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How to Create a National Cross-domain Ontology and Linked Data Infrastructure and Use It on the Semantic Web

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http://seco.cs.aalto.fi/u/eahyvone/

Contents

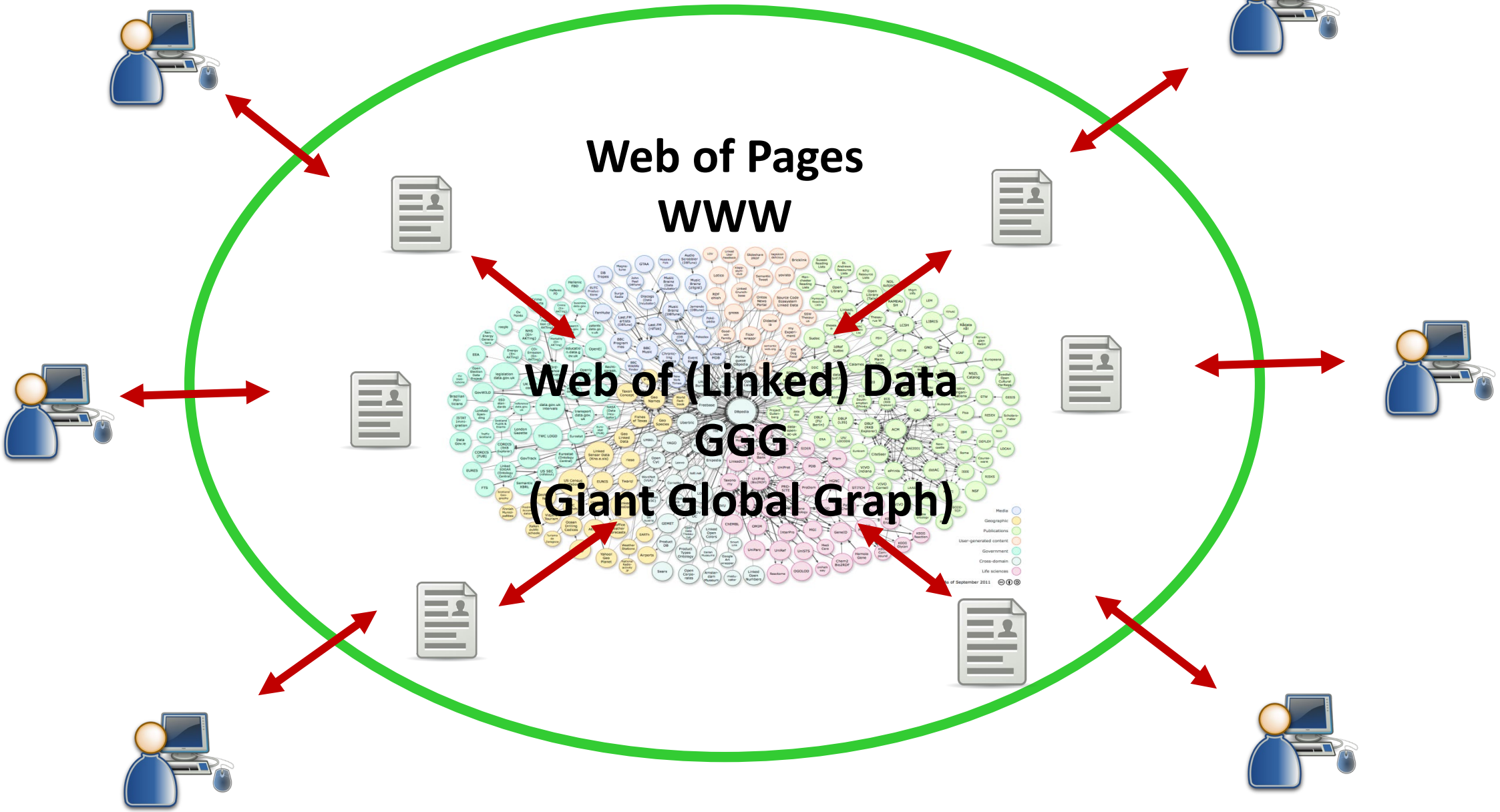
1. Semantic Web
   - Extending the Layer Cake Model
2. How to Build a National LOD Infrastructure?
   - Lessons learned in Finland
3. How to use SW Infra for Applications?
   - Sampo Model and series of systems
4. Paradigm Shifts in Web Publishing

1. SEMANTIC WEB

EXTENDING THE LAYER CAKE MODEL

Semantic Web

Web for People



Why Linked (Open) Data

- Enriching everybody's data collaboratively from separate silos
  - Everybody wins by collaboration!

- Creating Findable, Accessible, Interoperable, Re-usable data
  - The value of data increases!

FAIR

GO FAIR

https://www.go-fair.org/fair-principles/

- Creating more intelligent applications for the public, curators, and researchers
  - The machine "understands" linked data!

Evolving Layer Cake Model of W3C

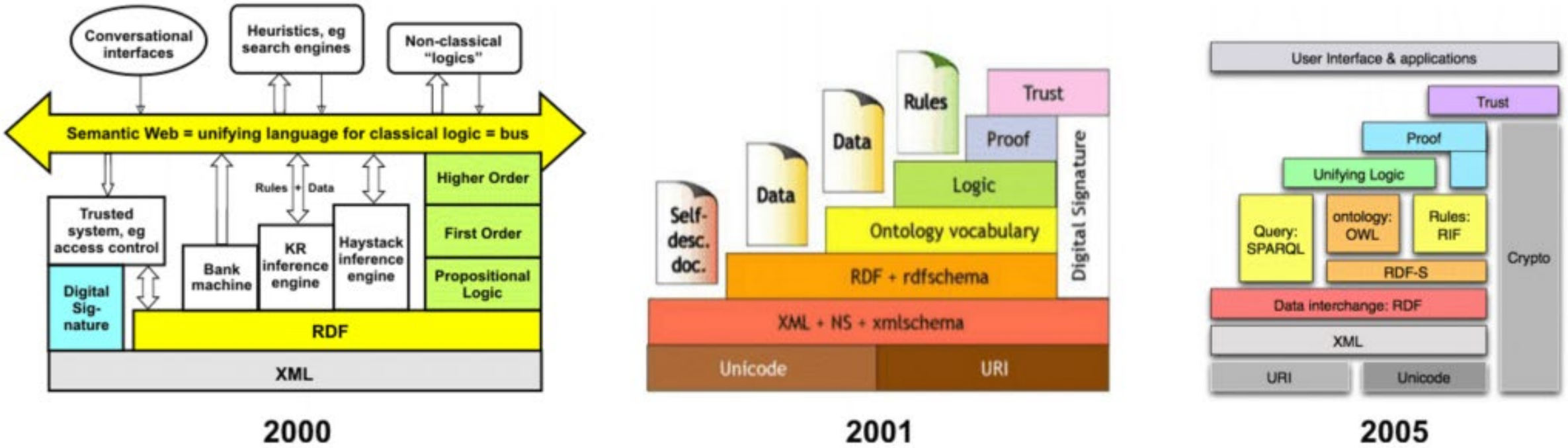


Figure 4. Evolution of the Semantic Web from 2000 to 2005

John Sowa: http://www.jfsowa.com/ikl/

Kingsley Uyi Idehen: https://medium.com/openlink-software-blog/semantic-web-layer-cake-tweak-explained-6ba5c6ac3fab

Key Challenges Addressed

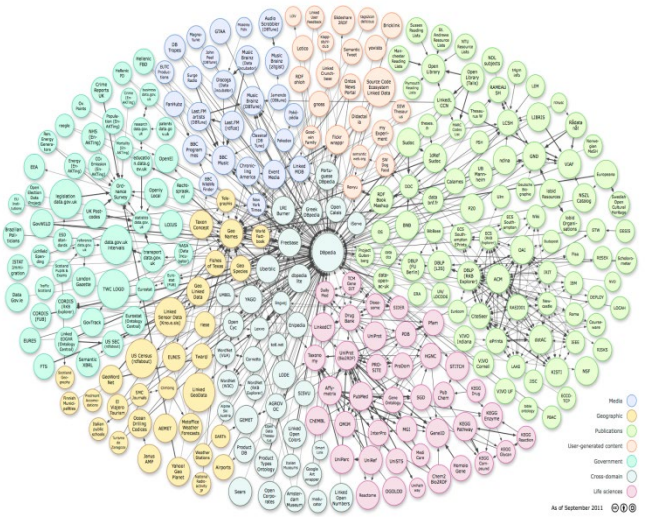
- W3C SW standards are based of First Order Predicate Logic
- Logic is a nice application domain agnostic model for
  - Knowledge representation and
  - Reasoning

- **Domain-specific models** are needed, too
  - Based on W3C SW standards
- **National level models** are needed using W3C SW standards
  - To support national languages, terminologies, data models, practices, …

Result: Content Infrastructure

Traditional Infras:
(rail)roads, electricity, …

Semantic Content Infra:
Ontologies, data, metadata, …



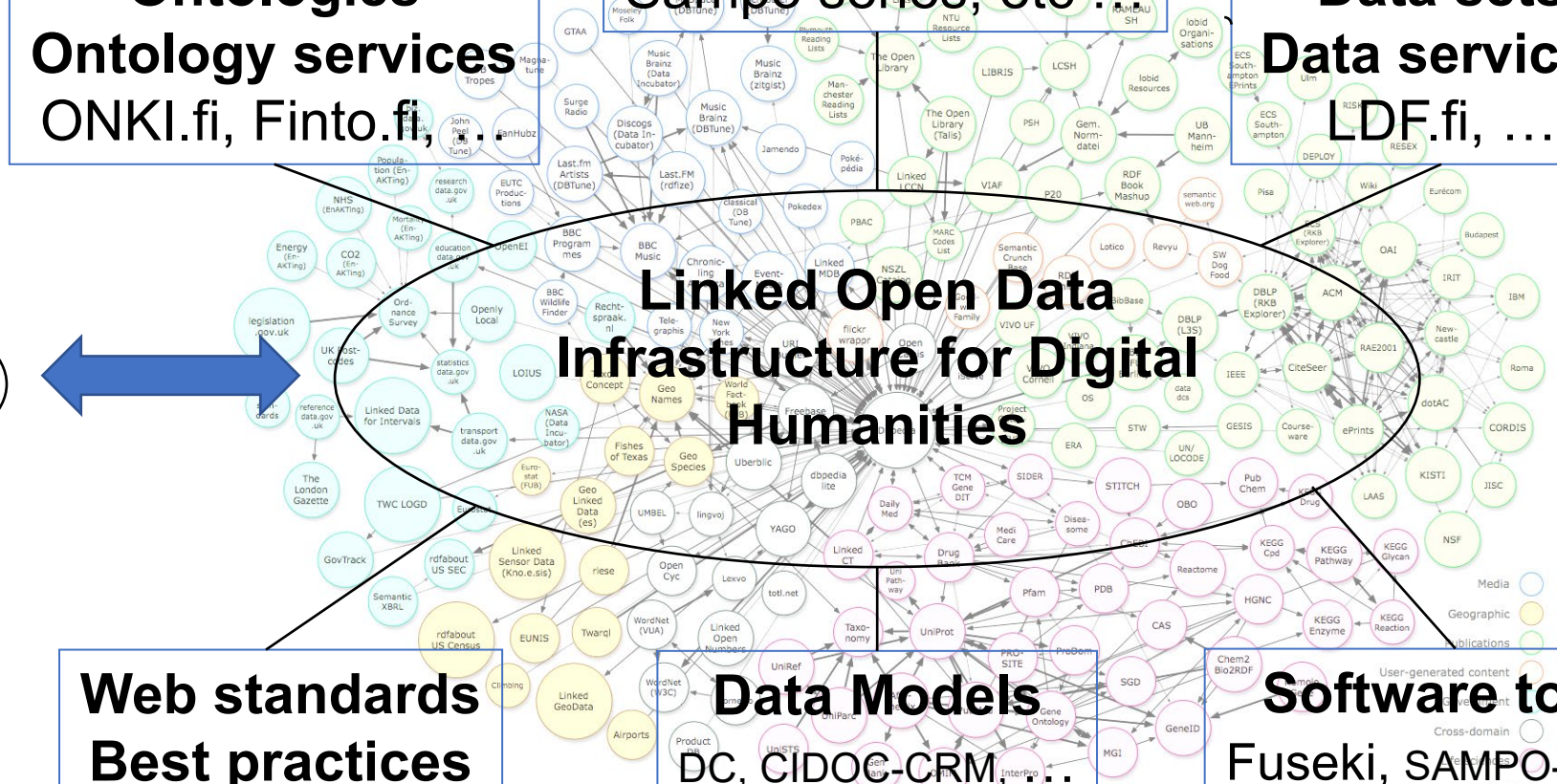
Linked Open Data Finland: Elements of a National Infrastructure

Applications
Sampo series, etc . . .

Ontologies
Ontology services
ONKI.fi, Finto.fi, . . .

Data sets
Data services
LDF.fi, …

Human Infrastructure



Web standards
Best practices
W3C, …

Data Models
DC, CIDOC-CRM, …

Software tools
Fuseki, SAMPO-UI, …

2. HOW TO BUILD A NATIONAL LOD INFRASTRUCTURE?

Lessons learned in Finland

Starting Point Challenge 2002-2004

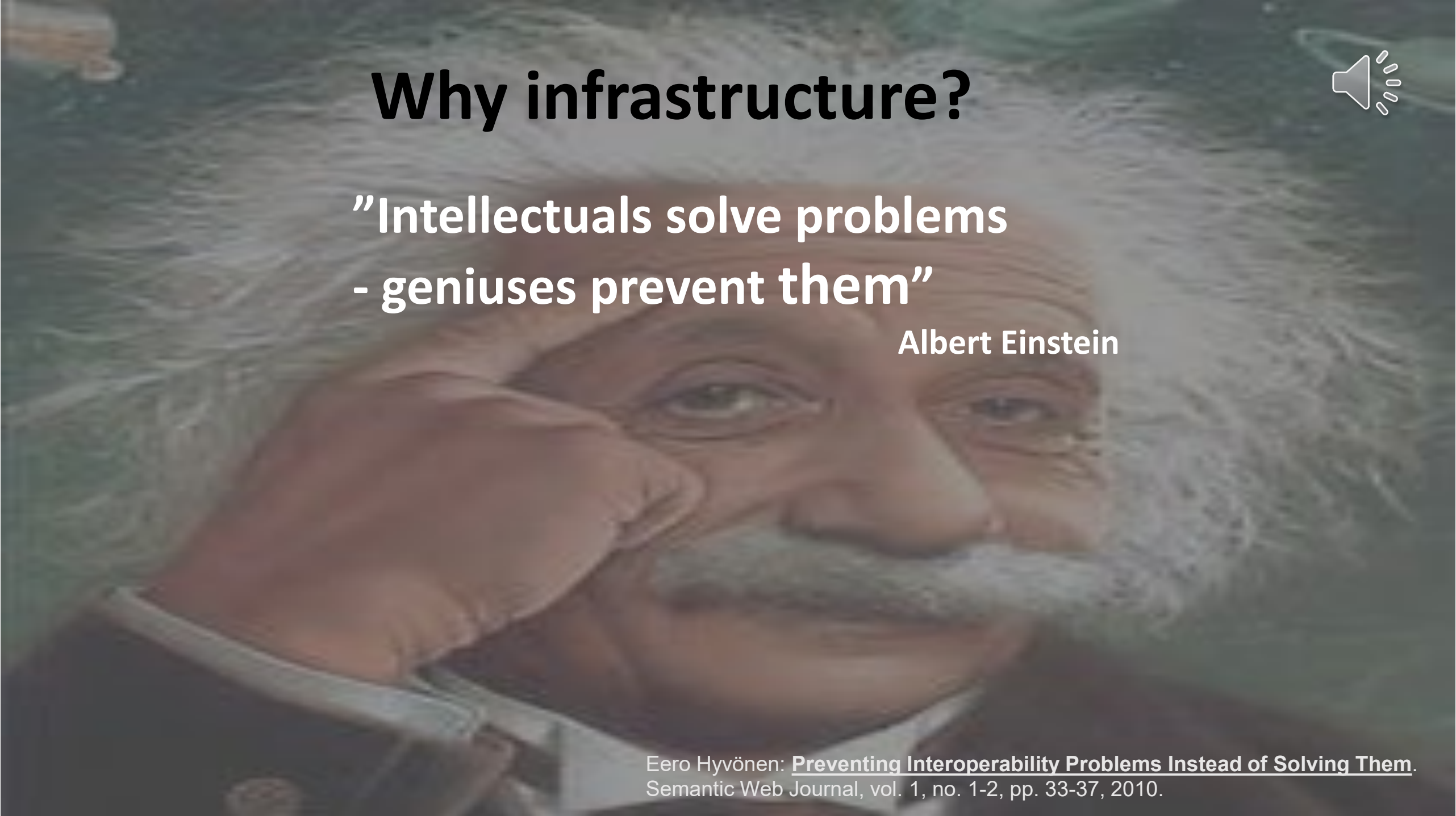
- Lessons learned when developing *MuseumFinland – Finnish Museums on the Semantic web*:
  - Semantic Web is good for publishing heterogeneous distributed data
  - Ontologies were not available for SW applications
  - However, there were several thesauri in use
  - Lots of data had been indexed using them
- Developing large cross-domain thesauri is a challenge
  - Domain specific expert groups are needed

=> National FinnONTO Ontology Initiative in Finland 2003-2012

FinnONTO Solution Approach 2003-2012

- Paradigm change: thesauri -> ontologies
  - Shared ontologies harmonize, interlink, and enrich data automatically
- Linked ontologies: Align ontologies for cross-domain applications
- Support distributed domain-specific ontology development
  - By different expert groups
- Support re-use by centralized ontology services
  - APIs for legacy systems to use
- Create a sustainable infrastructure for maintaining ontologies
- Gradually move to URI-based data indexing on a national level

Why infrastructure?



”Intellectuals solve problems
- geniuses prevent them”

Albert Einstein

Eero Hyvönen: **Preventing Interoperability Problems Instead of Solving Them**. Semantic Web Journal, vol. 1, no. 1-2, pp. 33-37, 2010.

Major Domain Ontology Types

- General concept ontologies
- Actor ontologies
- Place ontologies
- Time and period ontologies
- Event ontologies
- Domain nomenclatures and terminologies
  - E.g., medical terms

- Domain ”ontology” refers thesaurus or gazetteer like KOSs whose resources are used is element values of metadata descriptions

General Concept Ontologies

Traditional keyword thesauri

- General terms like ”wagon”, ”city”, ”war”, ”chair”, ...
- Correspond to classes of individuals
- (However, many keyword thesauri contain individuals, too)

Examples

- Art and Architecture Thesaurus (AAT) (culture)
- Library of Congress Subject Headings (LCSH) (library)
- UNSPSC (products and services)
- ...

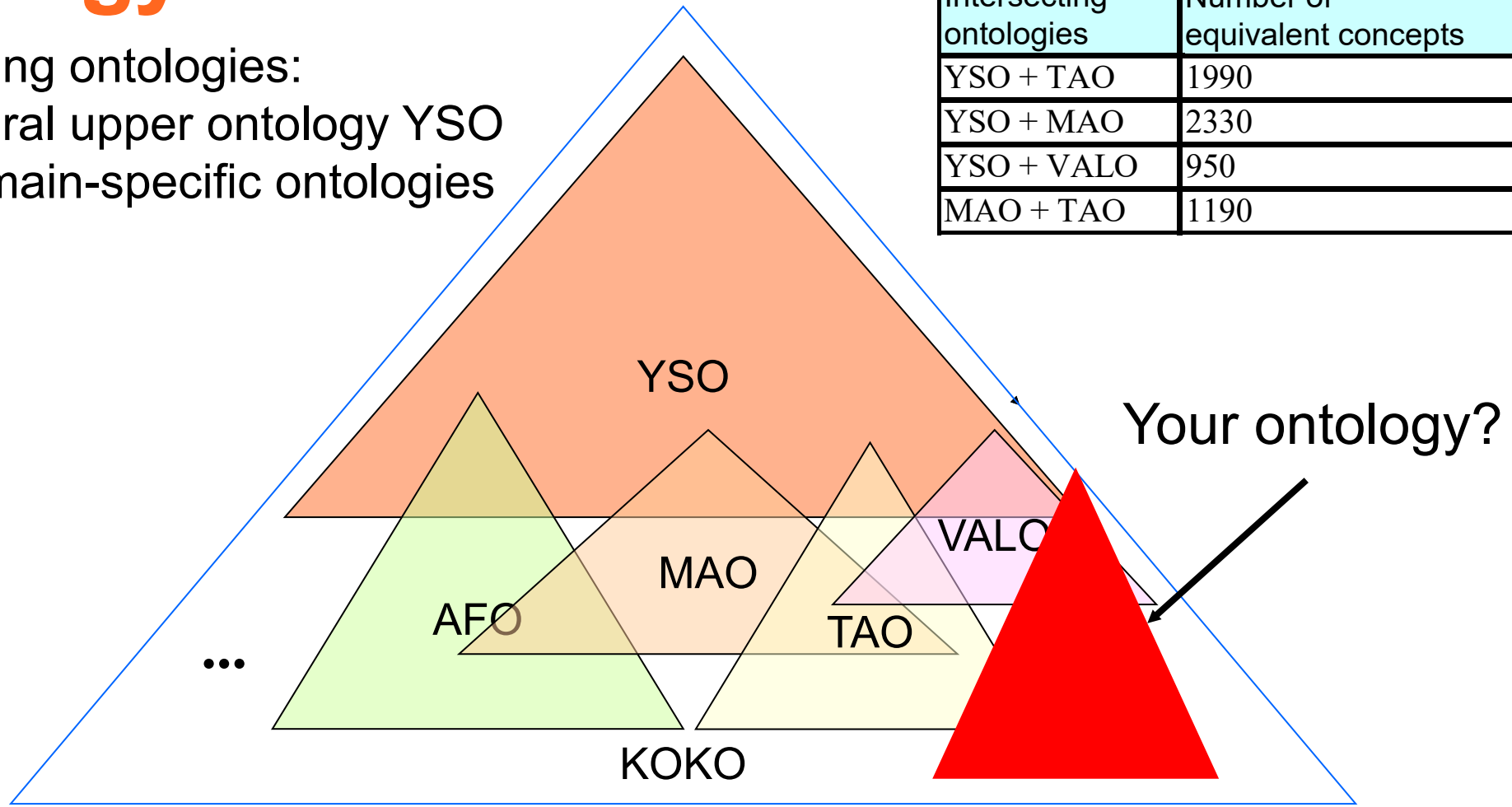
KOKO: From Thesauri to Ontologies - Linked Open Ontology Cloud

	Name	Ontology domain	Underlying thesaurus	Size	Maintaining Organization
1	YSO	General domain	General Finnish Thesaurus, YSA, Allärs	23700	National Library, Åbo Academy
2	MUSO	Music	Thesaurus of Music, MUSA/CILLA	1000	National Library
3	MAO	Museum domain	Thesaurus of Museum Domain, MASA	6800	National Board of Antiquities
4	AFO	Agriculture, foresty	Agriforest Thesaurus	5500	Viikki Science Library
5	TAO	Applied arts	Thesaurus of Applied Arts	2600	University of Eastern Finland and Library of Aalto University
6	VALO	Photography	Thesaurus of Photography Literature, Thesaurus of Photography Technology	1900	Finnish Museum of Photography
7	MERO	Seafaring, shipping	Thesaurus of Seafaring	1400	Finnish Transport Agency
8	KAUNO	Literature subjects	Thesaurus of Literature, Bella	4900	Finnish Public Libraries, Kirjastot.fi
9	JUHO	Public government	Thesaurus of Finnish Government, VNAS	6400	Ministry of Finance
10	TERO	Health promotion	YSA, TESA, MeSH, Stameta	22000	Various organizations
11	KITO	Literature research	Thesaurus of Literature Research	900	Finnish Literature Society
12	KULO	Culture research	Thesaurus for Folk Culture Studies	1600	Finnish Literature Society
13	KTO	Linguistics	Thesaurus of Linguistics	1000	Research Institute for the Languages in
14	PUHO	Defense	Thesaurus of Defence Administration	2000	Finnish Defence Forces
15	POIO	Points of interest	TGN, Geonames, LDG, SUO	4600	Various organizations
	TOTAL			**86300**	

Case: Holistic Collaborative Finnish Ontology KOKO

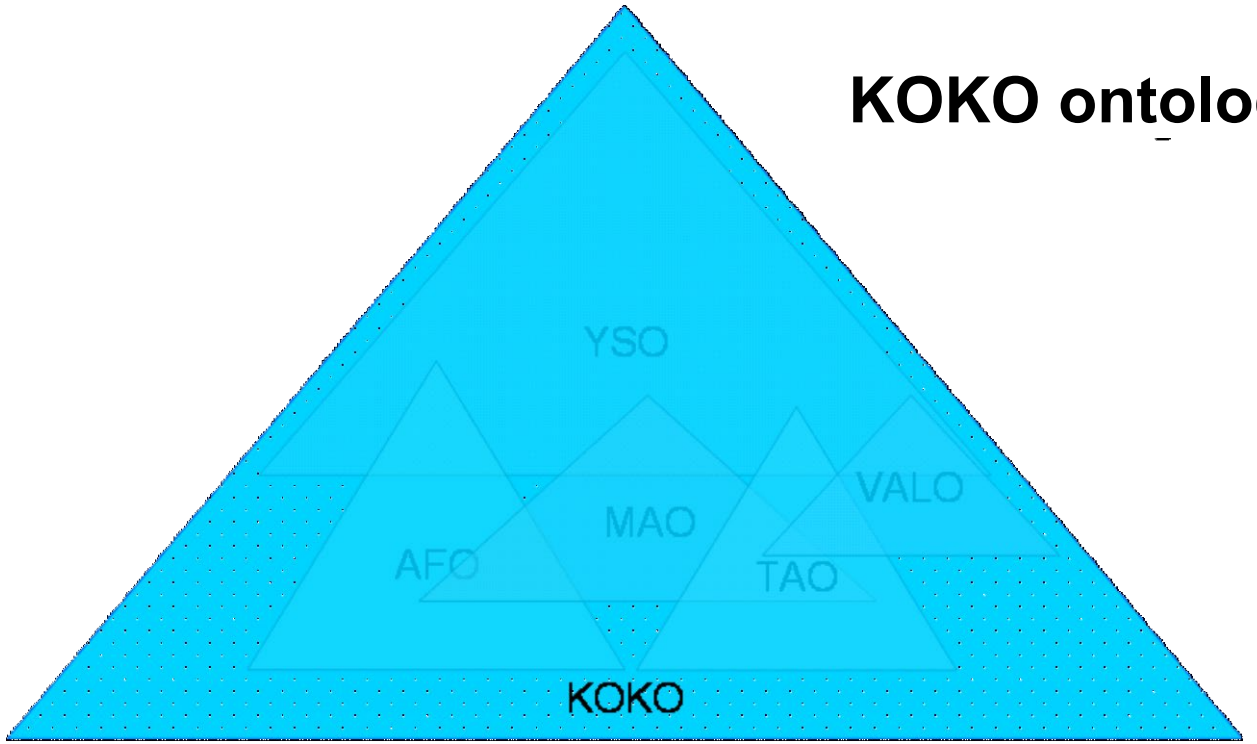
Aligning ontologies:
General upper ontology YSO
+ domain-specific ontologies

Intersecting ontologies	Number of equivalent concepts
YSO + TAO	1990
YSO + MAO	2330
YSO + VALO	950
MAO + TAO	1190



[Hyvönen et al., ESWC 2009]

KOKO from the “end-user” viewpoint



Thesaurus -> Ontology Transformation Method

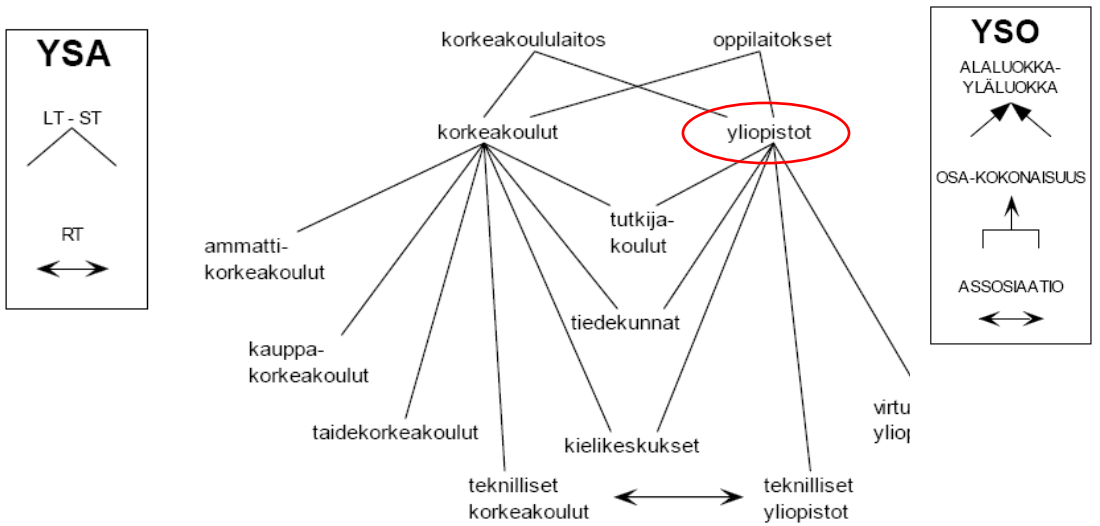
- **Transformation into light-weight ontologies based on RDF Schema**
  - SKOS was developed only later on

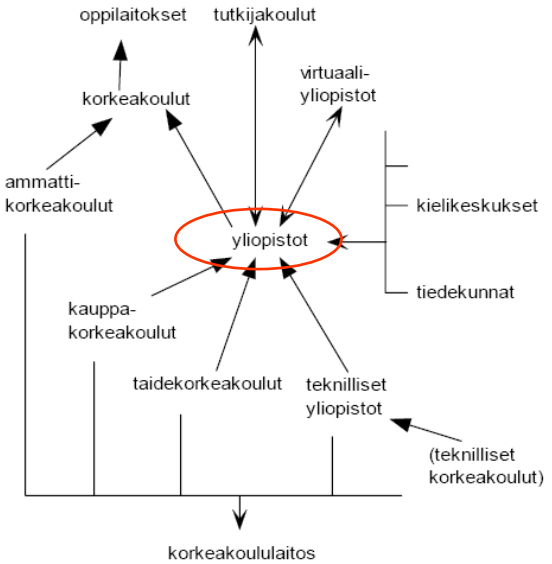
- **First transform thesaurus into a subClassOf ontology and then edit it manually using Protégé :**

1. **Disambiguate vague terms and re-position new split concepts**
   - E.g., “child” as age group =/= “child” as a family relation
2. **Disambiguate BT relations into subClassOf and partOf**
3. **Complement fragmentary BT clusters into full subClassOf hierarchies**

Example: University Terminology YSA Thesaurus -> YSO Ontology

YSA Thesaurus → **YSO Ontology**

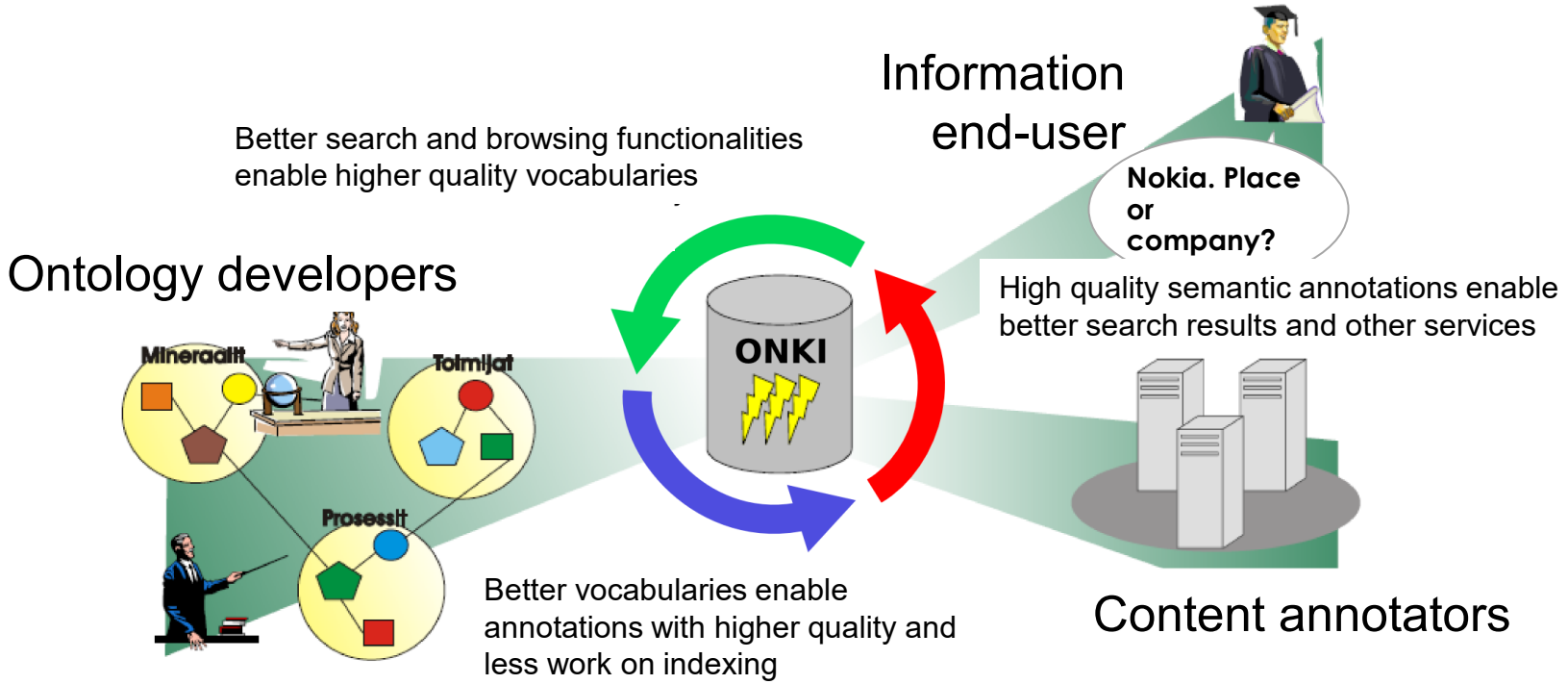




Semantic relations in use:
BT/NT and RT

Semantic relations in use:
subClassOf, partOf, and relatedConcept

Ontology library services: ONKI.fi concept

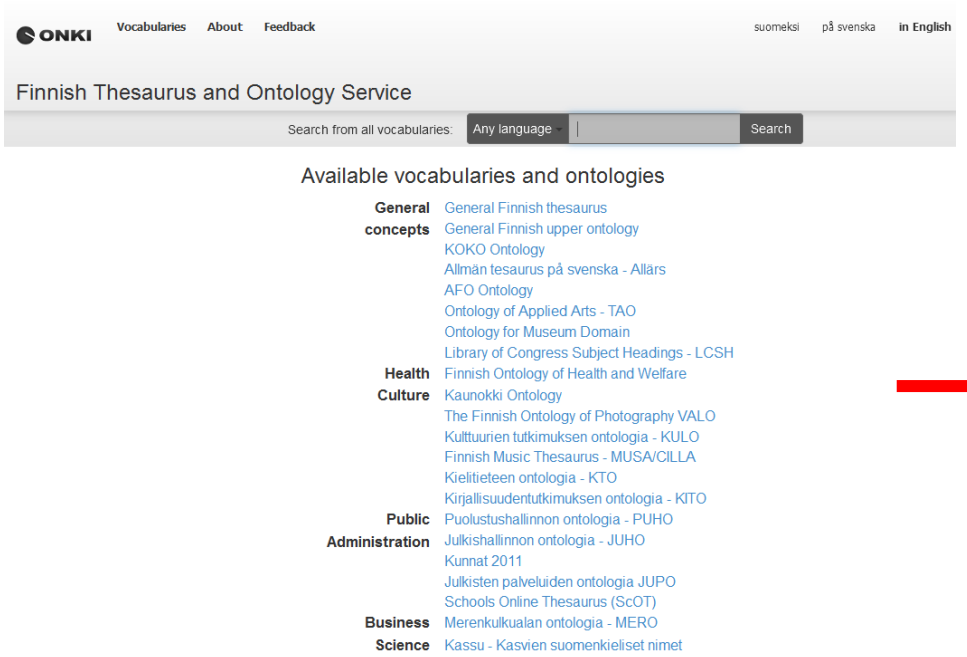


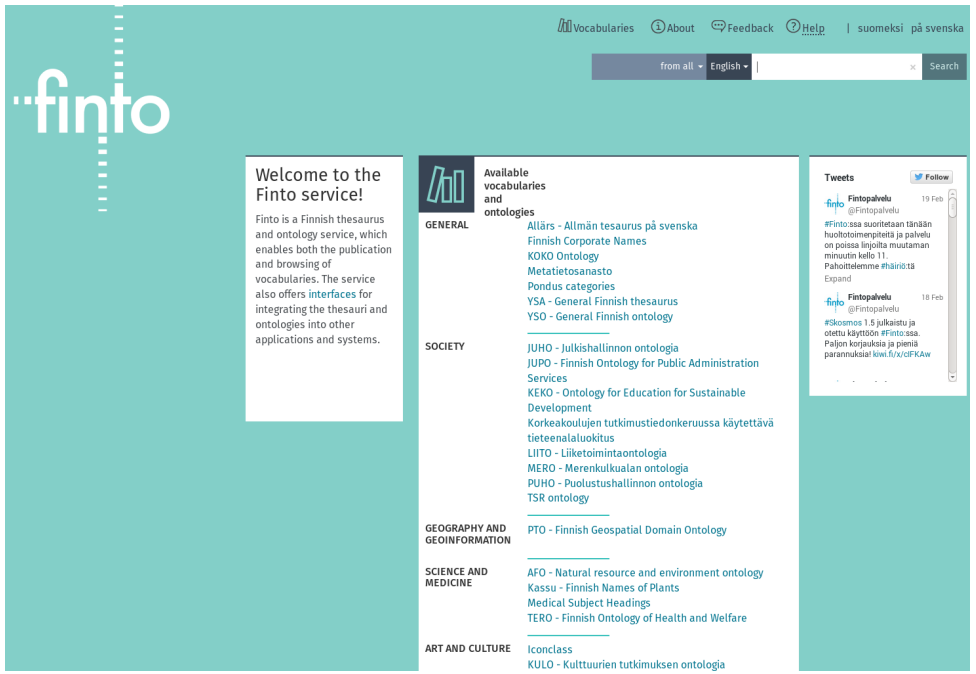
Supporters of the national semantic web infrastructure
Companies, government, EU, ...

KOKO ontologies and ONKI service deployed January 2014 by the National Library as Finto

Permanent free national service funded my Finnish ministries

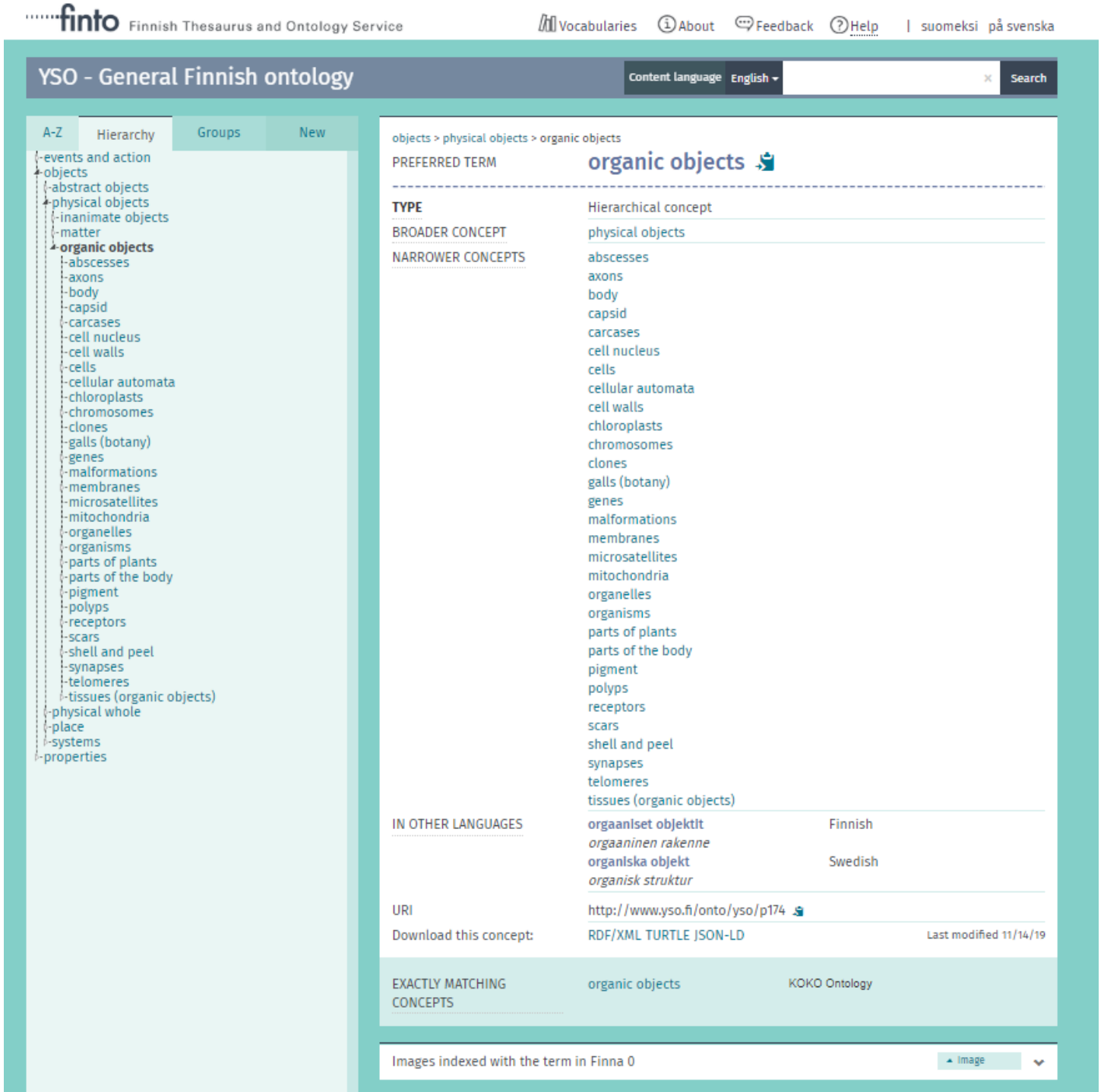
2019: 32 million API calls
2020: 2,1 million page visits
2020: 12% increase in use





[Suominen et al., ESWC, 2014]

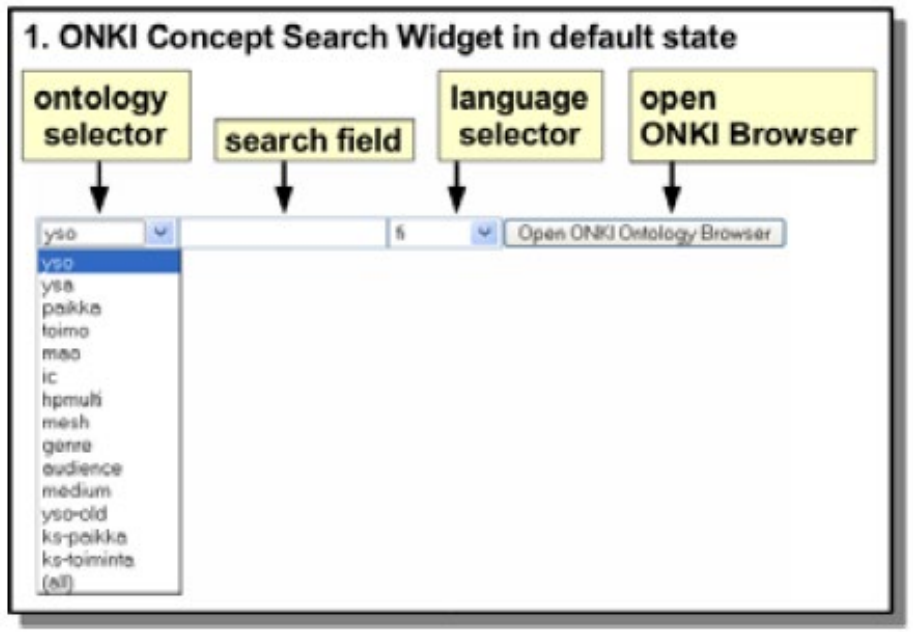
Aalto University
School of Science

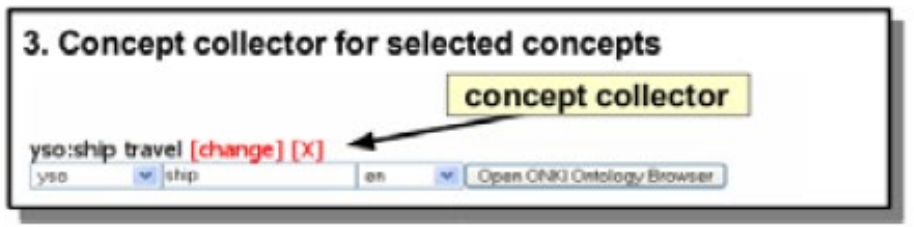


SeCo

ONKI Widget for Mashups

- Ontology services are automatically available after publishing a vocabulary or ontology with ONKI
- Simple AJAX-based widget for creating mash-ups





How to Deal with Overlapping Concepts in KOKO Ontology Cloud?

- YSO concepts are widely used in the domain ontologies
  - Up to 60% in some cases
  - YSO is good for a general upper ontology
- Domain ontologies also share concepts with each other
  - Much less than with YSO but up to 40% in some cases
- Lesson learned
  - Lots of redundant thesaurus work has been done in the intersecting areas
  - Collaborative re-organization of ontology work is needed, but is difficult
    - There is clearly need for merging some ontologies
    - How to deal with intersecting concepts?
    - How to manage distributed work of domain specific expert groups?
    - How propagate changes through the Linked Ontology Cloud?
  - Stakeholders work on these challenges in the Finto network / National Library

[Frosterus et al., IJMSO, 2016]

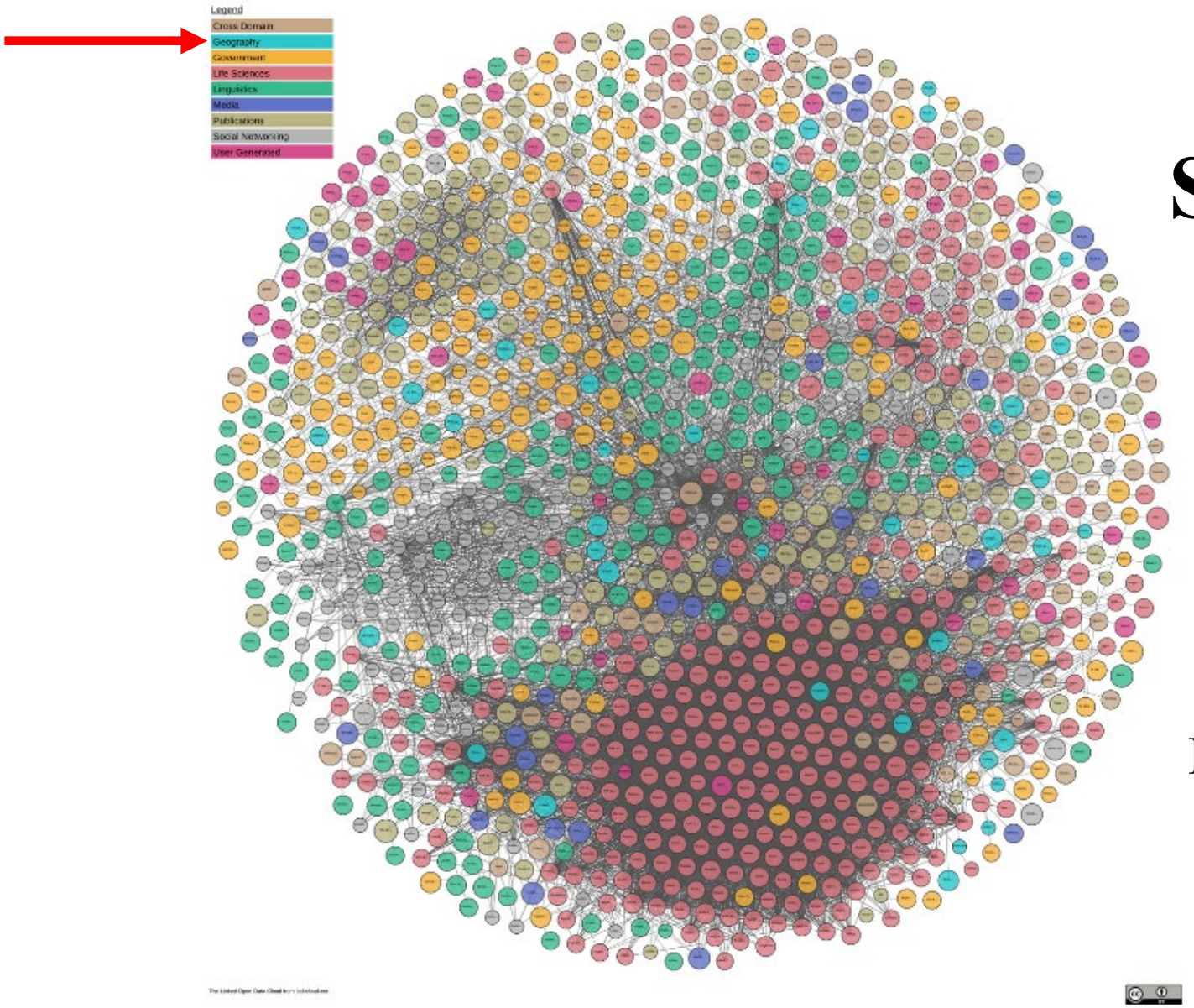
Actor Ontologies: Resolving Identities

URI: http://dbpedia.org/resource/Pyotr_Ilyich_Tchaikovsky

Pjotr Tšaikovski (fi)
Пётр Ильи́ч Чайко́вский (ru)
Pyotr Ilyich Tchaikovsky (en)
Pjotr Tjajkovskij (sv)
Pjotr Tsjajkovskij (no)
Pjotr Iljitsch Tschaikowski (de)
Piotr Ilitch Tchaïkovski (fr)
Piotr Ilich Chaikovski (es)
Pëtr Il'ič Čajkovskij (it)
Pjotr Iljitsj Tsjaikovski (nl)
Piotr Ilitch Tchaikovsky (pt)
Piotr Czajkowski (pl)
Piotr Ilici Ceaikovski (ro)
Pjotr Iljics Csajkovszkij (hu)

Geography: A Key Element in the Linked Open Data Cloud

https://lod-cloud.net/

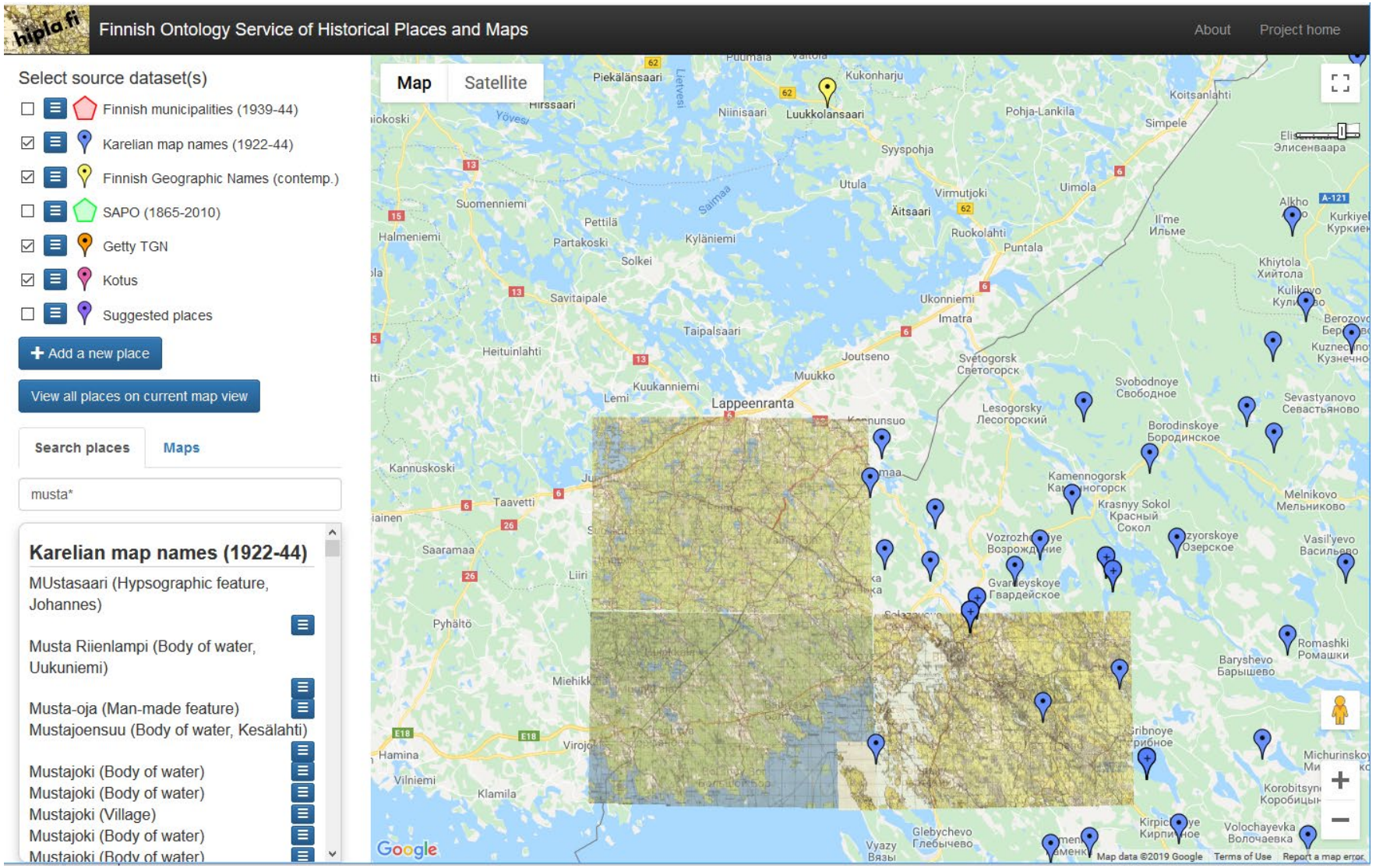


Semantic Web

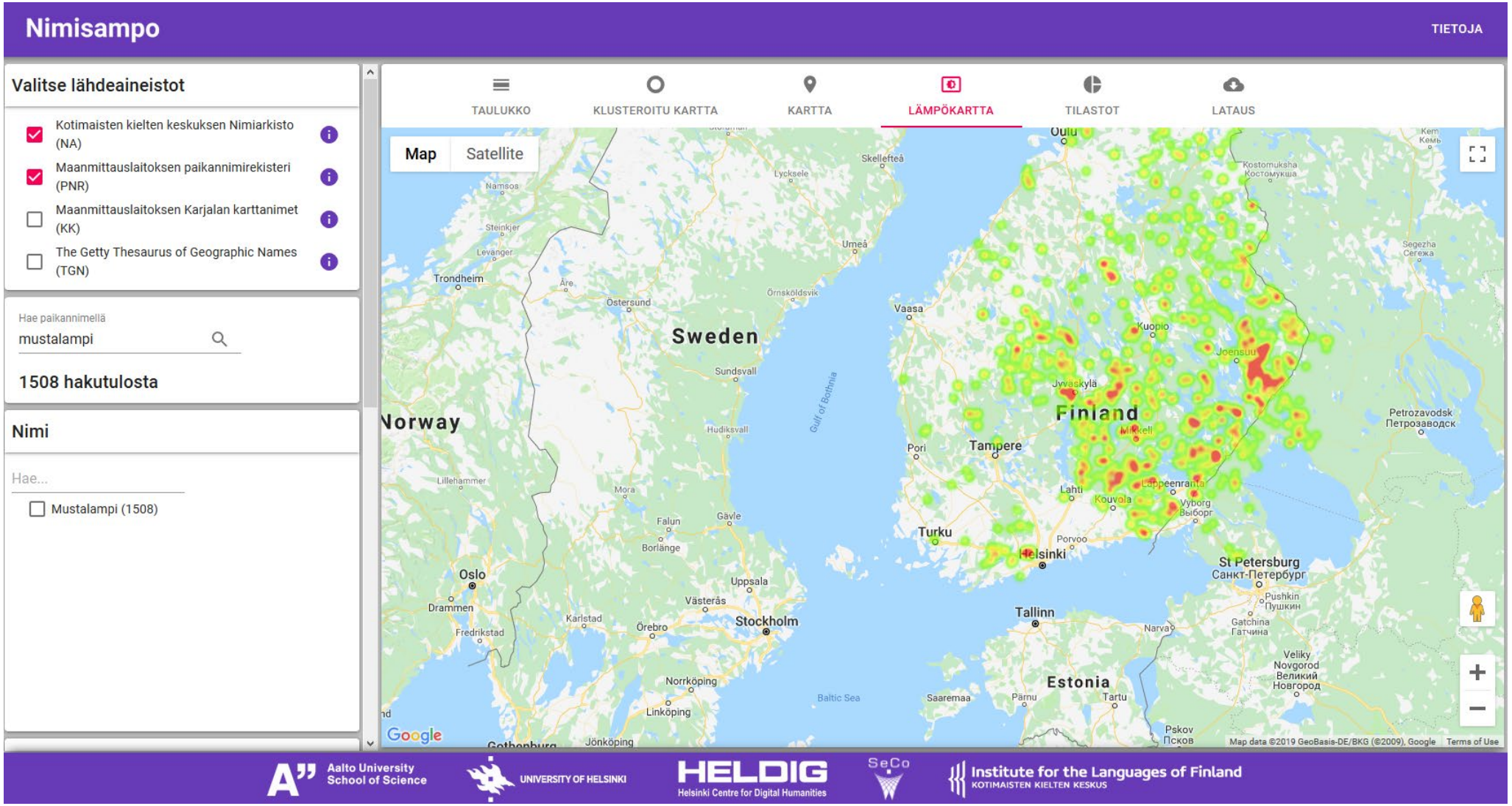
LODstats.aksw.org:
10 000 datasets
150 000 000 000 triples

Finnish Ontology Service of Historical Places and Maps:

http://hipla.fi



NameSampo: http://nimisampo.fi



There are 1508 places with name “Mustalampi” (= black small lake) in Finland!

Time Ontologies

- Modeling linear and cyclic time
- Time periods are different in different countries
  - *E.g., Bronze Age in Egypt and Nordic Countries*
- Modeling uncertainty in time

Event Ontologies

Events are ”semantic glue” that link together:

- **Places where events occur**
- **Times when events occur**
- **Actors who participate in events in roles**
- **Other related events**

Shared Metadata Schemas

Two Main Approaches

Dublin Core approach

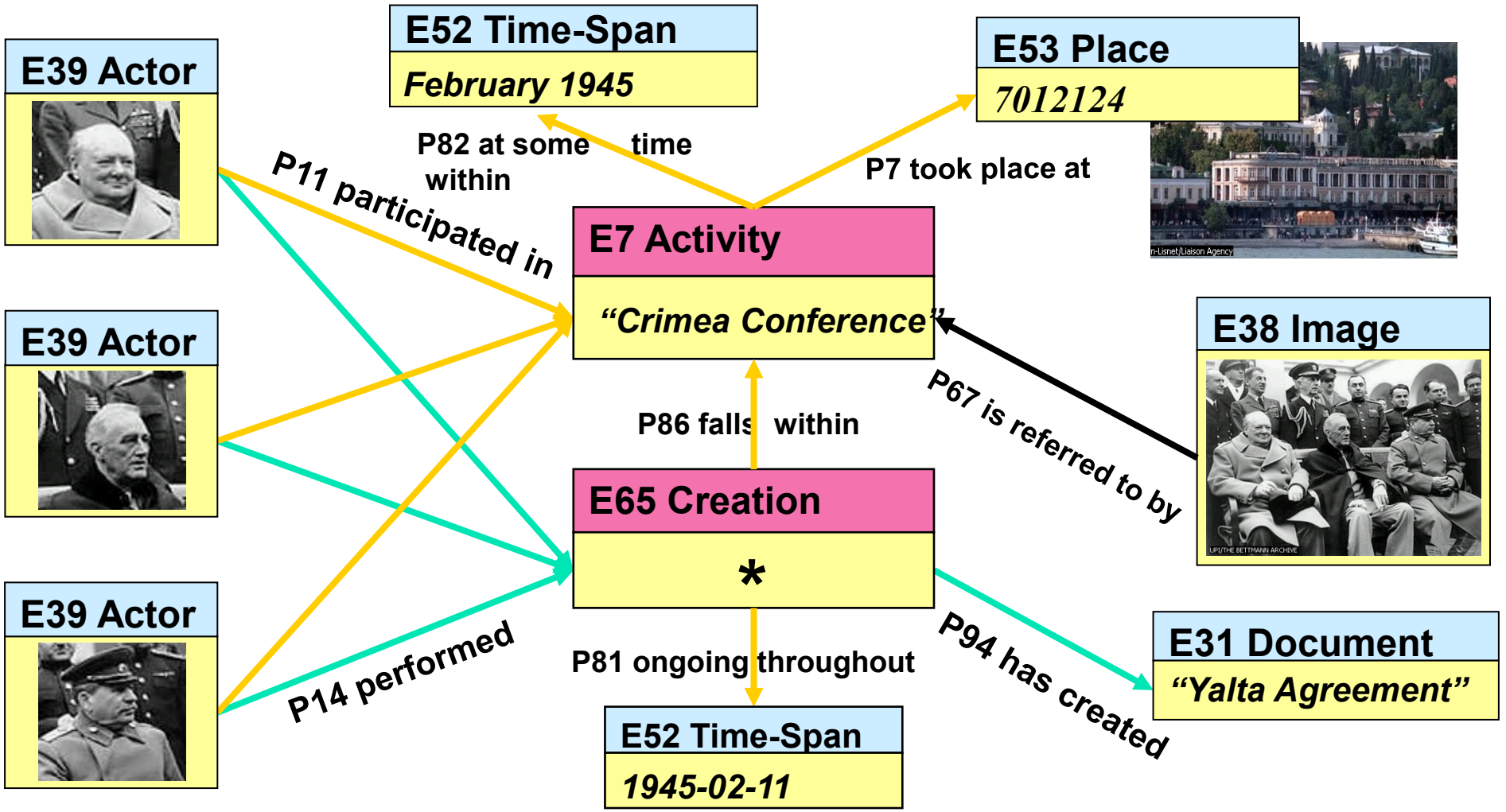
- **Mapping/refining schemas using subproperties**
- **“Dumb down principle” is used**
- **https://dublincore.org/**

Using foundational ontology models

- **Different schemas are mapped onto a shared ontology**
- **CIDOC CRM is a prominent standard of this**
  - http://www.cidoc-crm.org/

CIDOC CRM:

Using events as the foundation for knowledge representation



[Slide by: Stephen Stead]

Lessons Learned: Ontologies

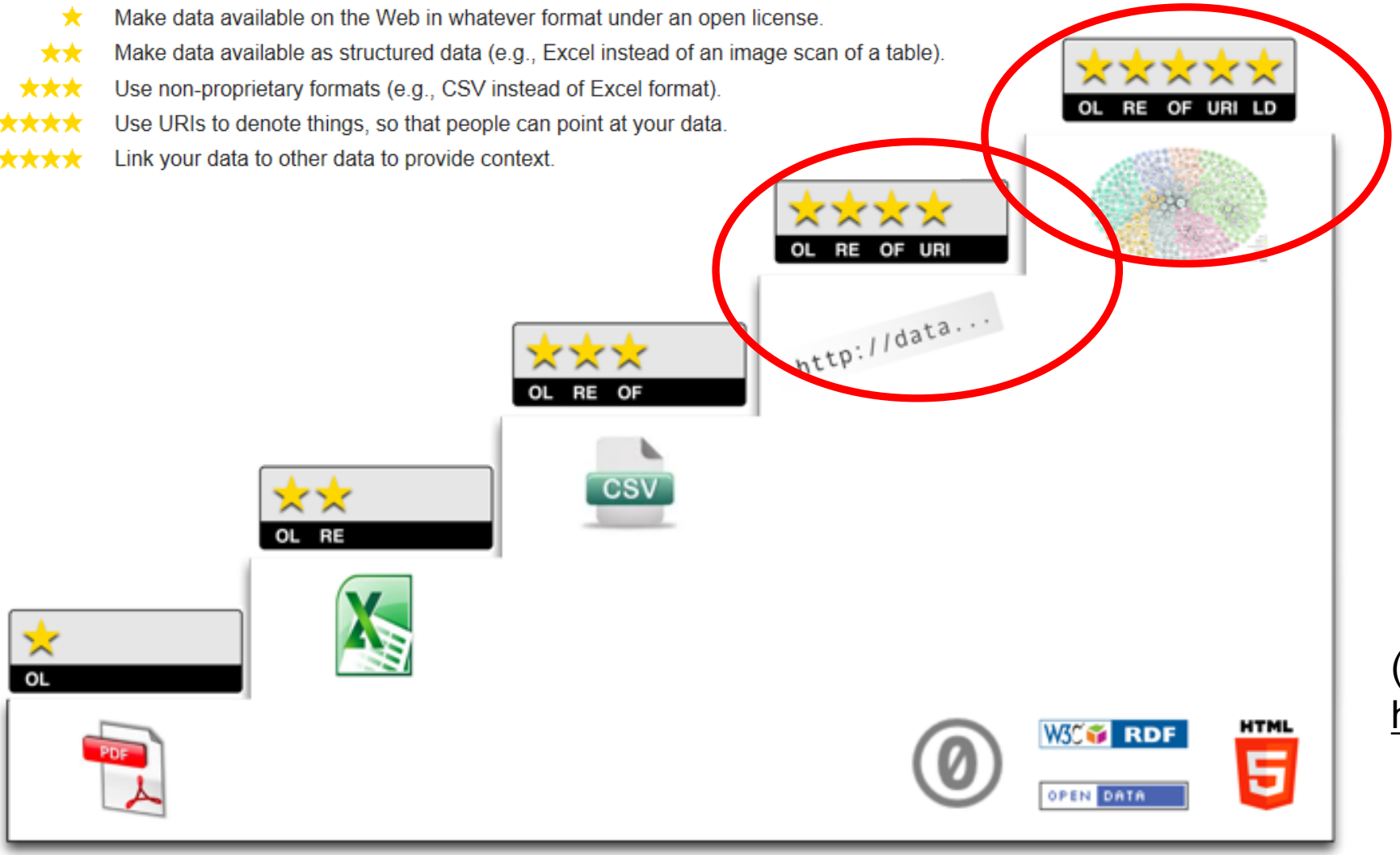
- **Ontology development**
  - "Little semantics goes a long way" (Jim Hendler)
  - Little can mean a lot of work in big ontologies
  - Just transforming thesauri into SKOS format is useful
- **Distributed domain-specific ontology development**
  - Needed but creates new linking challenges
- **Centralized national ontology services**
  - Very useful in a country like Finland
- **Focus on sustainability processes**
  - This is never ending work
- **Project management & funding**
  - Make baby steps: demonstrate use case after each step
  - Create large collaboration networks including companies, too

Linked Data Service Infrastructure

Linked Data Finland 2012-

How to publish Linked Data?
5-star Linked Data model

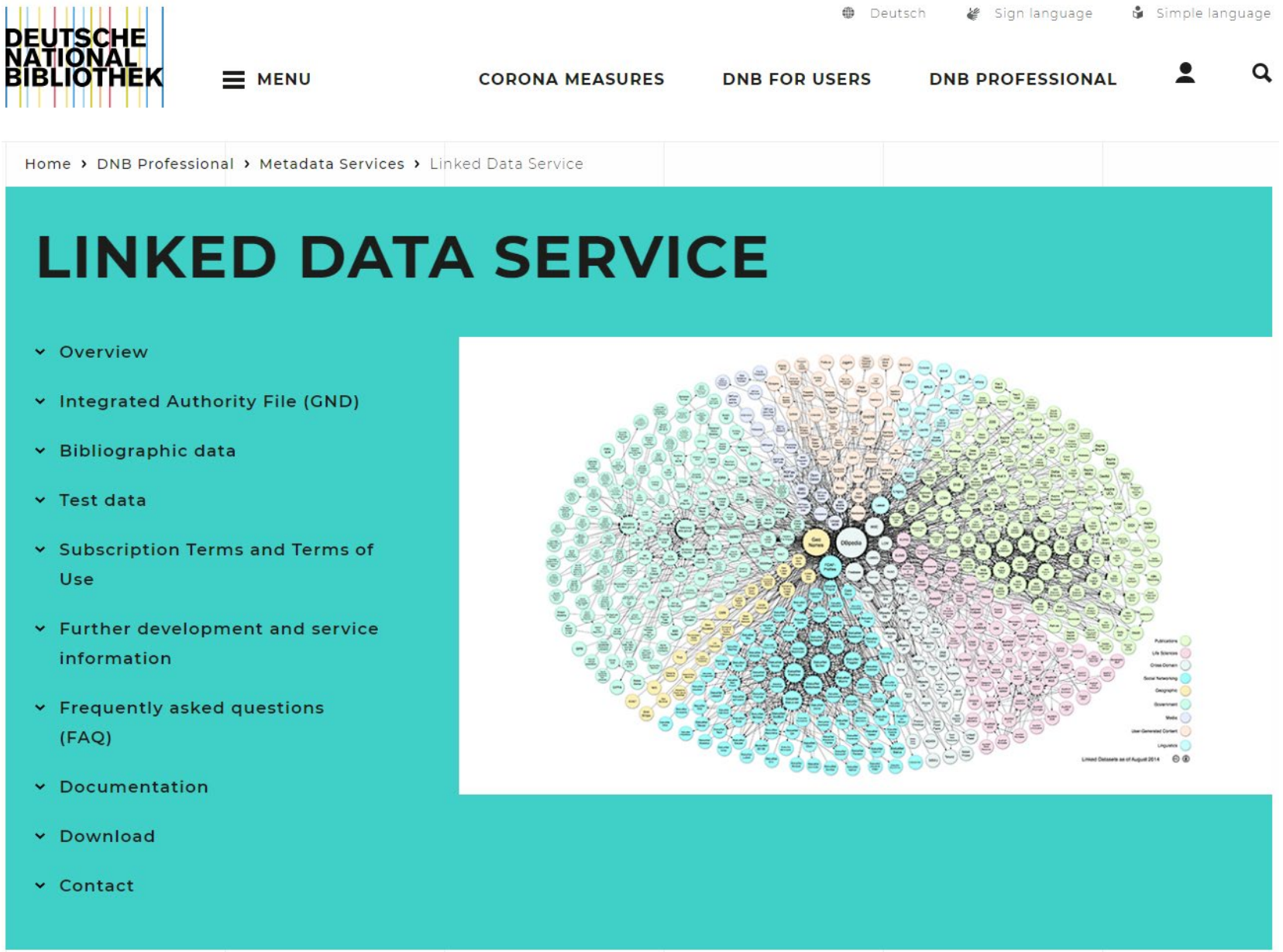
★ Make data available on the Web in whatever format under an open license.
★★ Make data available as structured data (e.g., Excel instead of an image scan of a table).
★★★ Use non-proprietary formats (e.g., CSV instead of Excel format).
★★★★ Use URIs to denote things, so that people can point at your data.
★★★★★ Link your data to other data to provide context.



(Tim Berners-Lee)
http://5stardata.info

https://www.dnb.de/EN/Professionell/Metadatendienste/Datenbezug/LDS/lds_node.html

An example of a Linked Data Service



Case: Linked Data Finland
”7-star” model and LDF.fi data hotel

Goals: enhance re-usability and data quality

7-star Linked Data Service

However, in our opinion, providing 5-star Linked Data is just the beginning. To actually make use of the datasets, consumers need more support in getting to know and access them, as well as a better grasp of their quality and provenance. To this end, we extend the model with two additional stars:

★★★★★★ Provide your data with a schema and documentation so that people can *understand and re-use* your data easily.

★★★★★★★ Validate your data and denote its provenance so that people can *trust the quality* of your data.

This added support should come with as little extra work as possible to the data publisher. Our hypothesis is that a lot of this can be done automatically, basing on the Linked Data core. A data publisher needs only to provide their data in the RDF format, and the LDF.fi portal will do the rest automatically. See the overview paper (in ESWC 2014 Proceedings, Springer-Verlag) for some more details about the underlying ideas.

Burj Al Arab

Why LDF.fi?

Living Laboratory for publishing Linked Open Data

- Same idea as in **ontology services**
- But for **data** and **schemas**

Data Services for

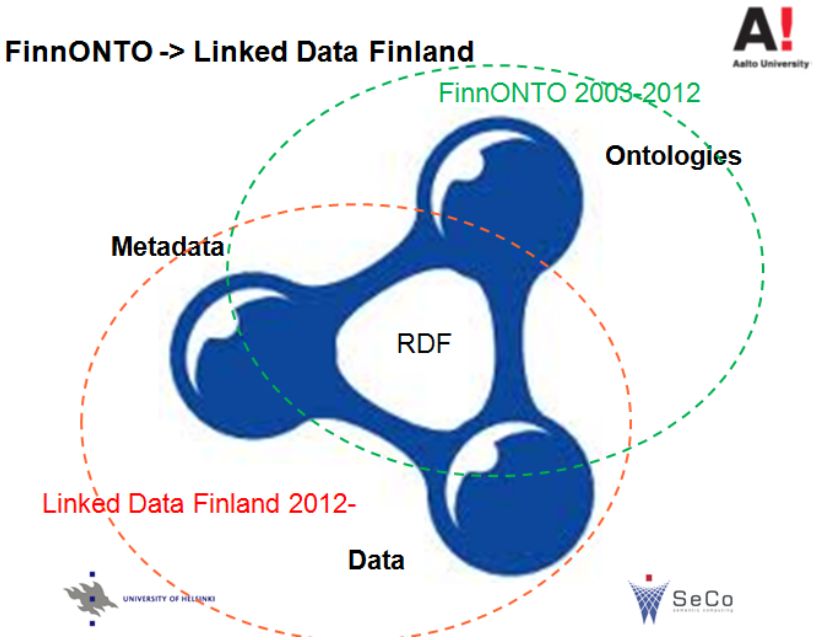
- Linked datasets
- Schemas

Links to

- Related services
- Related applications

Learning Center

- For publishing and using Linked Data



Linked Data Finland Living Lab http://ldf.fi

- Home
- Project
- Datasets
- Schemas
- Services
- Policies
- Documentation
- Validation
- Applications
- Your Data?

Linked Data Finland

Living Laboratory Data Service for the Semantic Web

This site is the Living Laboratory of the Linked Data Finland research initiative, conducted by the Semantic Computing Research Group at Aalto University in collaboration with University of Helsinki and a large consortium of Finnish public organizations and companies.

Our goal is to make life easier for both publishers as well as consumers of structured data on the Web. We base our work on the Linked Data paradigm and stack of standards, which combines an expressive, semantic data model (RDF) with standardized access mechanisms (SPARQL and live HTTP URIs).

5-star Linked Data

The baseline of our work is the 5-star Linked Data model, proposed originally by Tim Berners-Lee.

- ★ Make data available on the Web in whatever format.
- ★★ Make data available as structured data (e.g., Excel instead of an image scan of a table).
- ★★★ Use non-proprietary formats (e.g., CSV instead of Excel format).
- ★★★★ Use URIs to denote things, so that people can point at your data.
- ★★★★★ Link your data to other data to provide context.

7-star Linked Data Service

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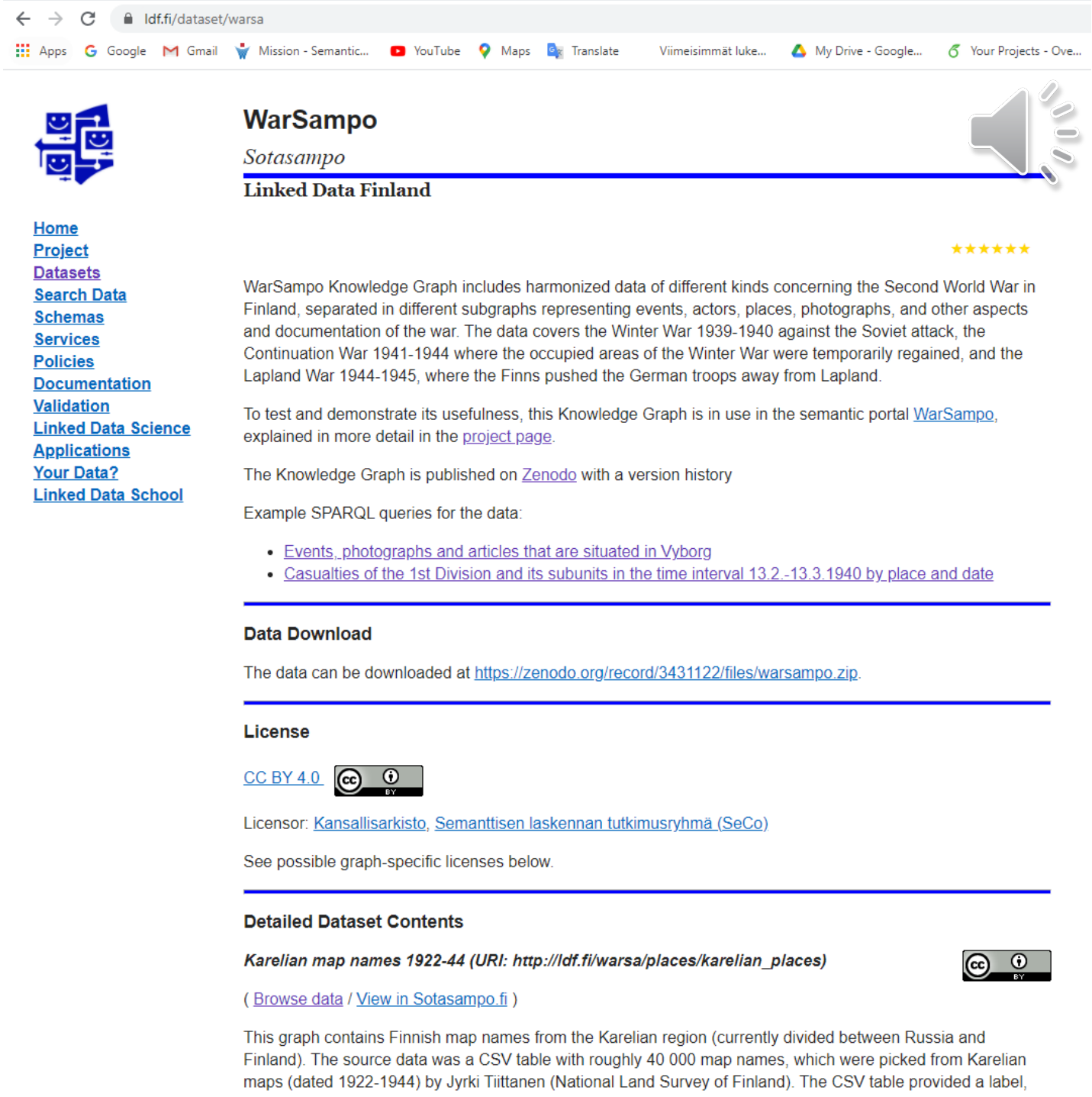
Example dataset: WarSampo Linked Data & SPARQL endpoint

https://www.ldf.fi/dataset/warsa

[Koho et al., SWJ, 2021]



Software Tools for the Semantic Web

Component Technologies and Tools for the Semantic Web

Languages & standards of W3C and others

- *Data exchange language:* *RDF*
- *Vocabulary/schema languages:* *SKOS, OWL*
- *Data/ontology query language:* *SPARQL*
- *Rules for reasoning:* *RIF, SWRL, …*
- *Metadata and ontology models* *DC, CIDOC CRM, …*

Triple stores for data services

- *Fuseki, Sesame, Redland, Virtuoso, …*
- *http://en.wikipedia.org/wiki/Triplestore*

Development tools

- Ontology editors
  - *Protégé https://protege.stanford.edu/*
  - *TopBraid Composer https://www.topquadrant.com/topbraid-composer-install/*
- Software development tools
  - *Java: Apache Jena https://jena.apache.org/*
  - *Python: RDFLib https://pypi.org/project/rdflib/*

Lessons Learned: Data Services

- **LDF.fi platforms makes data publishing very easy**
  - Services are generated automatically from Service Description metadata
- **Reusing services and support functions is cost-efficient**
  - Unnecessary re-implementions can be avoided
- **LDF.if is important for Human Infrastructure building**
  - In hackathons
  - In educational university courses
- **Basic services can be run with little maintenance**
  - However, technical expertise is needed
- **Sustainability is needed**
  - Part of national research infrastructure roadmap of the Academy of Finland
  - Servers provided “for free” for universities by CSC / Ministry of Education and Culture
- **Data maintenance issues remain a challenge**
  - How to keep the data & services up-to-date

3. HOW TO USE SW INFRA FOR APPLICATIONS?

Sampo Model and Sampo Series of Systems

Video “The Semantic Web and AI for Digital Humanities”: https://vimeo.com/470313703

video

Applications: Cultural Heritage ”Sampos” on the Semantic Web 2004-

Defense of Sampo, Ateneum, A. Gallen-Kallela, 1896

1. **MuseumFinland** – Finnish Museums on the Semantic Web (2004) **[39 000 users]**
2. **CultureSampo** – Finnish Culture on the Semantic Web (2008) **[107 000 users]**
3. **TravelSampo -** Mobile Contextualized Services of Cultural Tourism (2011)
4. **BookSampo** – Finnish Fiction Literature on the Semantic Web (2011) **[2 million users in 2020]**
5. **WW1LOD** – World War I Linked Open Data (2014)
6. **WarSampo –** Finnish World War 2 on the Semantic Web (2015-19) **[742 000 users]**
7. **Norssi Alumni on the Semantic Web** – Historical person registry using LOD (2017)
8. **U.S. Congress Prosopographer** – U.S. Congress Legislators 1789-2018
9. **BiographySampo** - Finnish Biographies on the Semantic Web (2018-20) **[50 000 users]**
10. **NameSampo** – Linked Data Workbench for Toponomastic Research (2019) **[37 000 users]**
11. **WarVictimSampo 1914-1922** – National War History **[29 000 ussers]**
12. **Mapping Manuscript Migrations (MMM)** – medieval and Renaissance manuscripts (2020)
13. **AcademySampo** – Finnish Academic People 1640 – 1899 (2021)
14. **FindSampo** – Archaeological Finds on the Semantic Web (2021)
15. **LetterSampo, LawSampo, ParliamentSampo**, … underway

Time Machine

https://seco.cs.aalto.fi/applications/sampo/

Sampo = Mythical artifact of the Finnish Epic Kalevala that gives to its owner riches and good fortune.
A metaphor of amazing technology.

Defense of Sampo,
National Gallery, Ateneum,
A. Gallen-Kallela, 1896

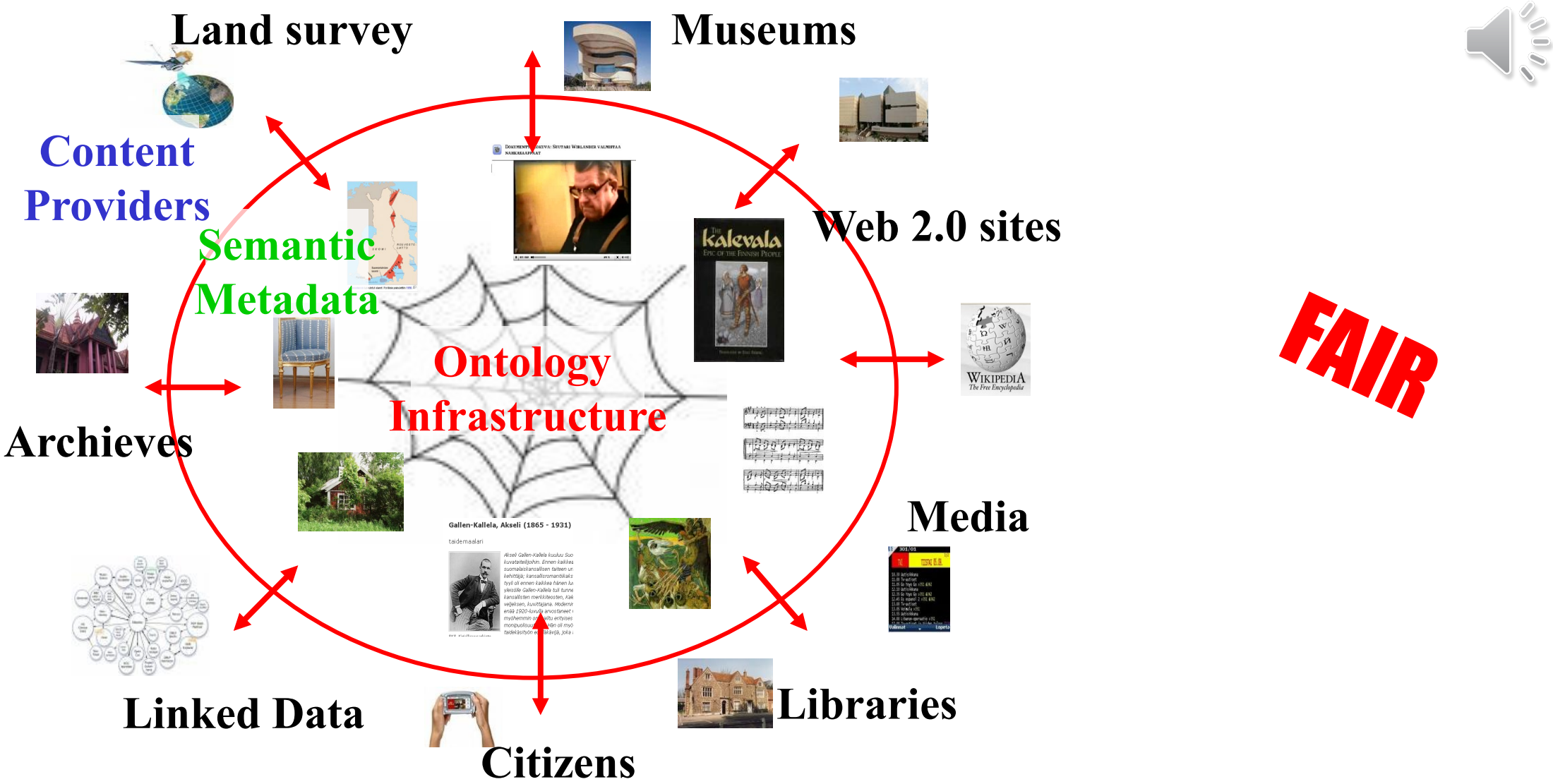
Sampo Model Principles

Table 1. Sampo Model Principles P1–P6

P1. Support collaborative data creation and publishing
P2. Use a shared open ontology infrastructure
P3. Support data analysis and knowledge discovery in addition to data exploration
P4. Provide multiple perspectives to the same data
P5. Standardize portal usage by a simple filter-analyze two-step cycle
P6. Make clear distinction between the LOD service and the user interface (UI)

https://seco.cs.aalto.fi/publications/2021/hyvonen-sampo-model-2021.pdf

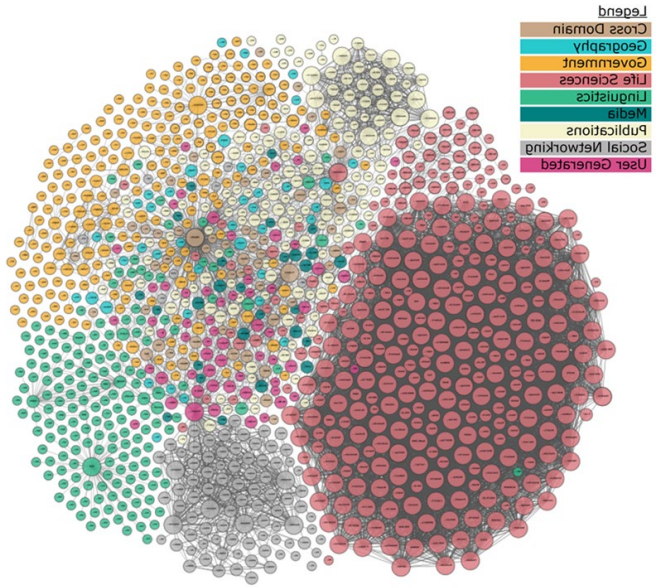
P1. Support collaborative data creation and publishing


Land survey
Museums
Content Providers
Semantic Metadata
Web 2.0 sites
Ontology Infrastructure
Archieves
Media
Linked Data
Libraries
Citizens
FAIR

P2. Use a shared open ontology infrastructure

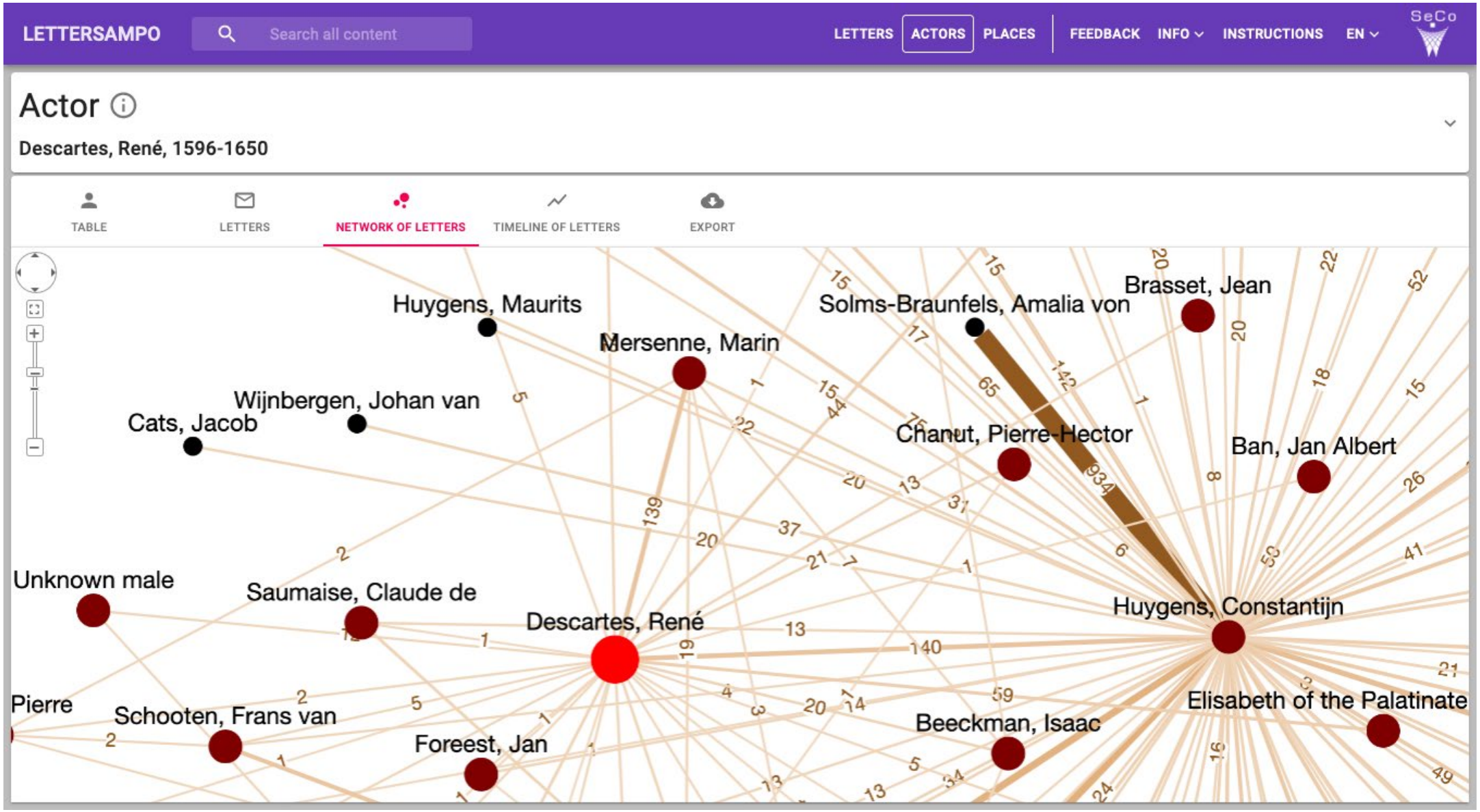
Elements of National Ontology Infrastructure for Digital Humanities

- **Domain ontologies**
  - Historical Places and Maps
  - Historical Persons
  - Historical Times
  - Historical Events
  - Historical Keyword Concepts
  - …
- **Shared metadata models**
  - Dublin Core, CIDOC CRM, …
- **Ontology and linked data services** online



P3. Support data analysis and knowledge discovery in addition to data exploration

LetterSampo: Network analyses of Early Modern Correspondences: Case Rene Descartes



BiographySampo: Correlations of Vocational Groups between Parents and Children using Google Colab

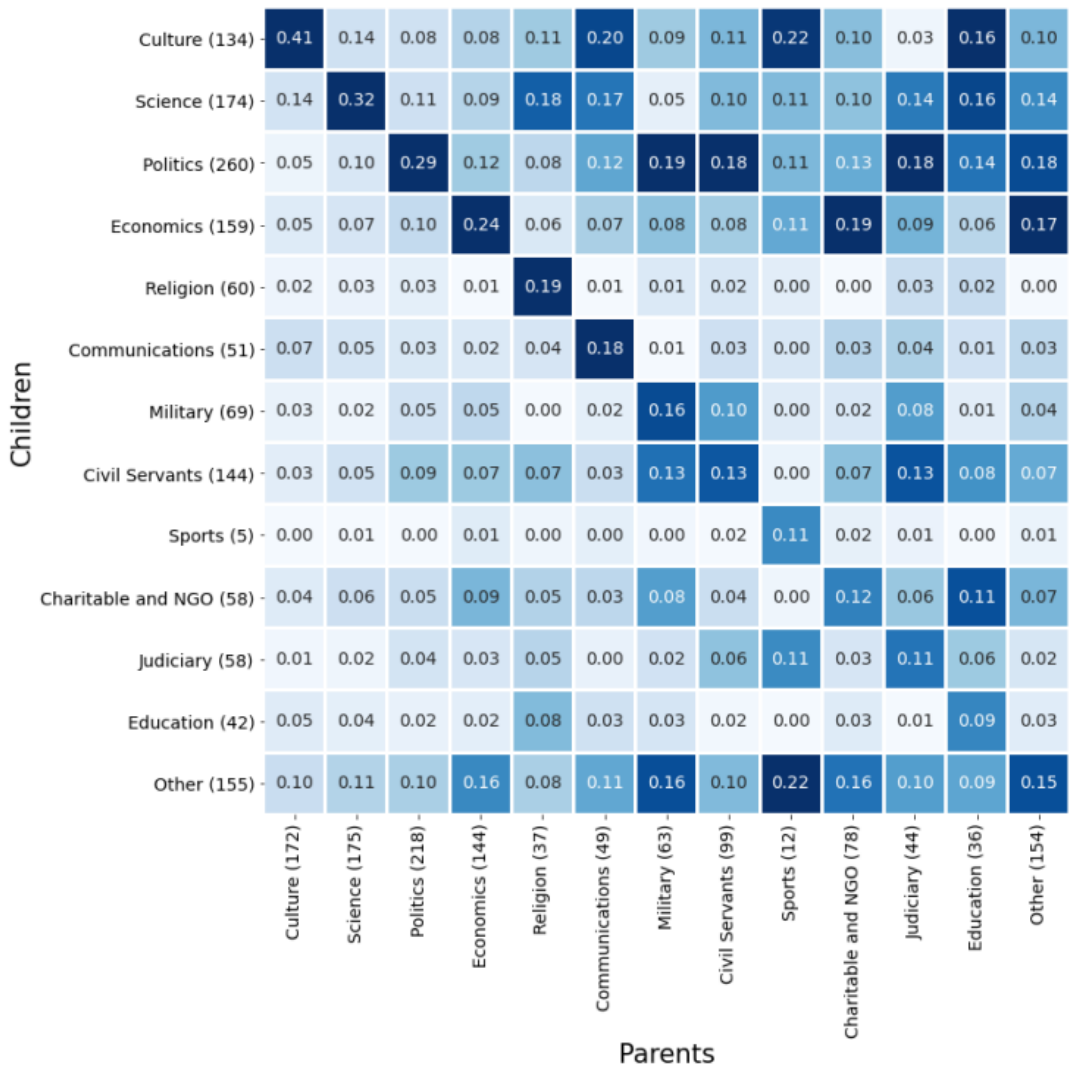
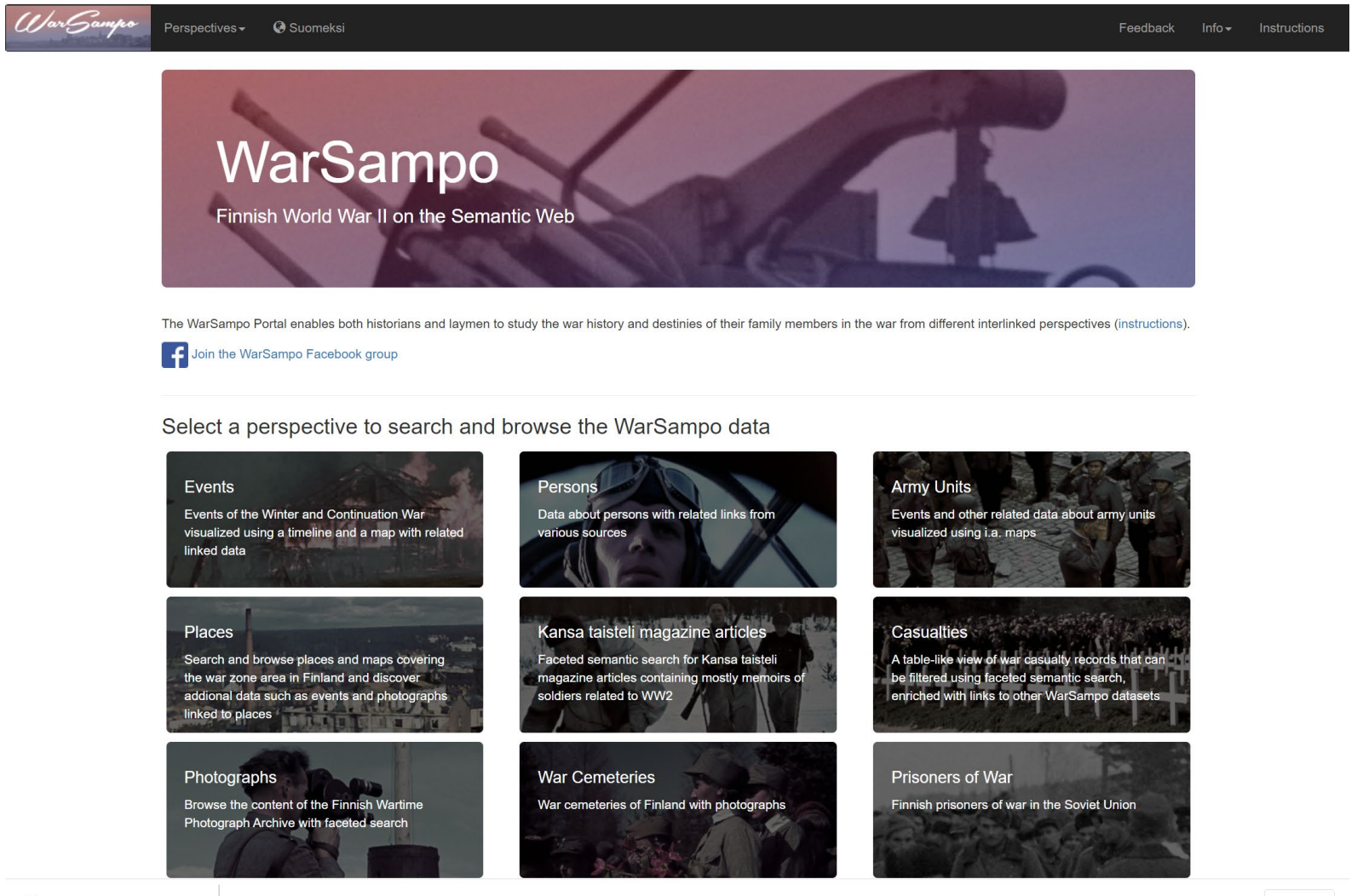


FIG. 13.: Correlations between the vocational groups of parents and children

P4. Provide multiple perspectives to the same data

WarSampo – Finnish World War II on the Semantic Web:
Nine perspectives to war history



P5. Standardize portal usage by a simple filter-analyze two-step cycle

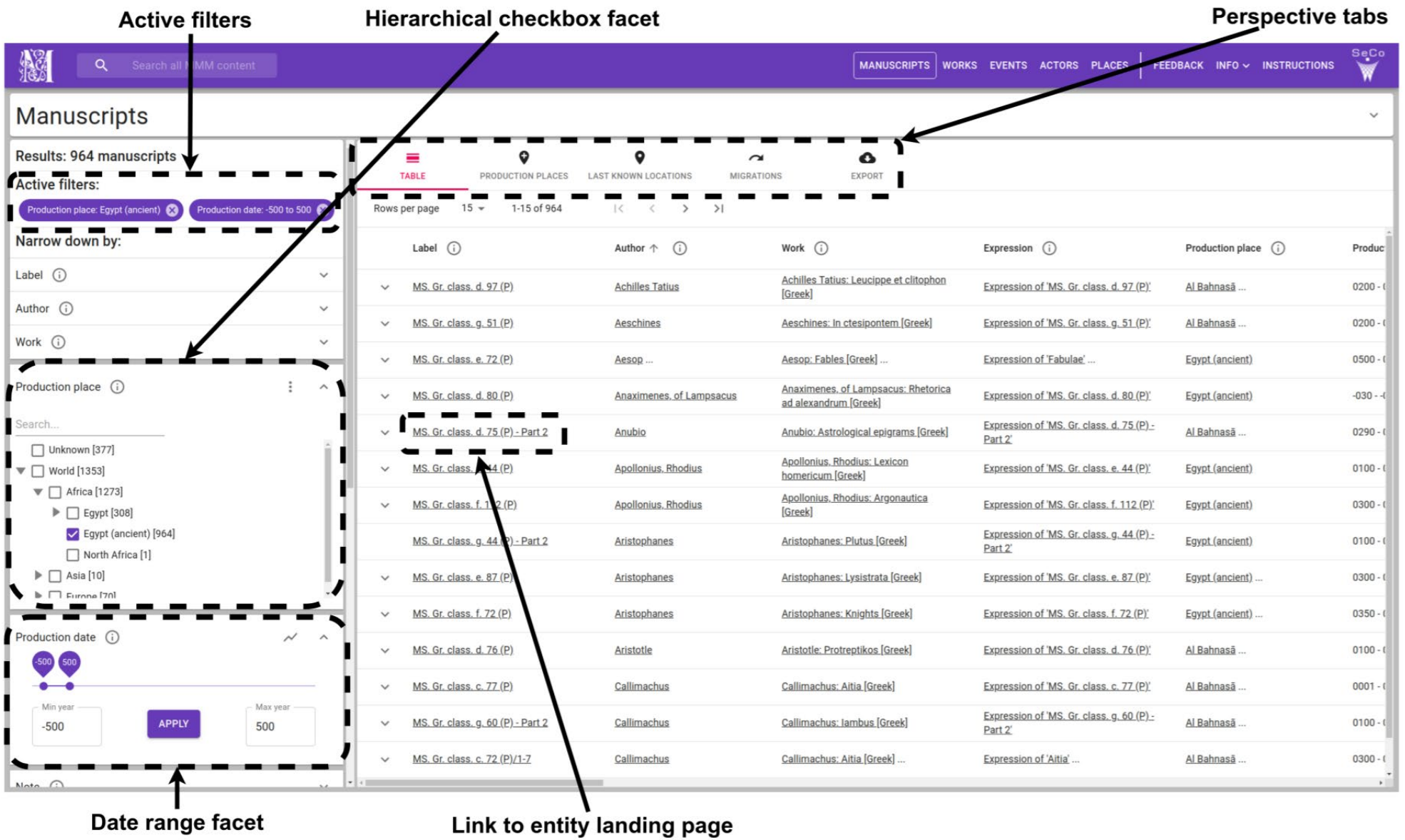
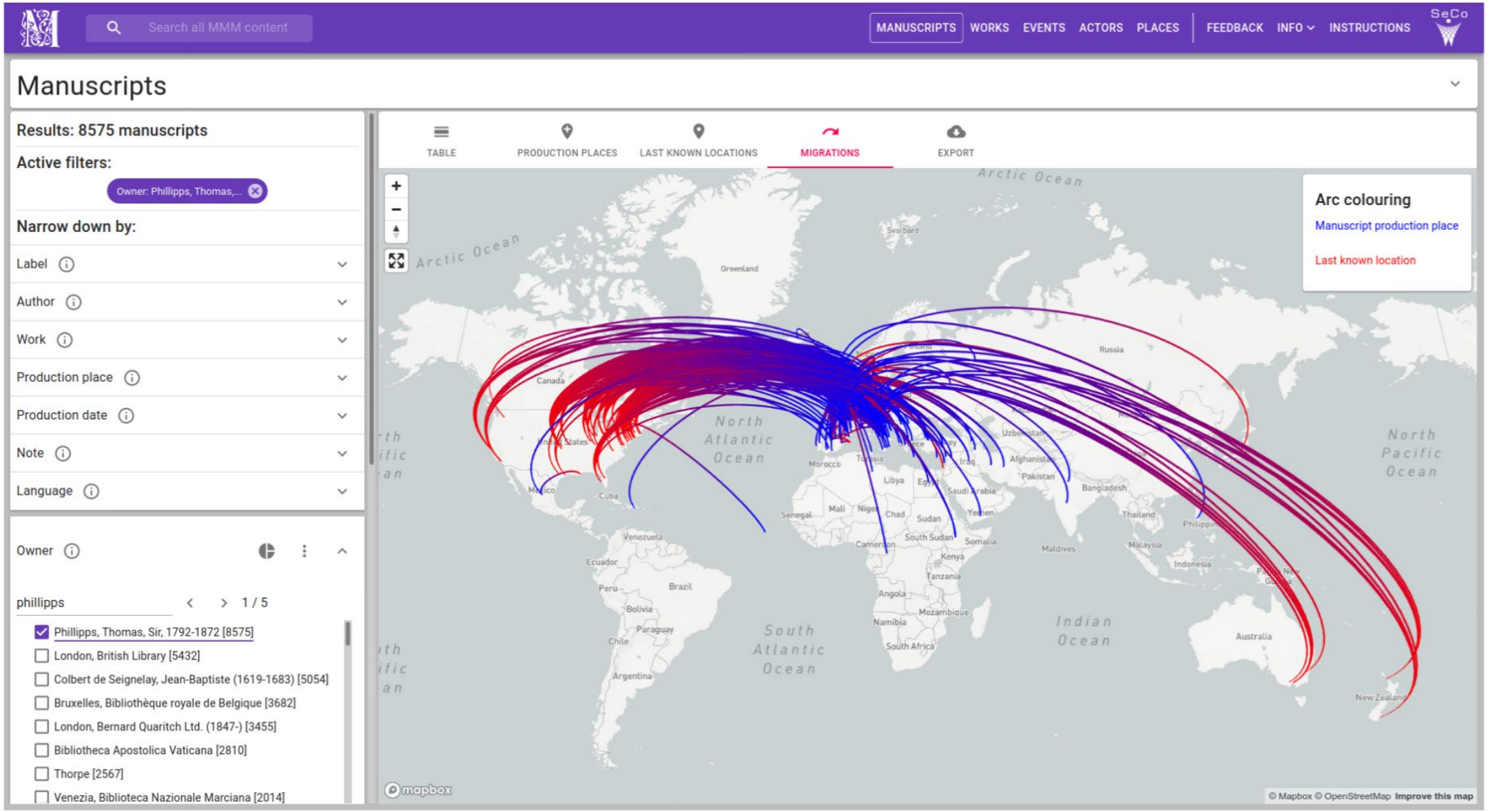


Figure 6. A selection of SAMPO-UI components for building a faceted search perspective of a semantic portal.

Mapping Manuscripts Migrations: Case Thomas Phillips (1792-1872)



P6. Make clear distinction between the LOD service and the user interface (UI)

Linked Data Publishing Model

Client Side
(Browser)

Application 2

Application 1

Application N

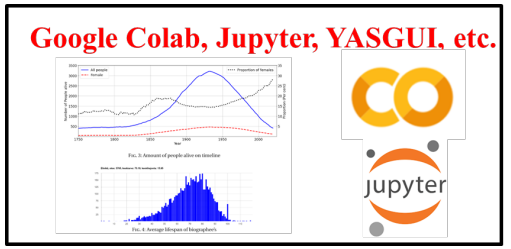
SPARQL

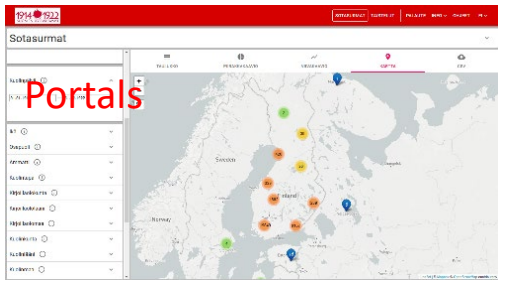
{REST API}

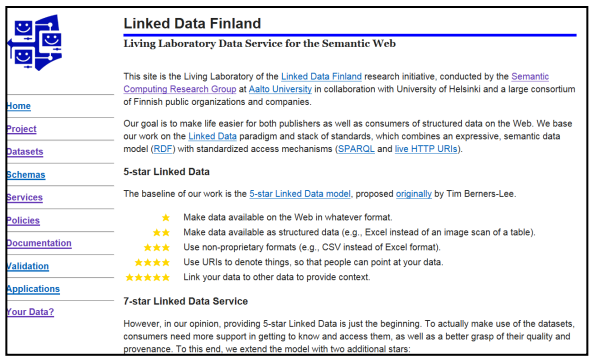
SPARQL End Point

Server Side
https://ldf.fi

Linked Data Finland Service
WWW Standard Model





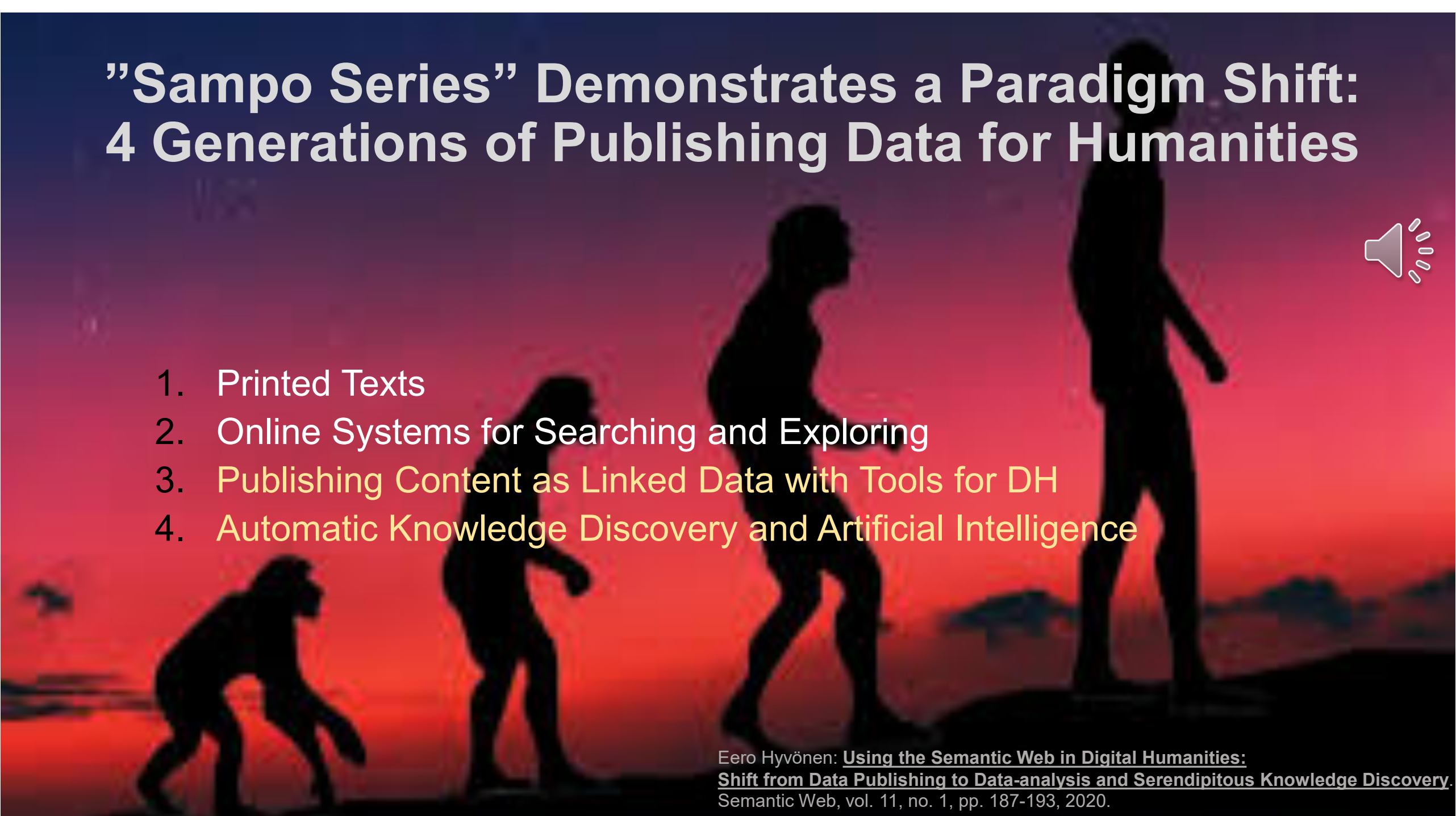


An Example of A Sampo Portal and Data Service

LetterSampo – Historical Letters on the Semantic Web (2021)

Example Video of a Sampo System: https://vimeo.com/461293952

”Sampo Series” Demonstrates a Paradigm Shift: 4 Generations of Publishing Data for Humanities



1. Printed Texts
2. Online Systems for Searching and Exploring
3. Publishing Content as Linked Data with Tools for DH
4. Automatic Knowledge Discovery and Artificial Intelligence

Eero Hyvönen: **Using the Semantic Web in Digital Humanities: Shift from Data Publishing to Data-analysis and Serendipitous Knowledge Discovery**. Semantic Web, vol. 11, no. 1, pp. 187-193, 2020.

Lessons Learned: Sampo Applications

- Domain agnostic SW standards and practices can be applied on “all” domains
- National SW infrastructure is the key for cost-efficient application development
- It is possible to create popular systems in use with novel features
- Reusable software tools such as Sampo-UI quite essential
- Sustainability of applications remains a challenge
  - Technologies are new to data owners
- Paradigm change in web publishing
  - new avenues to the future are open …

SUMMARY

Re-usable, shared LOD infrastructure is the key for successful Semantic Web Applications

But the Lunch is not Free

- More collaboration is needed -> complicates work
- Integration of semantic systems with legacy systems
- Manual annotations are costly and may not scale up
- Automatic annotation and linking lowers data quality

Need more source criticism and data literacy!

- What the data actually is and mean?
- Big data quality issues: completeness, skewness, errors

More Information – Questions?

https://seco.cs.aalto.fi/

Semantic Computing Research Group (SeCo)

Making computers and the web more intelligent and interoperable!

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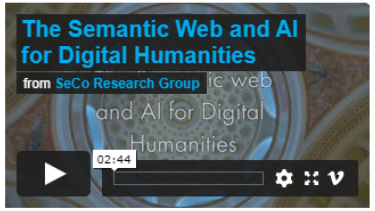
Semantic Computing Research Group (SeCo) researches machine-processable semantics related to, e.g., the Semantic Web. We are located at the Aalto University, School of Science, Department of Computer Science and HELDIG – Helsinki Centre for Digital Humanities, University of Helsinki, Faculty of Arts. Our group consists of researchers both from the Aalto University, School of Science, Department of Computer Science and University of Helsinki, Department of Computer Science, and HELDIG.

Our research is focused on semantic technologies, such as the Semantic Web and intelligent web services. In addition to research and publications, we also create prototype applications that demonstrate the new possibilities of semantic technologies, such as **semantic portals for end users**, **semantic infrastructural data and ontology services**, and **ontologies and tools** for creating semantic applications.



450 publications about the infras and their applications:
https://seco.cs.aalto.fi/publications/
Videos:
https://seco.cs.aalto.fi/applications/sampo/

Application Domains

Our work is highly cross-disciplinary, including application domains, such as Digital Humanities, Health, Learning, Government, Commerce, Geography, and Biology.

Selected SeCo Applications and Demos for End Users


Mapping Manuscript Migrations
Online since 2020. Try it!


WarVictimSampo 1914-1922
Online since 2019. Try it!


BiographySampo - Finnish Life Stories on the Semantic Web
Online since 2018. Try it!


U.S. Congress Prosopographer
Online since 2018. Try it!


Norssi Alumni on the Semantic Web
Online since 2017. Try it!


Semantic Finlex - Finnish Law


WarSampo - Second World War


Hipla.fi - Finnish Ontology


Semantic National Biography


BirdWatch - Mobile Semantic

Latest News

Five new SeCo papers accepted for the ISWC 2021
The 20th International Semantic Web Conference (ISWC 2021), the...
2.8.2021 6:53 by eahyvone

FindSampo ? Finnish Archaeological Finds on the Semantic Web
FindSampo – Finnish Archaeological Finds on the Semantic

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intangible

Eero Hyvönen: Relevance Feedback Search Based on Automatic Annotation and Classification of Texts

Eero Hyvönen: How to Create a National Cross-domain Ontology and Linked Data Infrastructure and Use It on the Semantic Web

Eero Hyvönen, Esko Ikkala, Mikko Koho, Jouni Tuominen, Toby Burrows, Lynn Ransom, and Hanno Wijsman: Mapping Manuscript Migrations on the Semantic Web: A Semantic Portal and Linked Open Data Service for Premodern Manuscript Research

Petri Leskinen and Eero Hyvönen: Reconciling and Using Historical Person Registers as Linked Open Data in the AcademySampo Knowledge Graph

SeCo on Twitter

Tweets by @secoresearch

SeCo Research Group Retweeted

ManuscriptMigrations
@MSMigrations
"Harmonizing and publishing heterogeneous