

Knowledge Graphs

Lecture 6 – Intelligent Applications with Knowledge Graphs and Deep Learning
6.5 Semantic Search

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Knowledge Graphs

Lecture 6: Intelligent Applications with Knowledge Graphs and Deep Learning

6.1 The Graph in Knowledge Graphs

Excursion 8: Distributional Semantics and Language Models

6.2 Knowledge Graph Embeddings

6.3 Knowledge Graph Completion

6.4 Knowledge Graphs and Language Models

6.5 Semantic Search

6.6 Exploratory Search and Recommender Systems



How do we find this?

Los dos hermanos



"Two fearsome sea monsters attack a disabled ship off the shore of America, which is shown in close proximity to Japan"

How to annotate Information Resources



comment: "Two fearsome sea monsters attack a disabled ship off the shore of America, which is shown in close proximity to Japan."
 position: area coordinates (x_1, y_1, x_2, y_1)

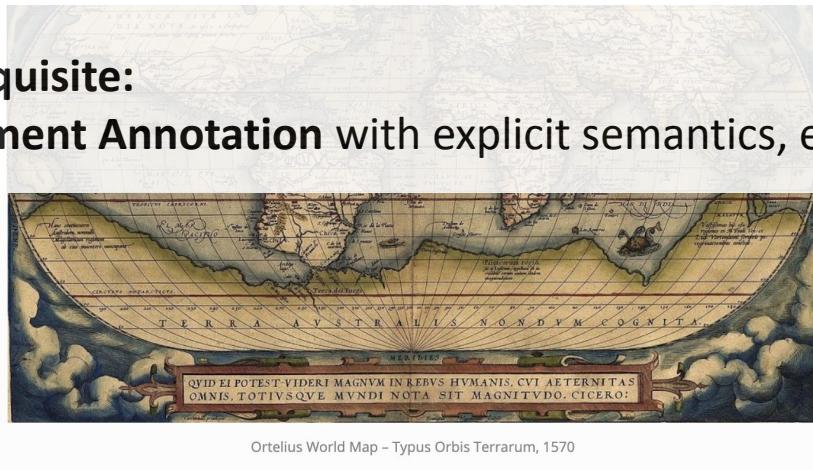
title: "Indiae Orientalis, Insularumque Adiacientium Typus"
 book: "Theatrum Orbis Terrarum, Latin edition"
 author: Abraham Ortelius
 date: 1603

External
Information?

"Indiae Orientalis, Insularumque Adiacientium Typus" from the Theatrum Orbis Terrarum of Abraham Ortelius, 1603 Latin edition.

Semantic Technologies Supported Information Retrieval

- Prerequisite:
Document Annotation with explicit semantics, e.g. semantic entities



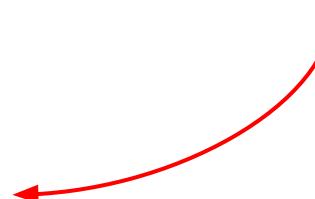
Example for
Semantic Annotation

On May 20, 1570, Belgian cartographer and geographer **Abraham Ortelius** published the first modern atlas, the *Theatrum Orbis Terrarum*, in Antwerp. The map consists of 53 sheets and sustaining text bound to form a book for engraving.

Abraham Ortelius – Early Years

Abraham Ortelius was born in Antwerp, but grew up in a small town near Antwerp. At a young age, he was appointed geographer to the Duke of Alva, who was in charge of the Spanish Netherlands. He traveled extensively through Europe, visiting France, Italy, and Spain.

Abraham Ortelius	
Abraham Ortelius (also Ortels, Orthellius, Wortels; 14 April 1527 – 28 June 1598) was a Flemish cartographer and geographer, specifically	
birth year	1527
death year	1598
death place	Antwerp

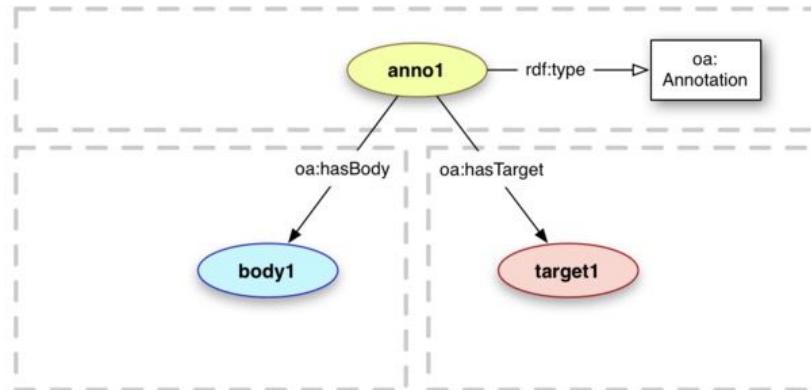


<http://scihi.org/abraham-ortelius-theatrum-orbis-terrarum/>

- Enables **entity-based Information Retrieval**
Language independent

Web Annotation Ontology

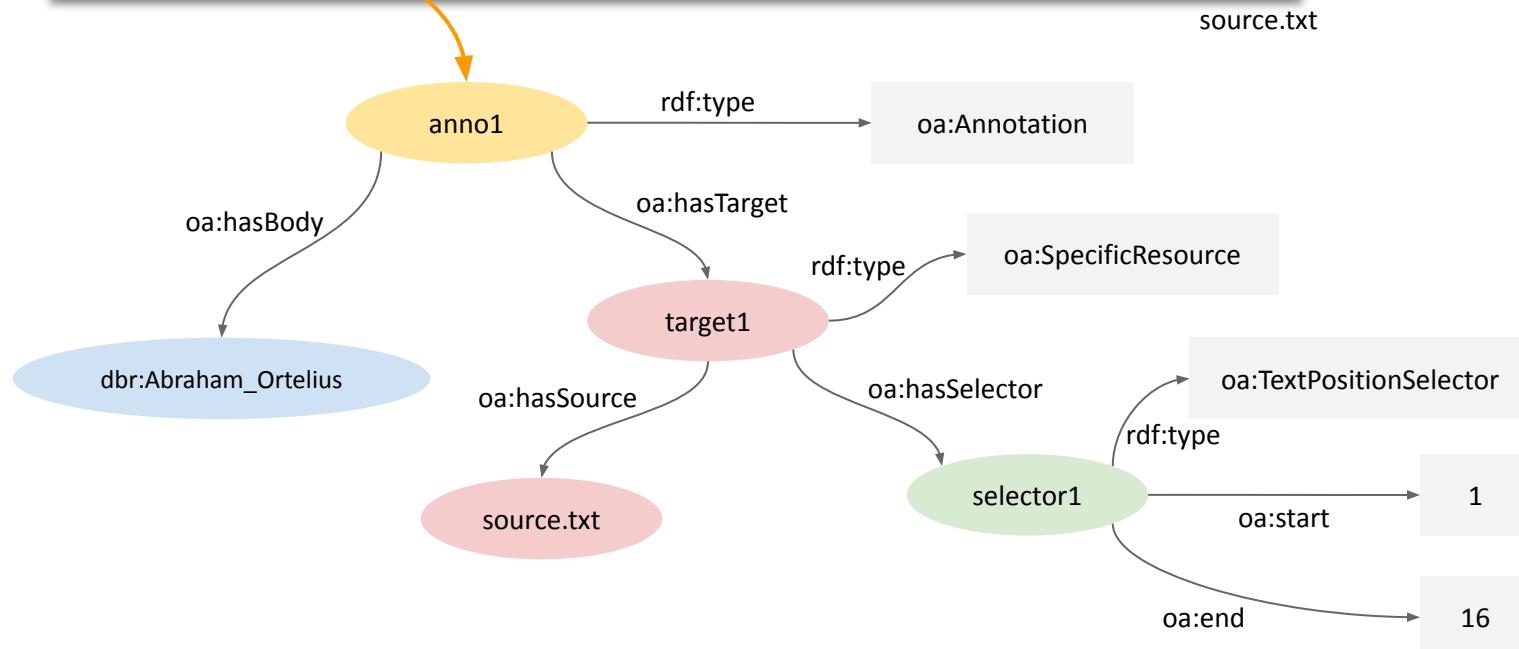
- The **Web Annotation Ontology** is a W3C Standard (2017) that “specifies an interoperable framework for creating associations between related resources, annotations, using a methodology that conforms to the Architecture of the World Wide Web.”



- The **Body** provides information which is describing the **Target**.

Semantic Annotation

Abraham Ortelius was a Brabantian cartographer, geographer, and cosmographer, conventionally recognized as the creator of the first modern atlas, the *Theatrum Orbis Terrarum*.



Abraham Ortelius (1527–1598)

[3]

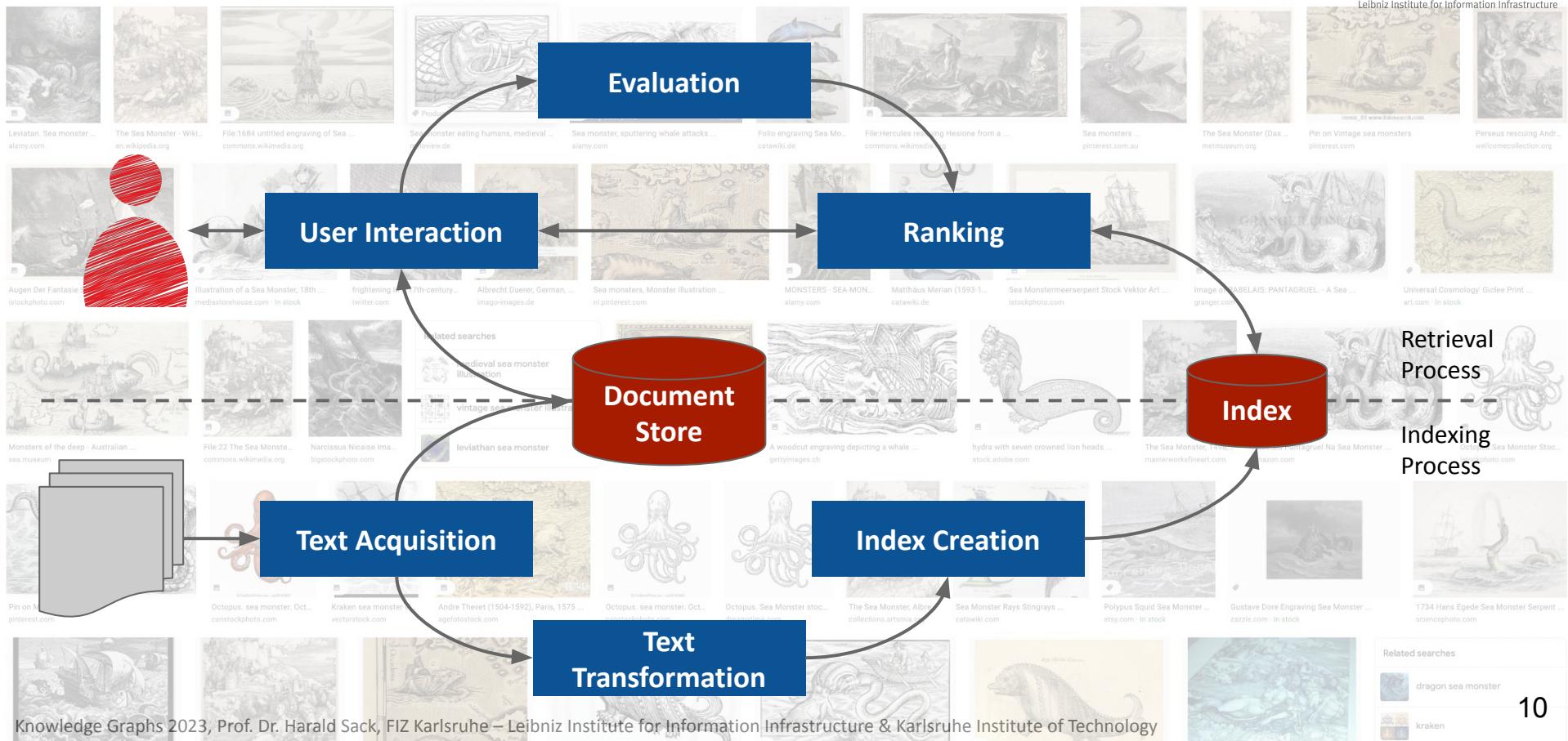
The Information Retrieval Dilemma



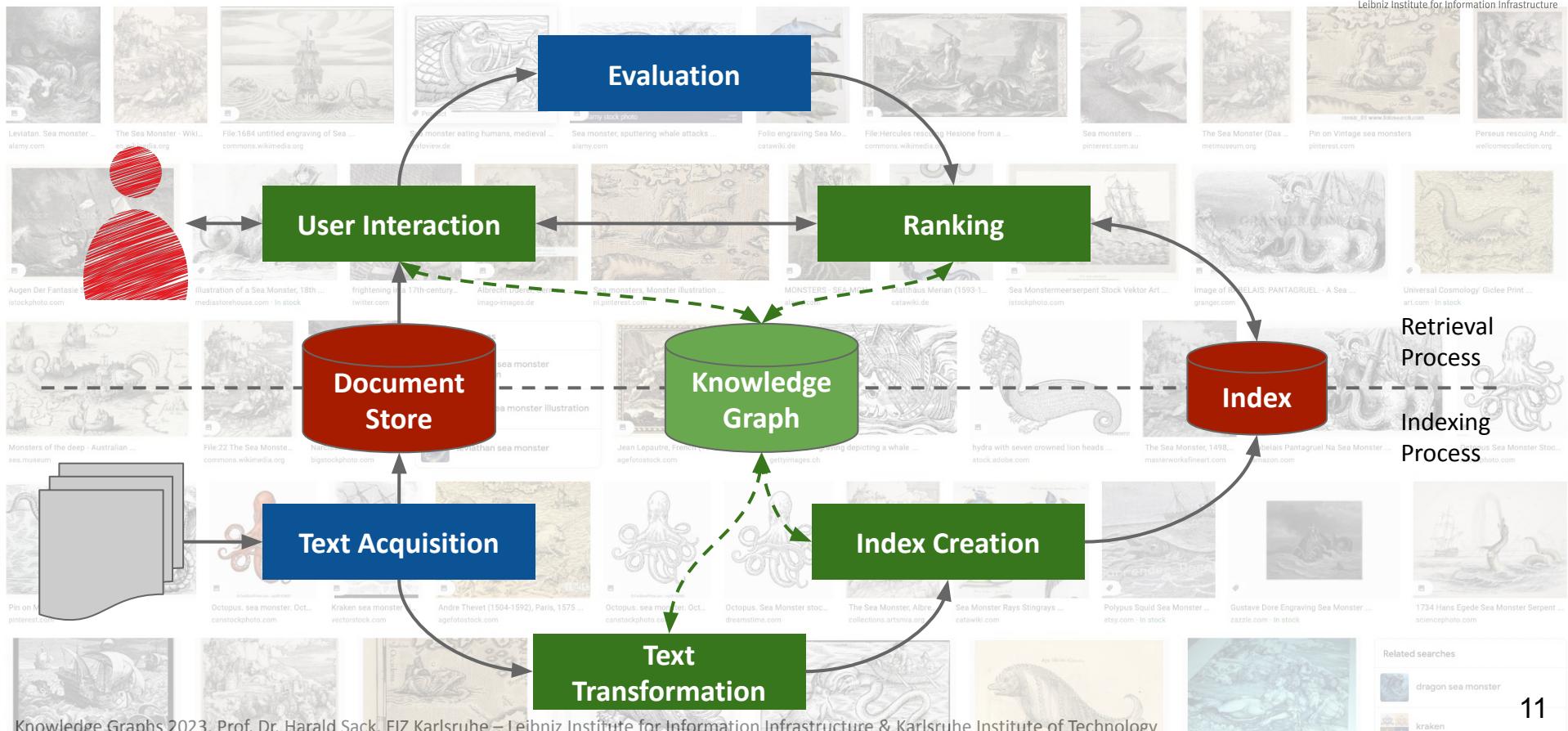
- Ambiguity of natural language (polysemy)
- Different words/expressions for the same concept (synonyms, metaphors, paraphrases, ...)
- Implicit (hidden) information
- Context knowledge and experience

How can Knowledge Graphs support IR?

The Information Retrieval Process



Semantic Technologies Supported IR



Semantic Search

Definition

Semantic Search is about

- going **beyond** documents and queries as **bag of words**,
- having a **deeper understanding** of document contents by leveraging **world knowledge** as structured data,
- going **beyond 10 blue links** and providing users with **direct answers** to their (natural language) questions.

Semantic Search

Possibilities

- **Prerequisite:** Annotation with explicit semantics, e.g. semantic entities
- Enables **entity-based Information Retrieval**
→ language independent
- Makes use of underlying Knowledge Bases, e.g.
 - content-based **similarities** among entities
 - content-based **relationships** between entities
- **Interoperable metadata** via semantic annotations
 - for content-based description
 - for structural and technical description
- **Content-Based Navigation and Result Filtering** (Search Facets)

Semantic Search

Benefits

- **Query String Refinement**
enables **more precise** or **more complete** search results.
- **Cross Referencing**
enables complementing search results with additional associated or similar information.
- **Fuzzy Search**
enables the determination of **nearby results** and **results related by content**.
- **Exploratory Search**
enables visualization and navigation of the search space.
- **Reasoning**
enables complementing search results with implicitly given information.

Entity-based Search

Simple Entity Matching

Query Processing:

Ortelius first Atlas

dbr:Abraham_Ortelius dbr:Atlas

Named Entity Linking

Indexing:

Ortelius publishes first world atlas

On May 22, 1570, bookmaking and map-making history were made. Abraham Ortelius, a Flemish book collector and engraver published the *Theatrum Orbis Terrarum* (Epitome of the Theater of the World) — the world's first atlas.

Entity Matching

Entity-Based Query Matching

- **simple entity matching**
- similarity-based entity matching
- relationship-based entity matching
- ...

Named Entity Linking

dbr:Atlas

Entity-based Search

Similarity-based Entity Matching

Query Processing:

Ortelius first Atlas

dbr:Abraham_Ortelius dbr:Atlas

Named Entity Linking

Indexing:

Mercator's atlas of Europe

Gerardus Mercator was perhaps the best-known mapmaker of all time. Rather than undertaking expeditions and mapping on the ground himself, however, he was an armchair cartographer.

dbr:Atlas
dbr:Gerardus_Mercator

Entity Matching

dbr:Abraham_Ortelius

semantic similarity

Entity-Based Query Matching

- simple entity matching
- **similarity-based entity matching**
- relationship-based entity matching
- ...

Two entities are considered **semantically similar**,

- if they share property-value pairs
- if they share properties with similar values.

Named Entity Linking

Entity-based Search

Relationship-based Entity Matching

Query Processing:

Ortelius first Atlas

dbr:Abraham_Ortelius dbr:Atlas

Named Entity Linking

Indexing:

Mercator's atlas of Europe

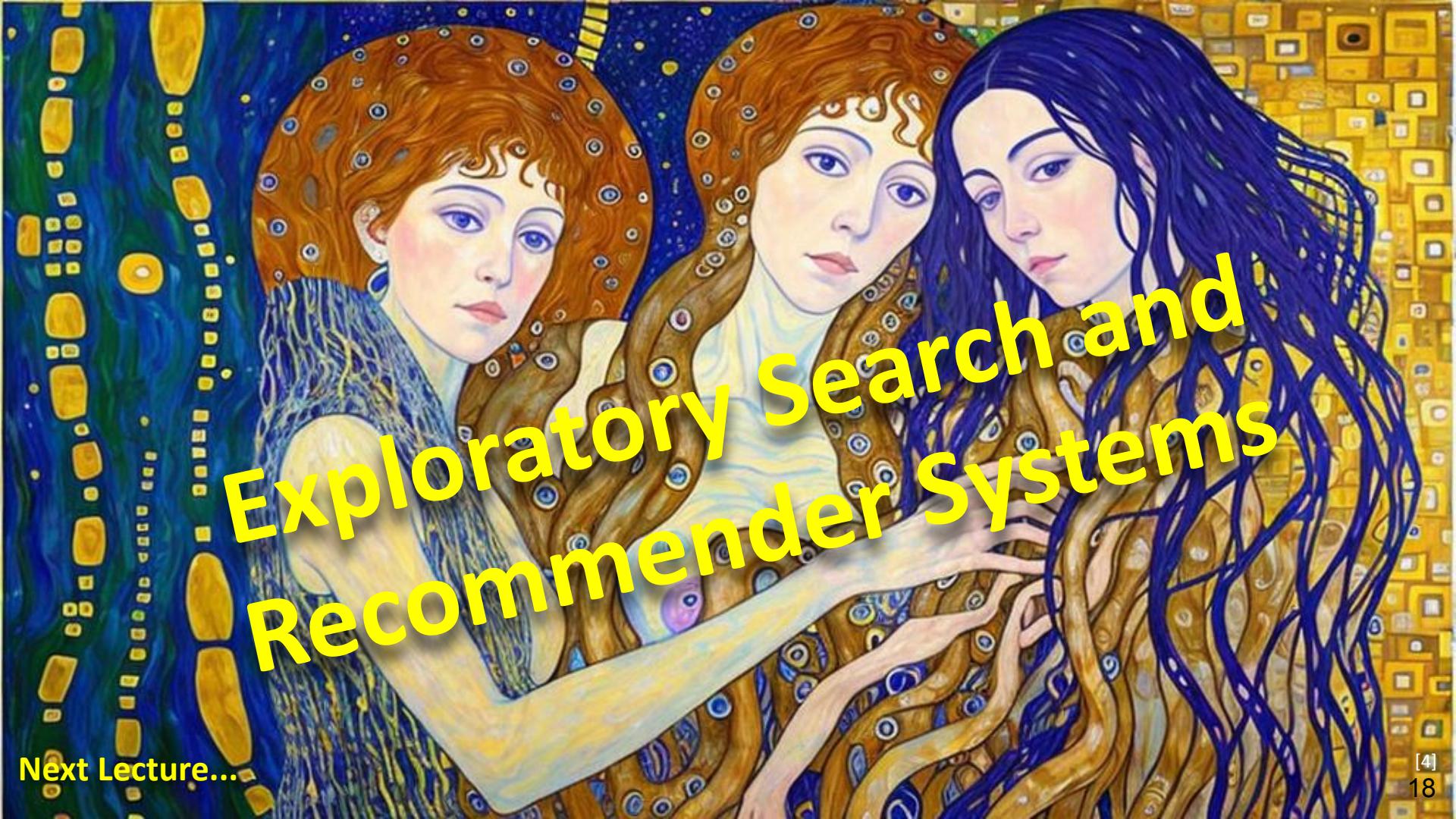
Gerardus Mercator was perhaps the best-known mapmaker of all time. Rather than undertaking expeditions and mapping on the ground himself, however, he was an armchair cartographer.

Named Entity Linking

Entity Matching

Entity-Based Query Matching

- simple entity matching
- **similarity-based entity matching**
- **relationship-based entity matching**
- ...

A stylized painting of three women with swirling, colorful hair in a blue and yellow abstract background. The women have blue eyes and are looking towards the viewer. The background features a grid of yellow squares and a blue starry pattern.

Exploratory Search and Recommender Systems

Next Lecture...

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Bibliographic References:

- Robert Sanderson, Paolo Ciccarese, Herbert Van de Sompel (2013), [Open Annotation Data Model, Community Draft](#), 08 February 2013
- Singhal, Amit (May 16, 2012). "[Introducing the Knowledge Graph: Things, Not Strings](#)". Google Official Blog.

Picture References:

- [1] "On this romantic painting in the style of Goya we see a pensive woman together together giant octopus who melancholically entangles the knowledge graph that extends into the vast empty space of the universe to the galaxies and stars.", created via ArtBot, Deliberate, 2023, [CC-BY-4.0],
<https://tinybots.net/artbot>
- [2] "Indiae Orientalis, Insularumque Adiacientium Typus," from the Theatrum Orbis Terrarum of Abraham Ortelius, 1603 Latin edition, [public domain],
https://commons.wikimedia.org/wiki/File:Two_fearsome_sea_monsters_attack_a_disabled_ship_off_the_shore_of_America,_which_is_shown_in_close_proximity_to_Japan.jpg
- [3] Peter Paul Rubens: Abraham Ortelius, 1633. [CC0], https://commons.wikimedia.org/wiki/File:Abraham_Ortelius_by_Peter_Paul_Rubens.jpg
- [4] "On this expressionistic painting in the style of Klimt we see a pensive woman together together giant octopus who melancholically entangles the knowledge graph that extends into the vast empty space of the universe to the galaxies and stars.", created via ArtBot, Deliberate, 2023, [CC-BY-4.0],
<https://tinybots.net/artbot>