, `awork`, `refauwork`, `refscope`

Algorithm	**Precision**	**Recall**	**F_1 Score**
CRF	**79.24%**	69.62%	**73.88%**
MaxEnt	75.29%	66.75%	70.43%
SVM	74.44%	**70.21%**	71.93%

`Aauthor` : P = 91.15%, R = 39.67%, F_1 = 54.53%

RelEx: Evaluation

- rule-based method

Precision	Recall	F_1 Score
93.33%	91.87%	92.60%

Missed `scope` relations:

- du [REFSCOPE chant 4] de l' [AWORK « Énéide »]
- Le [REFSCOPE livre 13] de la [AWORK « Chronique »]
- les [REFSCOPE v. 9–12] des [AWORK « Acharniens »]

NED: Method

Thuc. I 89, 1s.

1. match reference against knowledge base
   - exact/approximate string matching
     - `edit_distance("Tucidide","Thucydides") = 3`
   - Thuc. → `urn:cts:greekLit:tlg0003.tlg001`
2. normalise the reference scope
   - I 89, 1s. → 1.89.1–1.89.2
   - other possible variants:
     - 1.89.1–2
     - 1, 89, 1–2
3. assign unique ID
   - `urn:cts:greekLit:tlg0003.tlg001:1.89.1-1.89.2`

NED: Evaluation

Matching Type	**Precision**	**Recall**	**F_1 Score**
Exact	58.33%	62.88%	60.52%
Approximate (n=4)	61.04%	90.94%	73.05%
Approximate (n=7)	58.94%	94.76%	72.67%

NED: Error Types

1. abbreviation is highly ambiguous

   *But **Horace** undermines the suggestion that his own poetry will forever represent the Augustan Age. **Carm. 4, 15** in fact [...]*

2. ambiguous author mention

   *Esame dell' esegesi papiracea ad **Aristofane** : permanenza del lavoro degli eruditi alessandrini [...]*

NED: Error Types (contd.)

3 implicit topicalisation

*Dans son **chap. 5** sur le squelette et la respiration, **Lactance** utilise des sources disparates et arrive aux limites de son savoir médical.*

4 ambiguously expressed reference

*Analysis of the pederastic poems in the Theocritean corpus **(12 ; 23 ; 29 ; 30)** reveals that **Theocritus** reflects on mutuality in a relationship [...]*

Future Plans

Large-scale Extraction and Analysis

JSTOR data

- 130k articles, 320m tokens of text
- >200 years of classical scholarship

Analysis

- diachronic citation trends
- longitudinal network analysis

Bottleneck

- processing time (single machine, single process)
- parallelisation of the code, use of EPFL's cluster
  - pre-processing of JSTOR data, 6 months → 6 days

Citation Extraction

Improve Overall Accuracy

- test machine learning methods for RelEx and NED
- get more training data, expand entity set
- expand the knowledge base

Share the Software

- streamline installation
- improve documentation
- offer as web service
- offer as part of a research infrastructure

Thank you for your attention!

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