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/
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   • Sampo Model and series of systems

4. Paradigm Shifts in Web Publishing
1. SEMANTIC WEB

EXTENDING THE LAYER CAKE MODEL
Semantic Web

Web of Pages
WWW

Web of (Linked) Data
GGG
(Giant Global Graph)

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!

• Creating more intelligent applications for the public, curators, and researchers
  • The machine “understands” linked data!
Evolving Layer Cake Model of W3C

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

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

**Applications**
- Sampo series, etc...

**Data sets**
- Data services
- LDF.fi, ...

**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

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Ontology domain</th>
<th>Underlying thesaurus</th>
<th>Size</th>
<th>Maintaining Organization</th>
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<tbody>
<tr>
<td>YSO</td>
<td>General domain</td>
<td>General Finnish Thesaurus, YSA, Allärs</td>
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<td>National Library, Åbo Academy</td>
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<td>MUSO</td>
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<td>Thesaurus of Music, MUSA/CILLA</td>
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<td>National Library</td>
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<td>National Board of Antiquities</td>
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<td>AFO</td>
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<td>Agriforest Thesaurus</td>
<td>5500</td>
<td>Viikki Science Library</td>
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<td>University of Eastern Finland and Library of Aalto University</td>
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<td>VALO</td>
<td>Photography</td>
<td>Thesaurus of Photography Literature, Thesaurus of Photography Technology</td>
<td>1900</td>
<td>Finnish Museum of Photography</td>
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<td>MERO</td>
<td>Seafaring, shipping</td>
<td>Thesaurus of Seafaring</td>
<td>1400</td>
<td>Finnish Transport Agency</td>
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<td>KAUNO</td>
<td>Literature subjects</td>
<td>Thesaurus of Literature, Bella</td>
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<td>Finnish Public Libraries, Kirjastot.fi</td>
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<td>JUHO</td>
<td>Public government</td>
<td>Thesaurus of Finnish Government, VNOS</td>
<td>6400</td>
<td>Ministry of Finance</td>
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<td>TERO</td>
<td>Health promotion</td>
<td>YSA, TESA, MeSH, Stameta</td>
<td>22000</td>
<td>Various organizations</td>
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<td>Thesaurus of Literature Research</td>
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<td>Finnish Literature Society</td>
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<td>KULO</td>
<td>Culture research</td>
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<td>POIO</td>
<td>Points of interest</td>
<td>TGN, Geonames, LDG, SUO</td>
<td>4600</td>
<td>Various organizations</td>
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<td><strong>TOTAL</strong></td>
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<td><strong>86300</strong></td>
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</table>
Case: Holistic Collaborative Finnish Ontology KOKO

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

<table>
<thead>
<tr>
<th>Intersecting ontologies</th>
<th>Number of equivalent concepts</th>
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<tr>
<td>YSO + TAO</td>
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<td>YSO + MAO</td>
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<td>YSO + VALO</td>
<td>950</td>
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<td>MAO + TAO</td>
<td>1190</td>
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</table>

[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

Semantic relations in use:
BT/NT and RT

YSO Ontology

Semantic relations in use:
subClassOf, partOf, and relatedConcept
Ontology library services: ONKI.fi concept

Better search and browsing functionalities enable higher quality vocabularies

Better vocabularies enable annotations with higher quality and less work on indexing

High quality semantic annotations enable better search results and other services

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 by Finnish ministries

2019: 32 million API calls
2020: 2.1 million page visits
2020: 12% increase in use

[Suominen et al., ESWC, 2014]
<table>
<thead>
<tr>
<th>Type</th>
<th>PREFERRED TERM</th>
<th>BROADER CONCEPTS</th>
<th>NARROWER CONCEPTS</th>
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</thead>
<tbody>
<tr>
<td>Hierarchical concept</td>
<td>organic objects</td>
<td>physical objects</td>
<td>abscesses, anus, body, capsule, carcasses, cell nucleus, cell wall, cells, cellular automata, chloroplasts, chromosomes, clones, galls (botany), galls (botony), genes, malformations, membranes, microsatellites, mitochondria, organelles, orgonellae, organs, parts of plants, parts of the body, pigment, polyps, receptors, scars, shell and peel, synapses, telomers, tissues (organic objects)</td>
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</tr>
</tbody>
</table>
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 Ильич Чайковский (ru)
Pyotr Ilyich Tchaikovsky (en)
Pjotr Tjajkovskij (sv)
Pjotr Tsjajkovskij (no)
Pjotr Iljitsch Tschaikowski (de)
Piotr Ilitch Tchaikovski (fr)
Piotr Illich Chaikovski (es)
Pëtr Il'ič Čajkovskij (it)
Pjotr Iljitsj Tsjajovski (nl)
Piotr Ilitch Tchaikovsky (pt)
Piotr Czajkowskij (pl)
Piotr Ilici Ceaikovski (ro)
Pjotr Iljics Csajkovszkij (hu)
Geography: A Key Element in the Linked Open Data Cloud

https://lod-cloud.net/

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

Semantic Web
Finnish Ontology Service of Historical Places and Maps: http://hipla.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
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/](https://dublincore.org/)

Using foundational ontology models
- Different schemas are mapped onto a shared ontology
- CIDOC CRM is a prominent standard of this
CIDOC CRM:
Using events as the foundation for knowledge representation

E39 Actor

E39 Actor

E39 Actor

E31 Document
“Yalta Agreement”

E38 Image

E53 Place
7012124

E52 Time-Span
February 1945

P86 falls within

E52 Time-Span

P81 ongoing throughout

P94 has created

P11 participated in

P14 performed

P7 took place at

P82 at some time

P67 is referred to by

“Crimea Conference”

E7 Activity

E65 Creation

[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
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.
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 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 URLs).

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).
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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, ...

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

2. CultureSampo – Finnish Culture on the Semantic Web (2008) [107 000 users]
3. TravelSampo - Mobile Contextualized Services of Cultural Tourism (2011)
5. WW1LOD – World War I Linked Open Data (2014)
8. U.S. Congress Prosopographer – U.S. Congress Legislators 1789-2018
10. NameSampo — Linked Data Workbench for Toponomastic Research (2019) [37 000 users]
11. WarVictimSampo 1914-1922 – National War History [29 000 users]
15. LetterSampo, LawSampo, ParliamentSampo, … underway

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

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

P1. Support collaborative data creation and publishing
Ontology Infrastructure

- Land survey
- Museums
- Web 2.0 sites
- Archives
- Media
- Libraries
- Citizens
- Linked Data
- Content Providers
- Semantic Metadata

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

![Correlation Matrix](image)

**Figure 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 1

Application 2

Application N

SPARQL End Point

Server Side
https://ldf.fi

Linked Data Finland Service
WWW Standard Model

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

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

SeCo Welcomes You!
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 HELIOS – a 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 HELIOS.

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 infrastructure and ontology services, and ontologies and tools for creating semantic applications.

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

- Manuscript Migrations
  - Online since 2003

- VaihdonSampo 1914-1922
  - Online since 2019

- Biography/Sampo – Finnish Life Stories on the Semantic Web
  - Online since 2018

- U.S. Cypriotes Thesaprapher
  - Online since 2019

- Nomis Alumni on the Semantic Web
  - Online since 2017

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

450 publications about the infrastructures and their applications:
https://seco.cs.aalto.fi/publications/