Leibniz-Gemeinschaft

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R G Z M

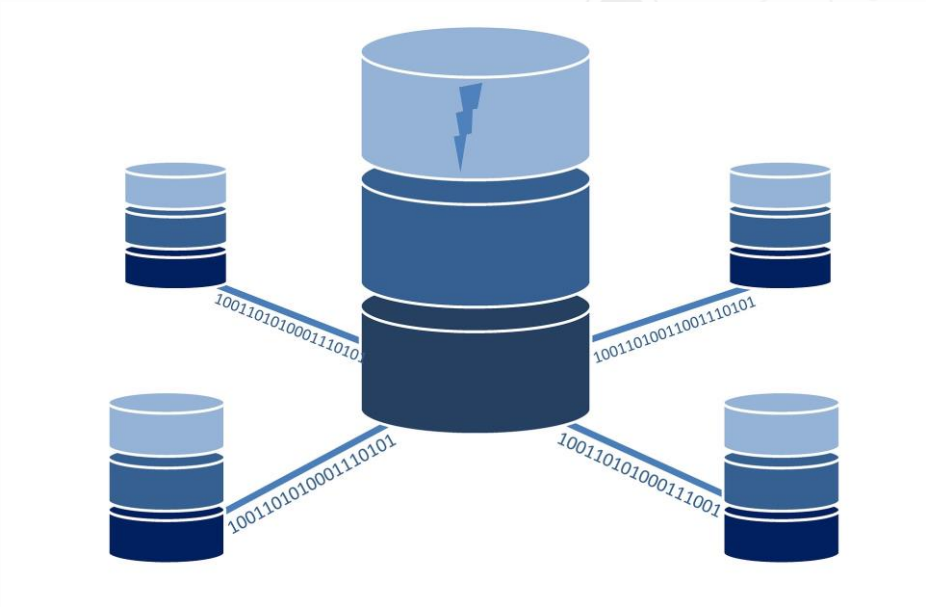
Taming Time –

Modelling uncertainty as reproducible Linked Open Data

Florian Thiery M.Sc.
Dr. Allard W. Mees FSA

Römisch-Germanisches Zentralmuseum Mainz
Department of Scientific Information Technology

The Römisch-Germanisches Zentralmuseum Mainz (RGZM) hosts already since the mid-1990s…



…several online available databases containing hundred thousands of data records, with content from many different archaeological disciplines.

These databases where constructed in interdisciplinary transnational projects and include a lot of…

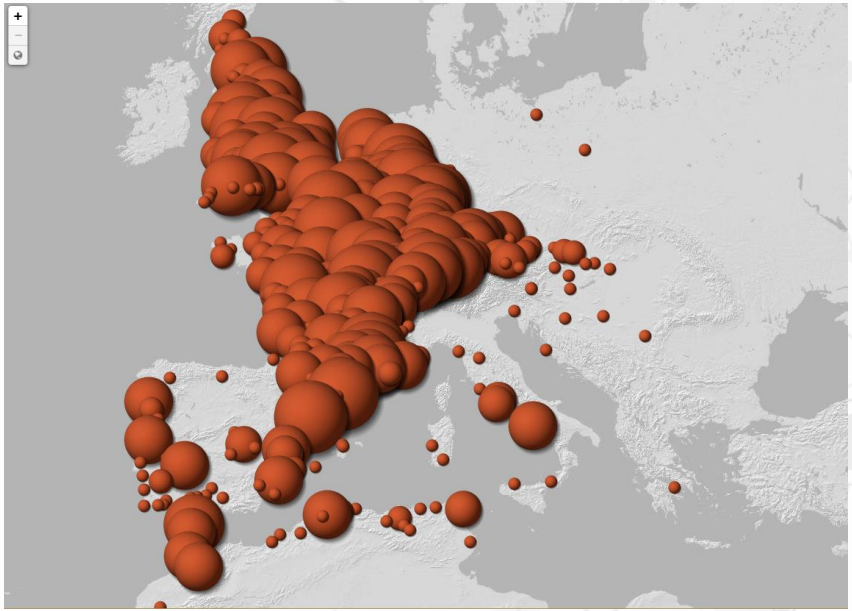
…“hidden archaeological assumptions”
in their relational
data models.

Especially short cutted relative chronological information and its dependencies are not modelled using transparent methods.

The aim of our project is to make these hidden assumptions in archaeology visible…

…and provide them as Linked Open Data to establish reproducible research as a fundament for Open Science.

In particular, the Samian Research database at the RGZM offers nearly 250'000 identified potter stamps from Europe, …

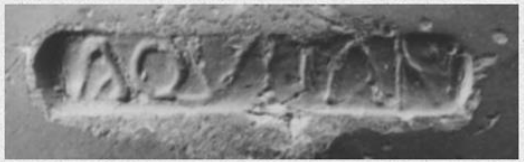


http://www.rgzm.de/samian

… which are traditionally dated in a short cutted way.

In Roman archaeology this is usually expressed by establishing "absolute dates" in well known “from-to” tables, …

Potter Aquitanus (about)	Die 11c 39 (die variety)	Reading AQVITANI
	Die position Base inside	
Kiln site La Graufesenque		
Date AD 40-65		
Form 27g (Cup) (form variety)	Form Attribute	Slip colour
Site Strasbourg *Argentor* (7.750000 , 48.583332)	Findspot	Findspot Character
(Site statistics)		
Repository	Museum Inv.Nr	Excavation Nr. 13160
Quantity 1		
Bibliography		
Comment		



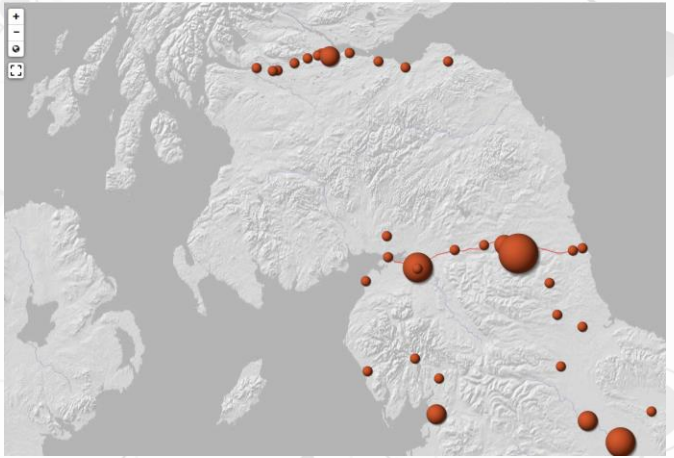
http://www.rgzm.de/samian

… whereas in reality, the situation is much more diffuse.

Datings are mainly derived from Limes parts. But the only absolute dated Limes part is Hadrian‘s Wall (122+ AD)…

Phil Champion / Hadrian's wall at Cuddy's Crags and Housesteads Crags CC BY-SA 2.0
https://commons.wikimedia.org/wiki/File:Hadrian%27s_wall_at_Cuddy%27s_Crags_and_Housesteads_Crags_-_geograph.org.uk_-_404992.jpg

… which is good for dating the Samian found at Hadrian‘s Wall …

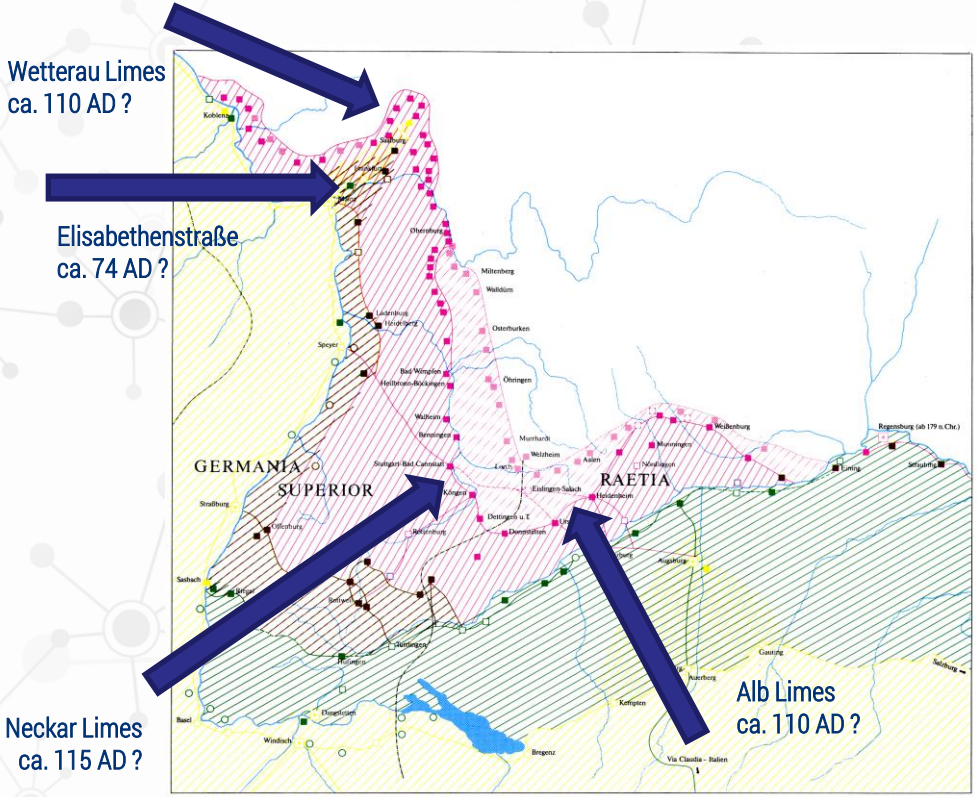


http://www.rgzm.de/samian (Distribution of Cinnamus ii on Hadrian‘s Wall)

The german Alb Limes, Neckar Limes, Elisabethenstraße and Wetterau Limes do not have absolute dates.

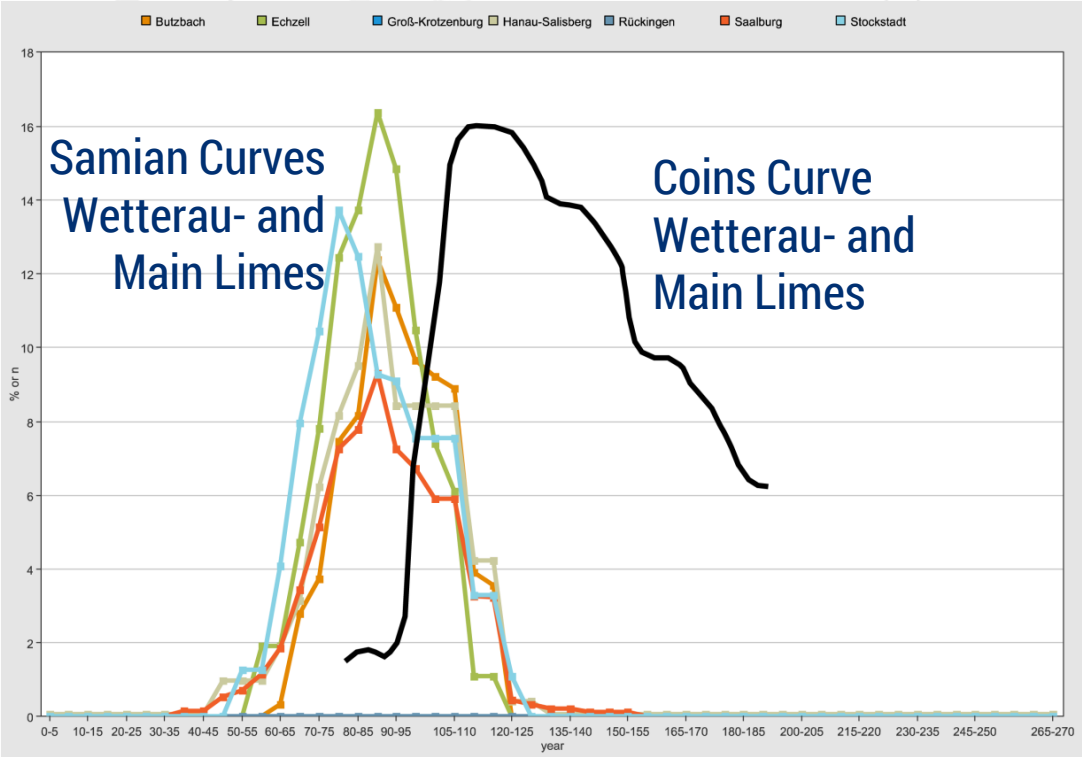
However, due to the progressing occupation, Limes phases have a relative chronology.

How to date these Limes phases?



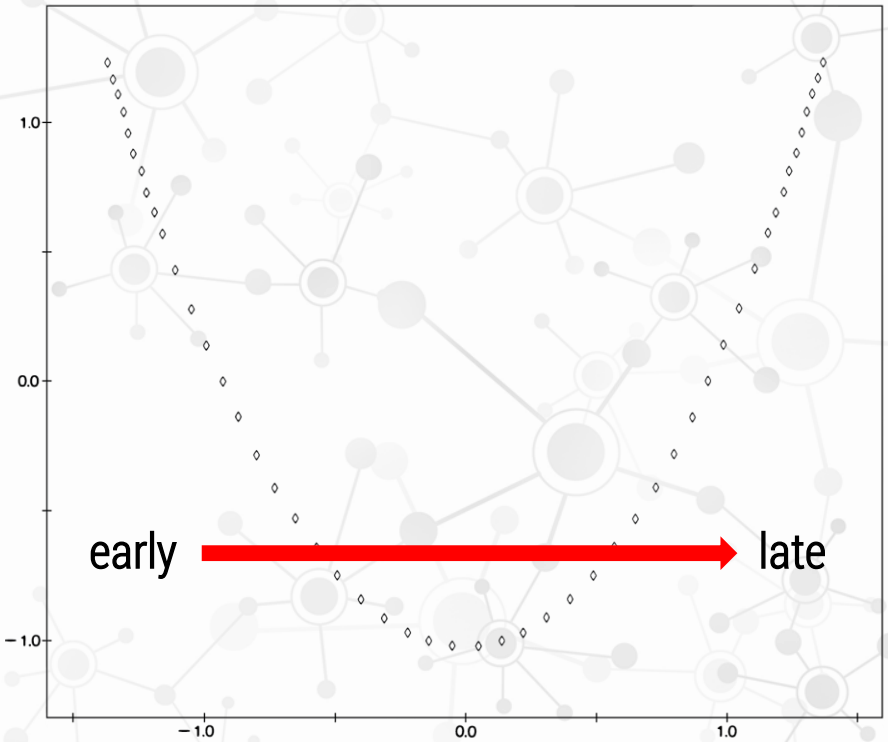
Kuhnen 1992, 79, Taf. 1

Who is right? There are diverging average Coin dating curves and Samian dating curves of german Limes parts.



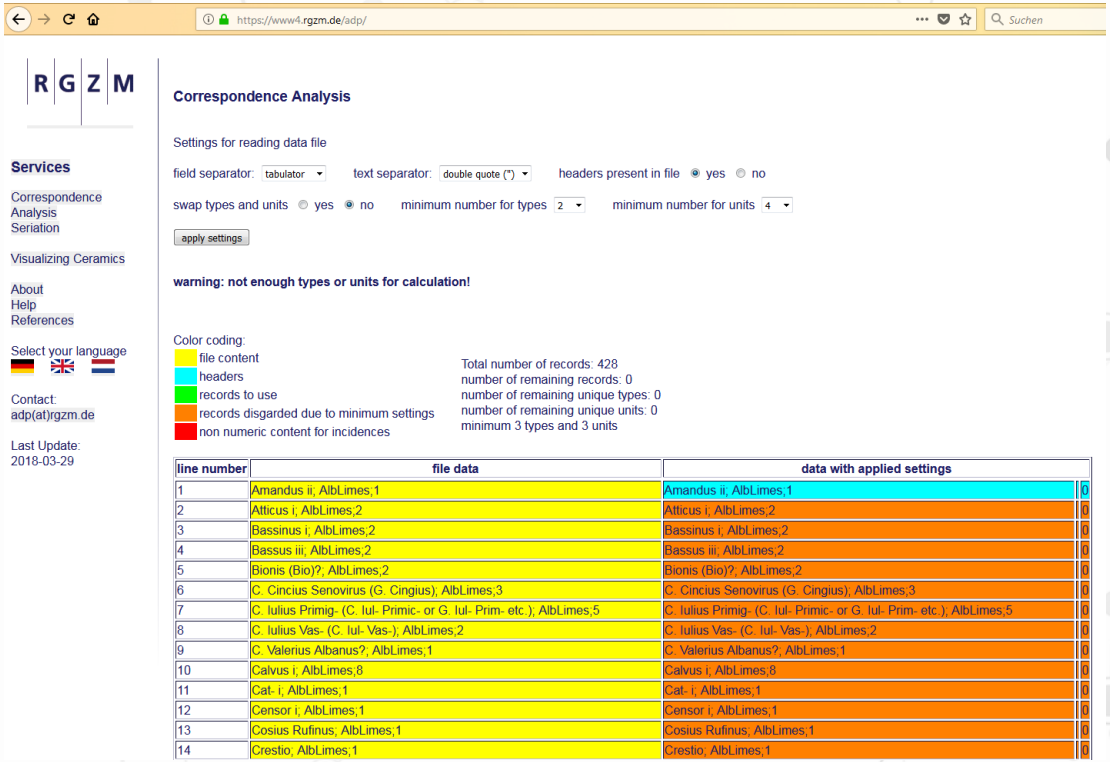
based on http://rgzm.de/samian

To achieve a chronology in Samian dating we use the horseshoe paradigma in Correspondence Analysis (CA).



based on Madsen 1988, 25, Fig. 11.

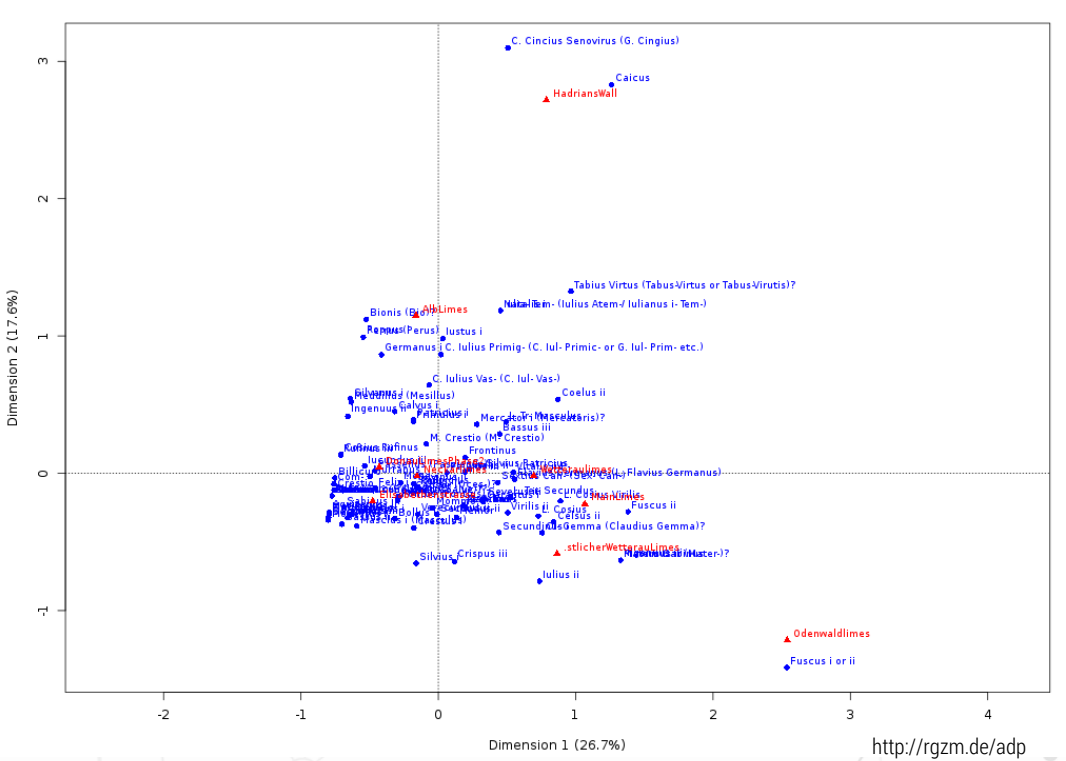
The easy accessible web based Correspondence Analyses at the RGZM ADP research tool only needs a CSV input file.



line number	file data	data with applied settings
1	Amandus ii; AlbLimes;1	Amandus ii; AlbLimes;1 0
2	Atticus i; AlbLimes;2	Atticus i; AlbLimes;2 0
3	Bassinus i; AlbLimes;2	Bassinus i; AlbLimes;2 0
4	Bassus iii; AlbLimes;2	Bassus iii; AlbLimes;2 0
5	Bionis (Bio)?; AlbLimes;2	Bionis (Bio)?; AlbLimes;2 0
6	C. Cincius Senovirus (G. Cingius); AlbLimes;3	C. Cincius Senovirus (G. Cingius); AlbLimes;3 0
7	C. Iulius Primig- (C. Iul- Primic- or G. Iul- Prim- etc.); AlbLimes;5	C. Iulius Primig- (C. Iul- Primic- or G. Iul- Prim- etc.); AlbLimes;5 0
8	C. Iulius Vas- (C. Iul- Vas-); AlbLimes;2	C. Iulius Vas- (C. Iul- Vas-); AlbLimes;2 0
9	C. Valerius Albanus?; AlbLimes;1	C. Valerius Albanus?; AlbLimes;1 0
10	Calvus i; AlbLimes;8	Calvus i; AlbLimes;8 0
11	Cat- i; AlbLimes;1	Cat- i; AlbLimes;1 0
12	Censor i; AlbLimes;1	Censor i; AlbLimes;1 0
13	Cosius Rufinus; AlbLimes;1	Cosius Rufinus; AlbLimes;1 0
14	Crestio; AlbLimes;1	Crestio; AlbLimes;1 0

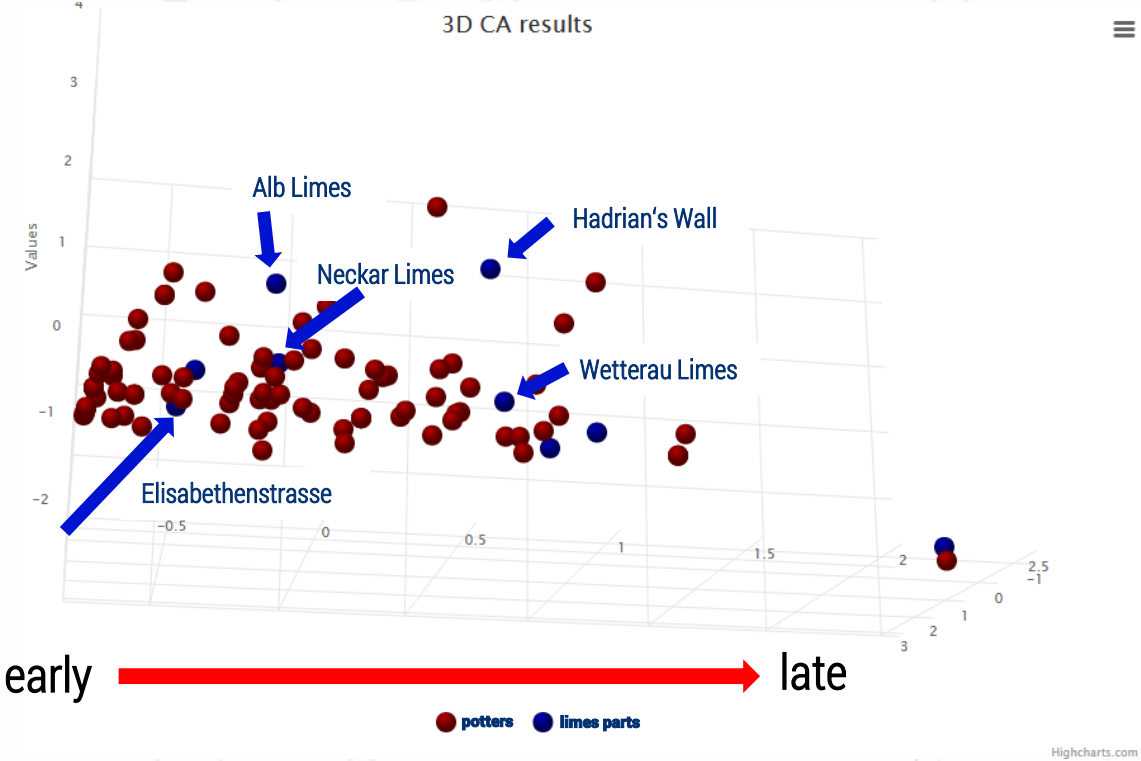
LimesPotters.csv used in http://rgzm.de/adp

The amount of time-overlap between the Limes parts can be defined by the number of potters they have in common.



http://rgzm.de/adp

A deeper look into the relative chronological relationships of the Limes fortresses: the more to the right, the later.



http://rgzm.de/adp

Calculating / dating Limes intervals using a Correspondence Analysis causes challenges, which have to be solved…

name	x	y	z	von	bis	fixed
AlbLimes	-0.162	1.149	-0.519	97	260	fixed
DonauLimesPhase2	-0.43	0.046	-0.372	70	260	fixed
Elisabethenstrasse	-0.479	-0.204	0.27	74	104	fixed
HadriansWall	0.787	2.717	2.279	122	230	fixed
MainLimes	1.067	-0.223	0.273	0	0	schwebend
Neckarlimes	-0.155	-0.021	-0.973	117	260	fixed
Odenwaldlimes	2.540	-1.215	1.228	0	0	schwebend
Wetteraulimes	0.695	-0.019	-0.092	110	260	fixed
ÖstlicherWetterauLimes	0.864	-0.585	-0.103	105	260	fixed

… some Limes parts have fixed datings.

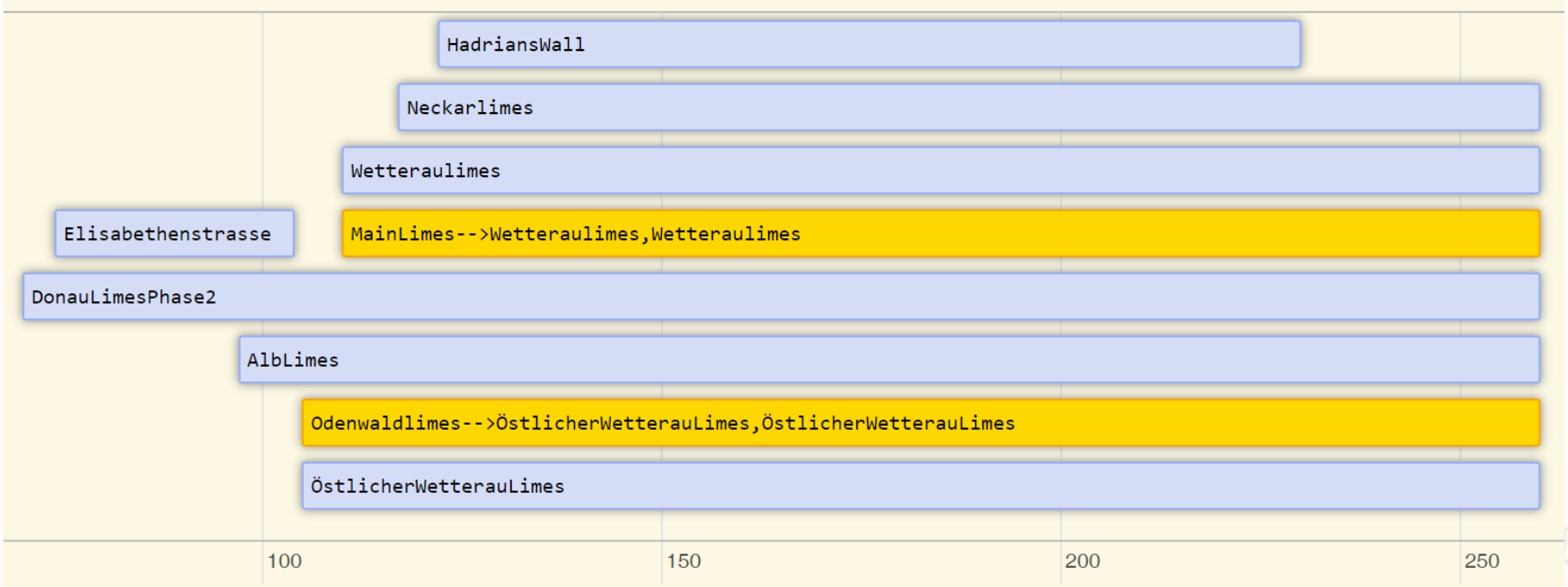
```
HadriansWall
```

… some Limes parts are floating between other fixed parts.

```
MainLimes-->Wetteraulimes,Wetteraulimes
```

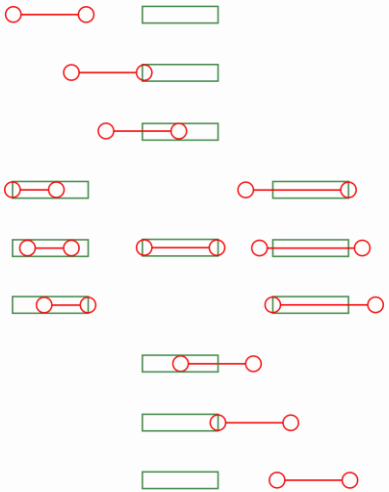
based on https://github.com/RGZM/alligator

After resolving them, time intervals with fixed “virtual fuzzy” datings are used to establish a relative chronology.



based on https://github.com/RGZM/alligator

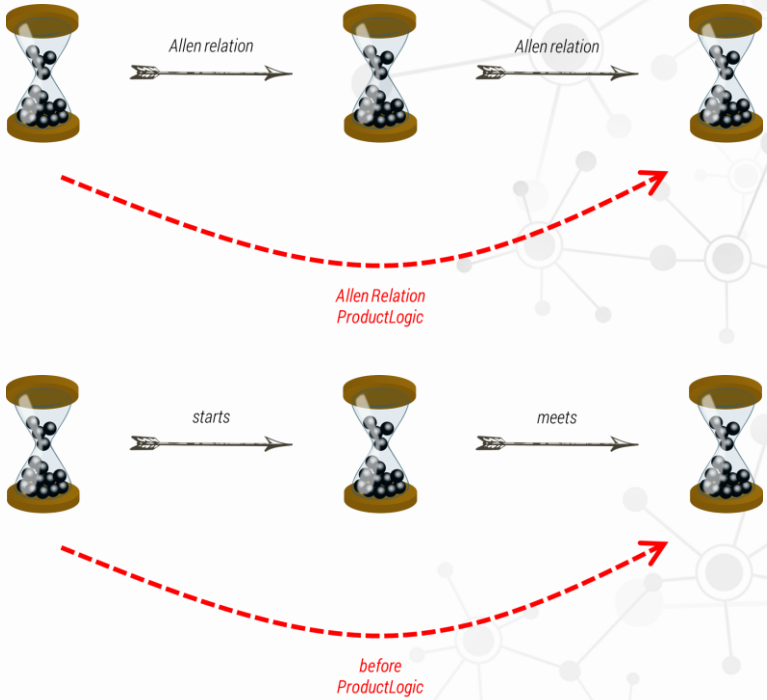
Modelling a relative chronology can be based on Allen's interval algebra to apply temporal reasoning…



based on Freksa (1992), Figure 3

… e.g. in the Academic Meta Tool (AMT) to create Linked Open Data for reproducible and transparent research.

An example for Role-Chain-Axioms within AMT representing Allen's interval algebra and its conclusions.



based on http://academic-meta-tool.xyz/ontology, amt:RoleChainAxiom

	b	m	o	fi	di	si	e	s	d	f	oi	mi	a	q
b	b	b	b	b	b	b	b	b	sb	sb	sb	sb	q	q
m	b	b	b	b	b	m	m	m	bc	bc	bc	tt	sv	q
o	b	b	ob	ob	ol	oc	o	o	bc	bc	ct	sc	sv	q
fi	b	m	ob	fi	di	di	fi	o	bc	tt	sc	sc	sv	q
di	ol	oc	oc	di	di	di	di	oc	ct	sc	sc	sc	sv	q
si	ol	oc	oc	di	di	si	si	hh	yc	oi	oi	mi	a	q
e	b	m	o	fi	di	si	e	s	d	f	oi	mi	a	q
s	b	b	ob	ob	ol	hh	si	s	d	d	yc	mi	a	q
d	b	b	sb	sb	q	yo	di	d	d	d	yo	a	a	q
f	b	m	bc	tt	sv	ys	fi	d	d	f	ys	a	a	q
oi	ol	oc	ct	sc	sv	ys	oi	yc	yc	oi	ys	a	a	q
mi	ol	hh	yc	mi	a	a	mi	yc	yc	mi	a	a	a	q
a	q	yo	yo	a	a	a	a	yo	yo	a	a	a	a	q
q	q	q	q	q	q	q	q	q	q	q	q	q	q	q

based on Freksa (1992), Figure 6

Time intervals with fixed “virtual fuzzy” datings are used to establish a relative chronology.

	AL	DL2	ES	HW	ML	NL	OL	WL	ÖWL	
AL	e	f	oi	di	fi	fi	fi	fi	fi	AlbLimes
DL2	fi	e	di	di	fi	fi	fi	fi	fi	DonauLimesPhase2
ES	o	d	e	b	b	b	b	b	b	Elisabethenstrasse
HW	d	d	a	e	d	d	d	d	d	HadriansWall
ML	f	f	a	di	e	fi	f	e	f	MainLimes
NL	f	f	a	di	f	e	f	f	f	Neckarlimes
OL	f	f	a	di	fi	fi	e	fi	e	Odenwaldlimes
WL	f	f	a	di	e	fi	f	e	f	Wetteraulimes
ÖWL	f	f	a	di	fi	fi	e	fi	e	ÖstlicherWetterauLimes

The degree of connection must be selected carefully, because of different reasoning results and conclusions.

	AL	DL2	ES	HW	ML	NL	OL	WL	ÖWL
AL	1,00	0,47	0,69	0,11	0,11	0,09	0,02	0,51	0,20
DL2	0,31	1,00	0,82	0,06	0,10	0,15	0,00	0,46	0,19
ES	0,19	0,34	1,00	0,03	0,06	0,07	0,01	0,28	0,12
HW	0,56	0,44	0,56	1,00	0,33	0,11	0,11	0,89	0,22
ML	0,36	0,50	0,71	0,21	1,00	0,29	0,21	0,79	0,50
NL	0,29	0,71	0,86	0,07	0,29	1,00	0,00	0,71	0,29
OL	0,25	0,00	0,25	0,25	0,75	0,00	1,00	0,50	0,75
WL	0,28	0,38	0,58	0,10	0,14	0,12	0,02	1,00	0,23
ÖWL	0,33	0,48	0,74	0,07	0,26	0,15	0,11	0,70	1,00

The connection degree depends on the **percentages of potters the Limes Parts have in common**.
range: [0;1] directed!

The connection degree depends on the **Pearson correlation coefficient**.
range: [0;1] undirected!

	AL	DL2	ES	HW	ML	NL	OL	WL	ÖWL
AL	1,000	0,791	0,786	0,679	0,584	0,637	0,303	0,769	0,679
DL2	0,791	1,000	0,884	0,601	0,655	0,808	0,229	0,792	0,739
ES	0,786	0,884	1,000	0,607	0,686	0,780	0,329	0,780	0,758
HW	0,679	0,601	0,607	1,000	0,561	0,473	0,356	0,762	0,525
ML	0,584	0,655	0,686	0,561	1,000	0,640	0,596	0,761	0,728
NL	0,637	0,808	0,780	0,473	0,640	1,000	0,172	0,762	0,653
OL	0,303	0,229	0,329	0,356	0,596	0,172	1,000	0,413	0,549
WL	0,769	0,792	0,780	0,762	0,761	0,762	0,413	1,000	0,804
ÖWL	0,679	0,739	0,758	0,525	0,728	0,653	0,549	0,804	1,000

AlbLimes
DonauLimesPhase2
Elisabethenstrasse
HadriansWall
MainLimes
Neckarlimes
Odenwaldlimes
Wetteraulimes
ÖstlicherWetterauLimes

AMT enables creating a *relative time ontology*, calculating and visualising inferred reasoning results in a web app.

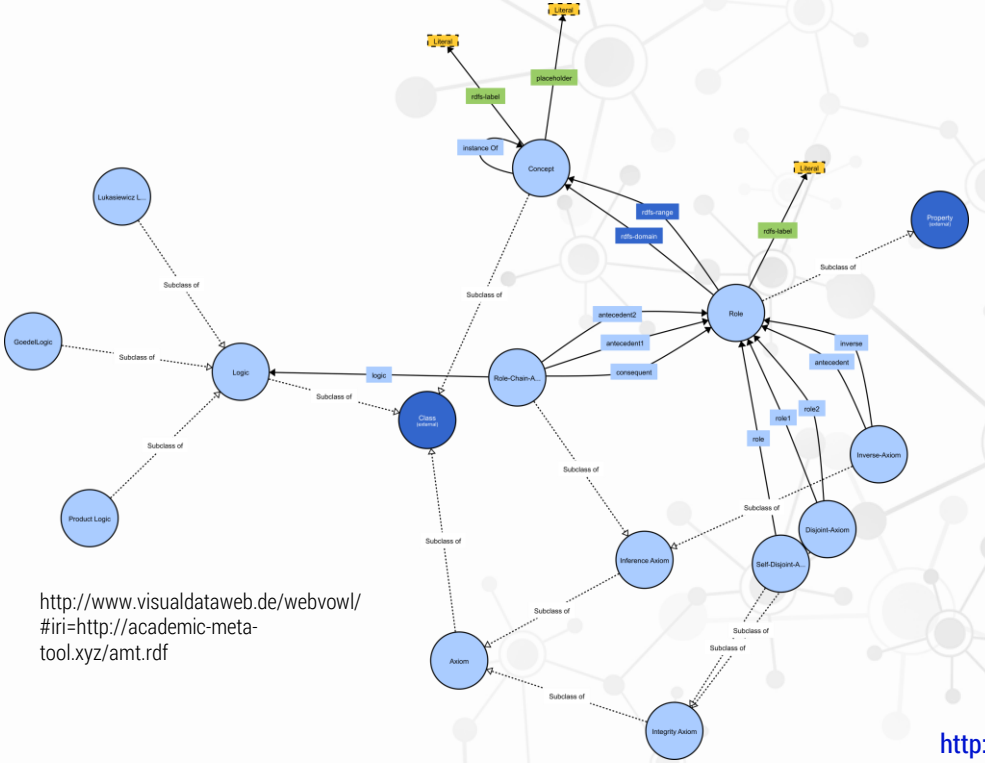
Academic Meta Tool

http://academic-meta-tool.xyz

created by
mainzed, i3mainz and RGZM

with ideas from
Martin Unold M.Sc. & Florian Thiery M.Sc.

The Academic Meta Tool is defined in a Web Ontology Language Ontology (OWL) and available on the World Wide Web.



http://www.visualdataweb.de/webvowl/#iri=http://academic-meta-tool.xyz/amt.rdf

Academic Meta Tool

ACADEMIC META TOOL VOCABULARY

Authors: Florian Thiery (i3mainz, RGZM) & Martin Unold (i3mainz)

Version: Penny Edition

Date: 2018-01-19

Abstract: A vocabulary for Academic Meta Tool.

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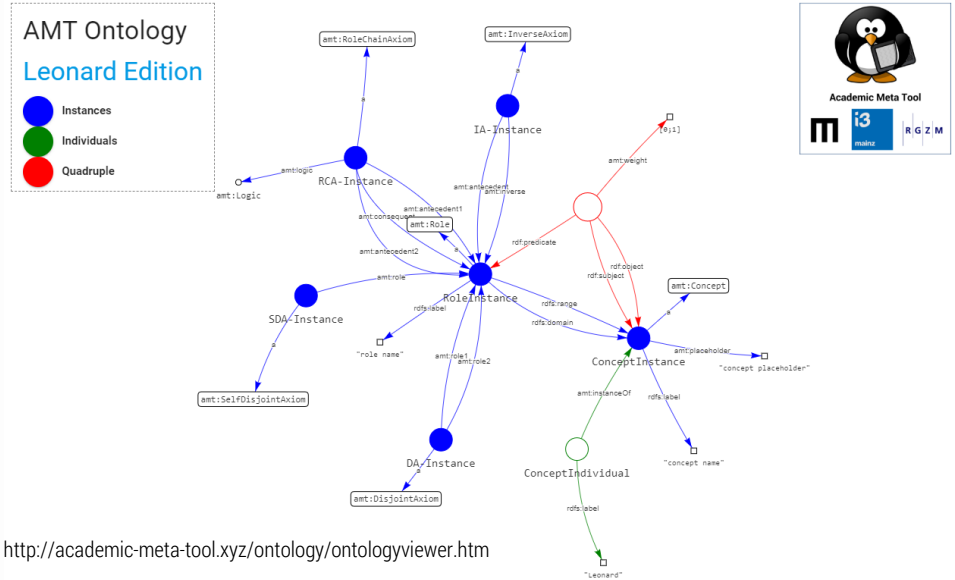
About this Document: This document is based on the GEOJSON-LD VOCABULARY by Sean Gillies (Mapbox) with a CC BY 4.0 license.

http://academic-meta-tool.xyz/vocab/
http://academic-meta-tool.xyz/amt.rdf
http://www.visualdataweb.de/webvowl/#iri=http://academic-meta-tool.xyz/amt.rdf
https://doi.org/10.5281/zenodo.1342530

This can be formulated as a RDF specific ontology, based on the '*Academic Meta Tool Ontology*'.



http://academic-meta-tool.xyz/ontology/ontologyviewer.htm

Academic Meta Tool

ACADEMIC META TOOL ONTOLOGY

Authors: Florian Thiery (i3mainz, RGZM) & Martin Unold (i3mainz)

Version: Leonard Edition

Date: 2018-01-19

Abstract: The Academic Meta Tool ontology / datamodel.

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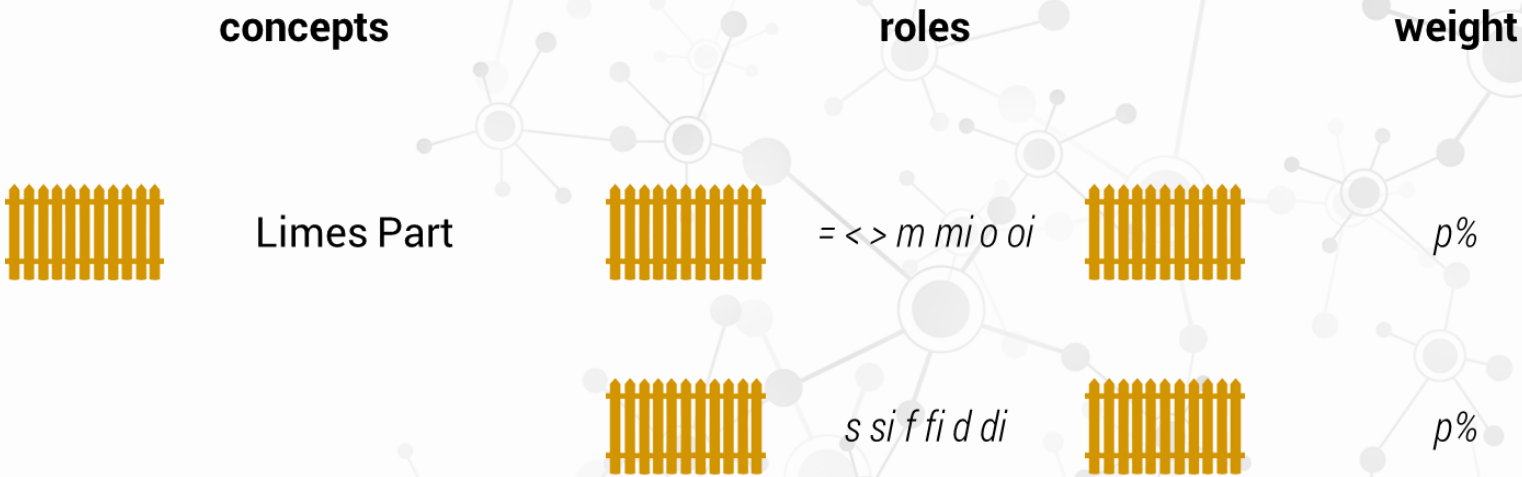
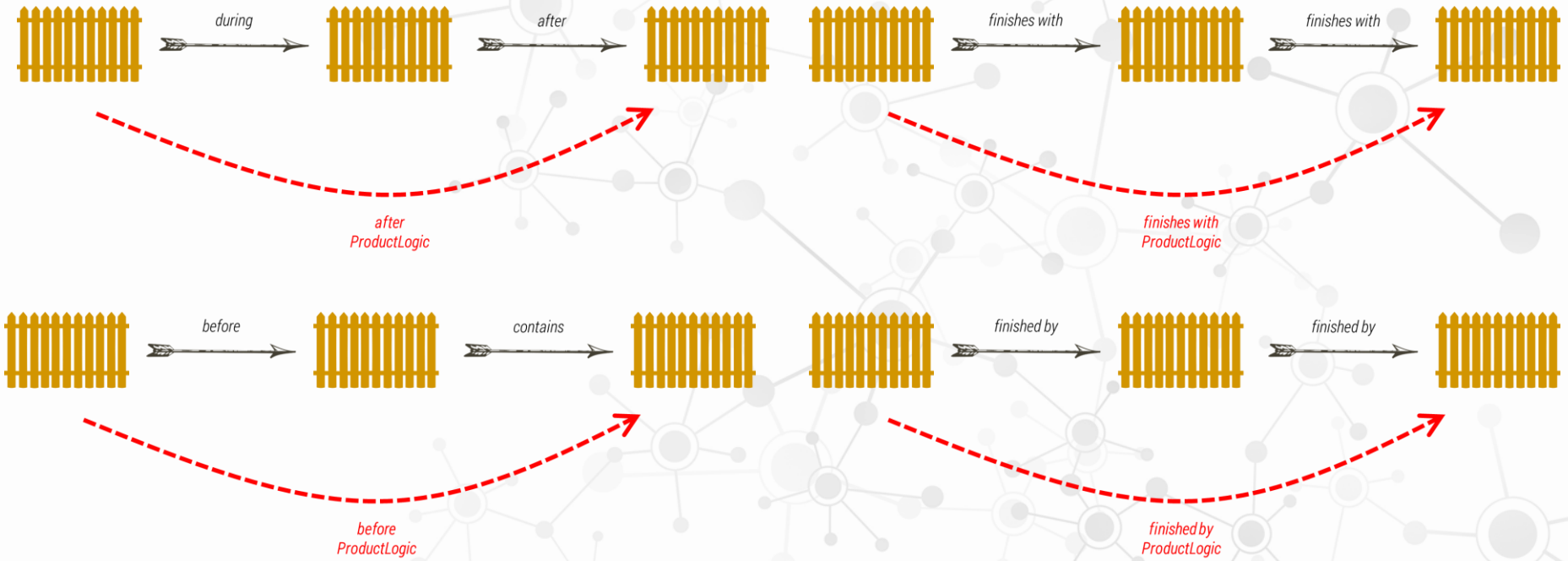
http://academic-meta-tool.xyz/ontology/
http://academic-meta-tool.xyz/ontology/ontologyviewer.htm
https://doi.org/10.5281/zenodo.1342536

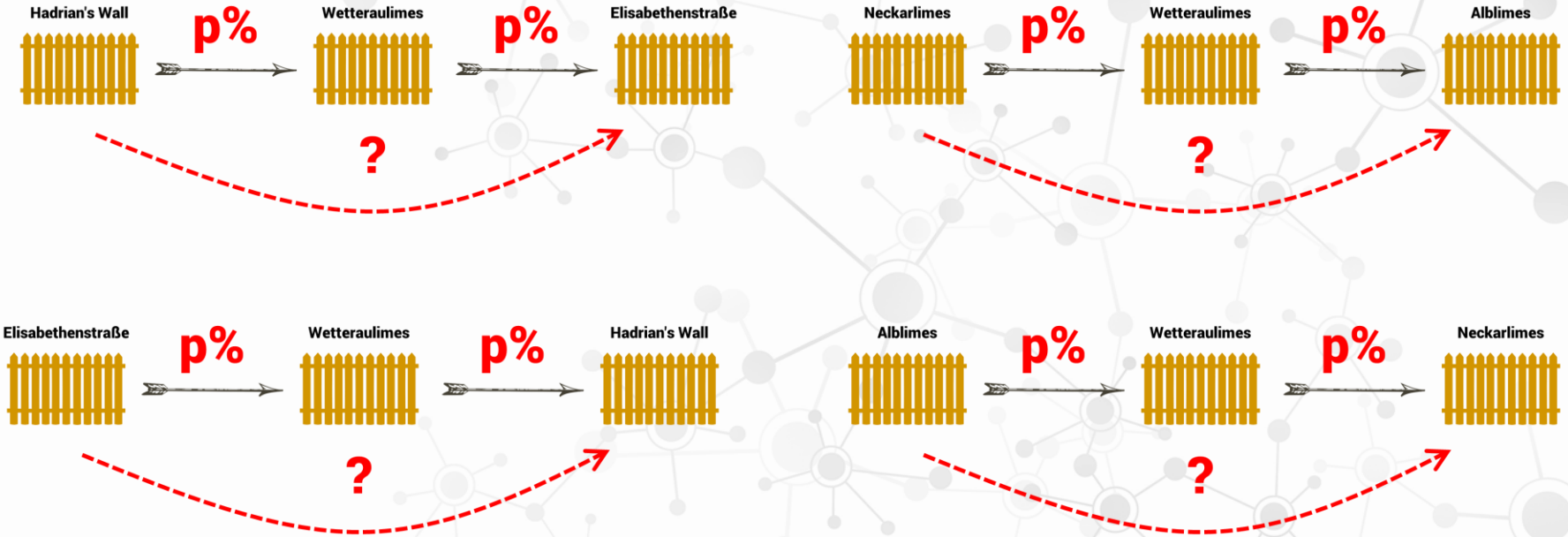
We use Concepts and Roles for creating a relative time ontology using Allen's interval algebra rules.



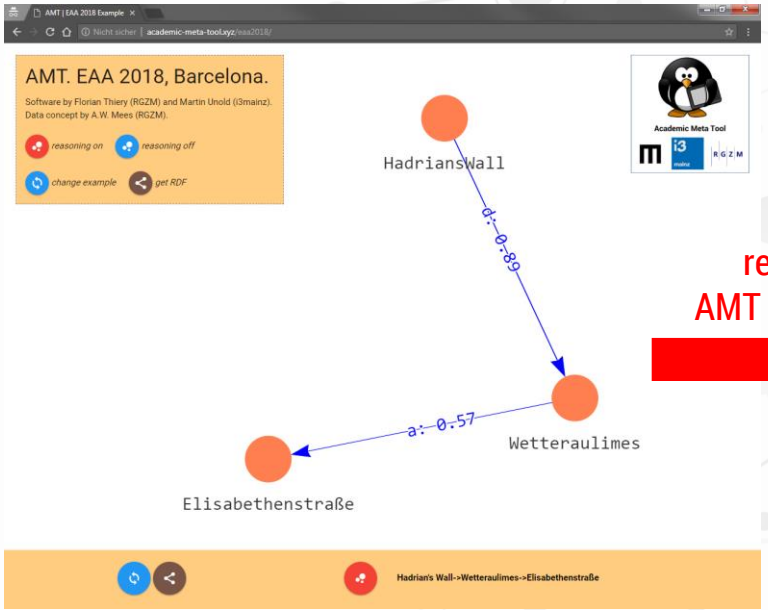
While using Role-Chain-Axioms to calculate the inferred results, reasoning is applied and visualised in a web viewer.



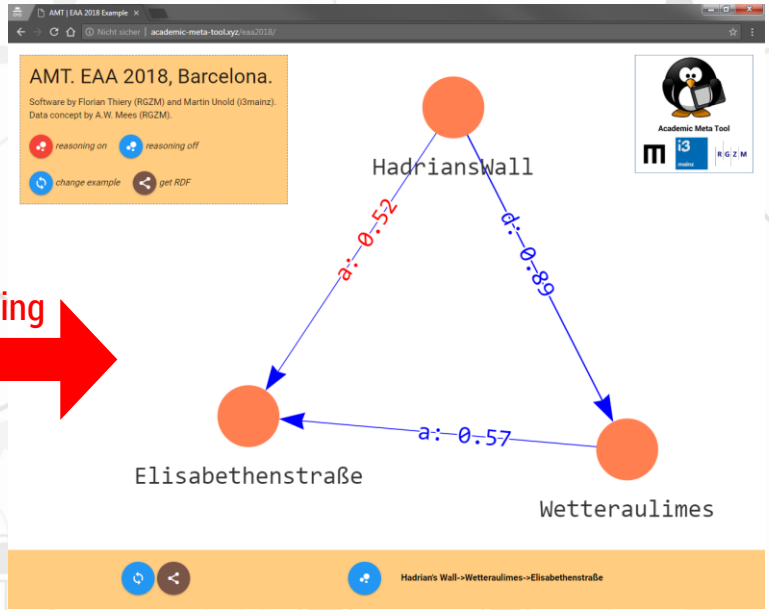
For demonstrating purposes, we use relative time reasoning based on some Limes parts: Set p% carefully!



Example 1: Hadrian‘s Wall weighted relations with other Limes parts and the inferred reasoning results using AMT.

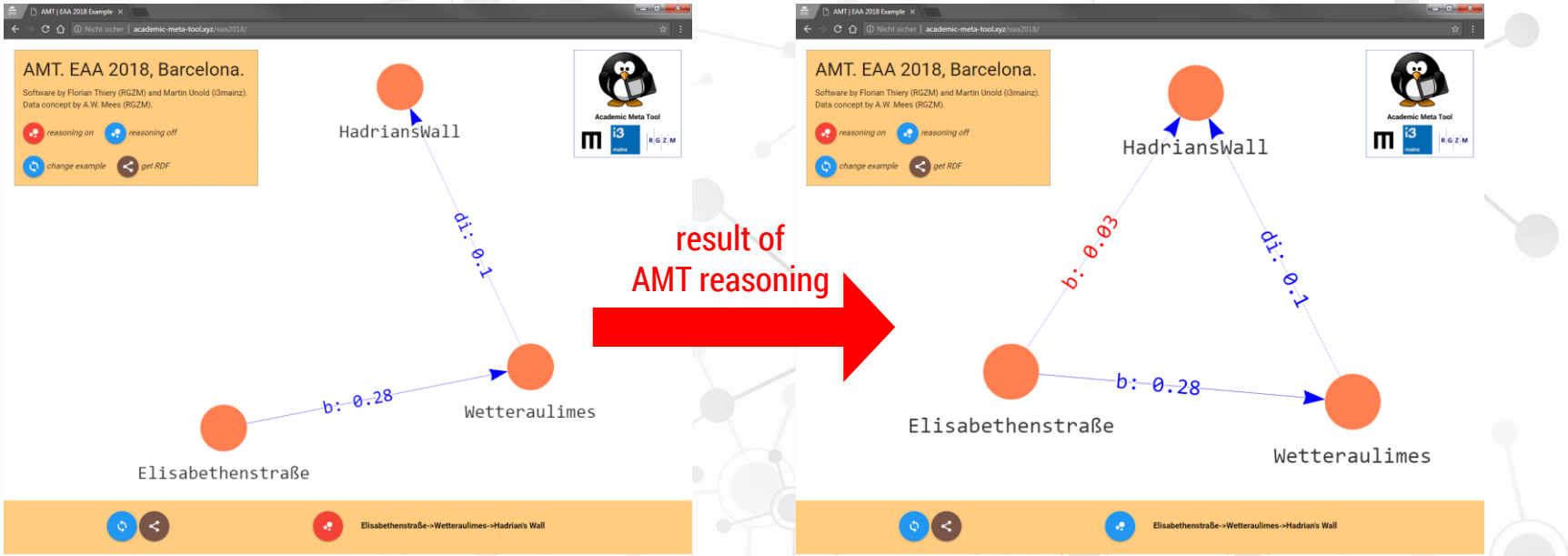


result of
AMT reasoning



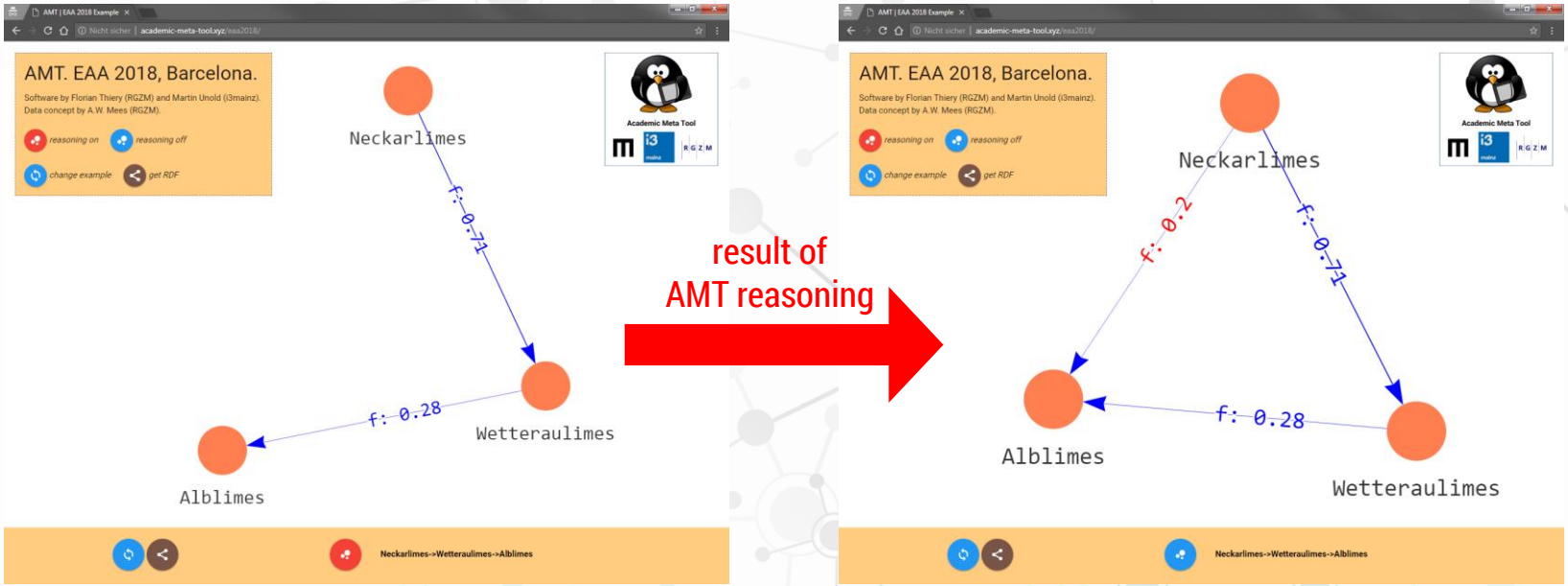
http://academic-meta-tool.xyz/eaa2018/

Example 1^{-1}: Elisabethenstraße weighted relations with other Limes parts and the inferred reasoning results using AMT.



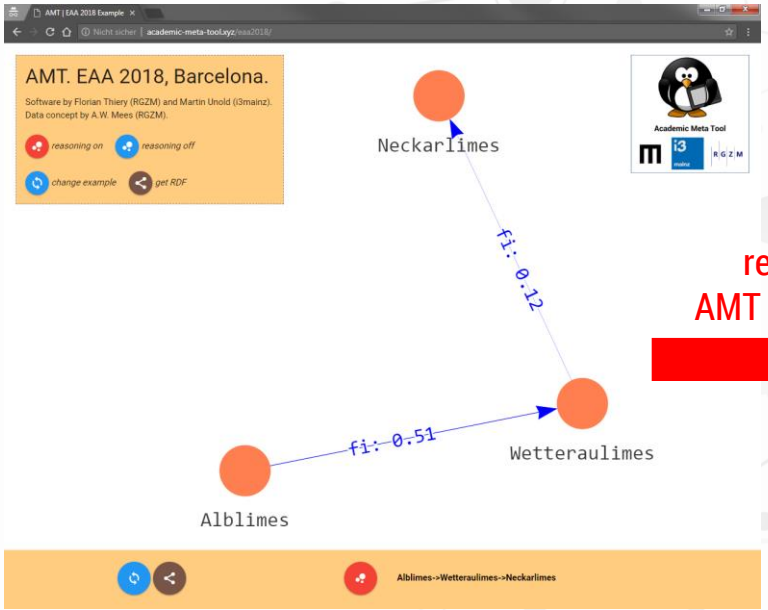
http://academic-meta-tool.xyz/eaa2018/

Example 2: Neckarlimes weighted relations with other Limes parts and the inferred reasoning results using AMT.

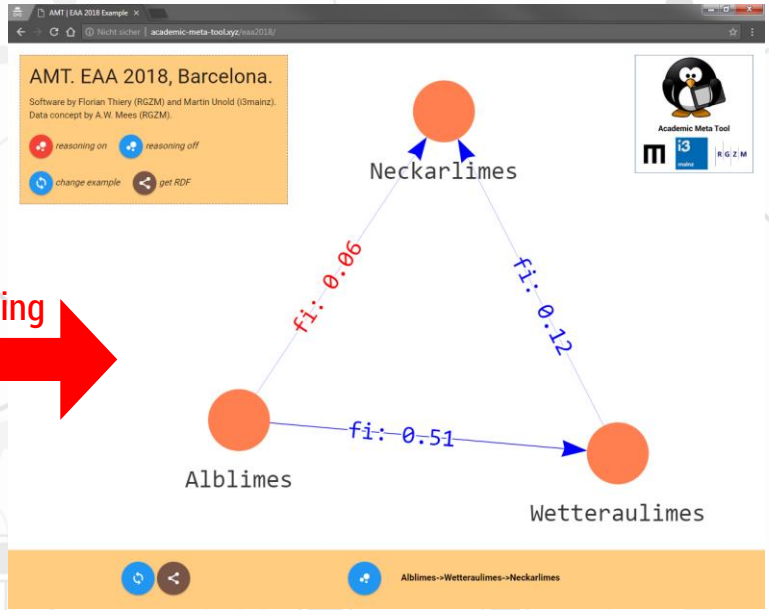


http://academic-meta-tool.xyz/eaa2018/

Example 2^{-1}: Alblimes weighted relations with other Limes parts and the inferred reasoning results using AMT.

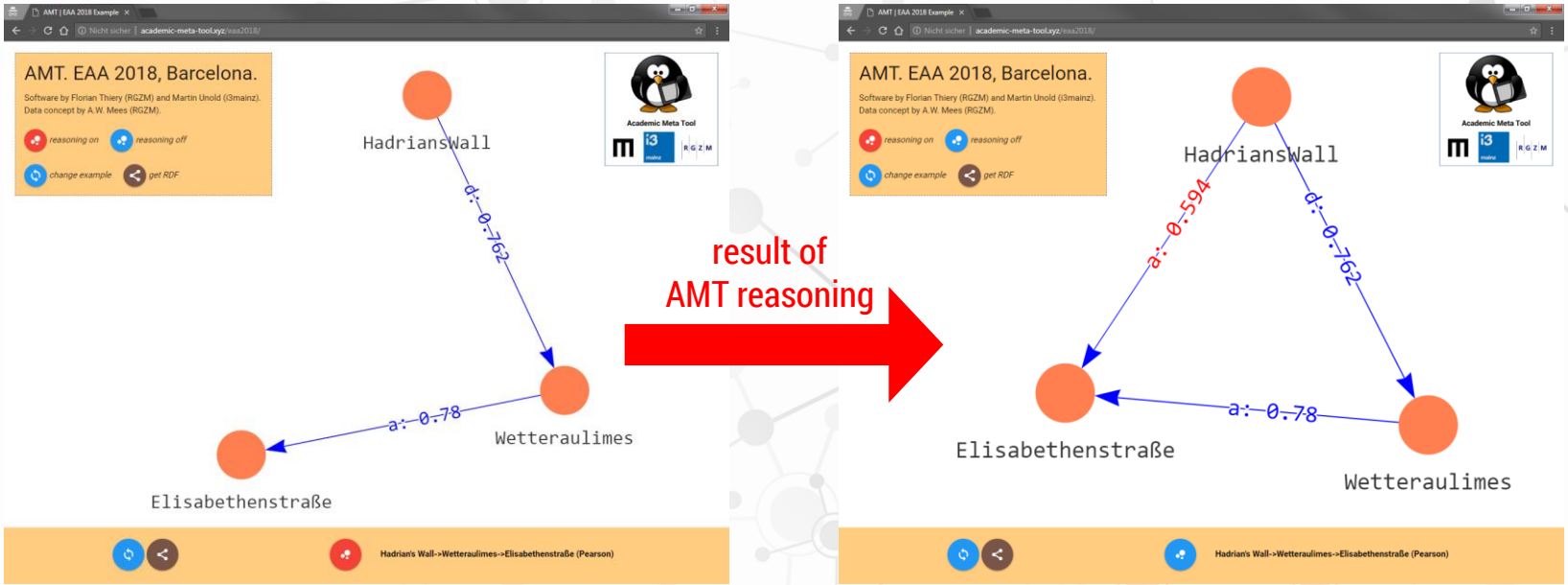


result of AMT reasoning



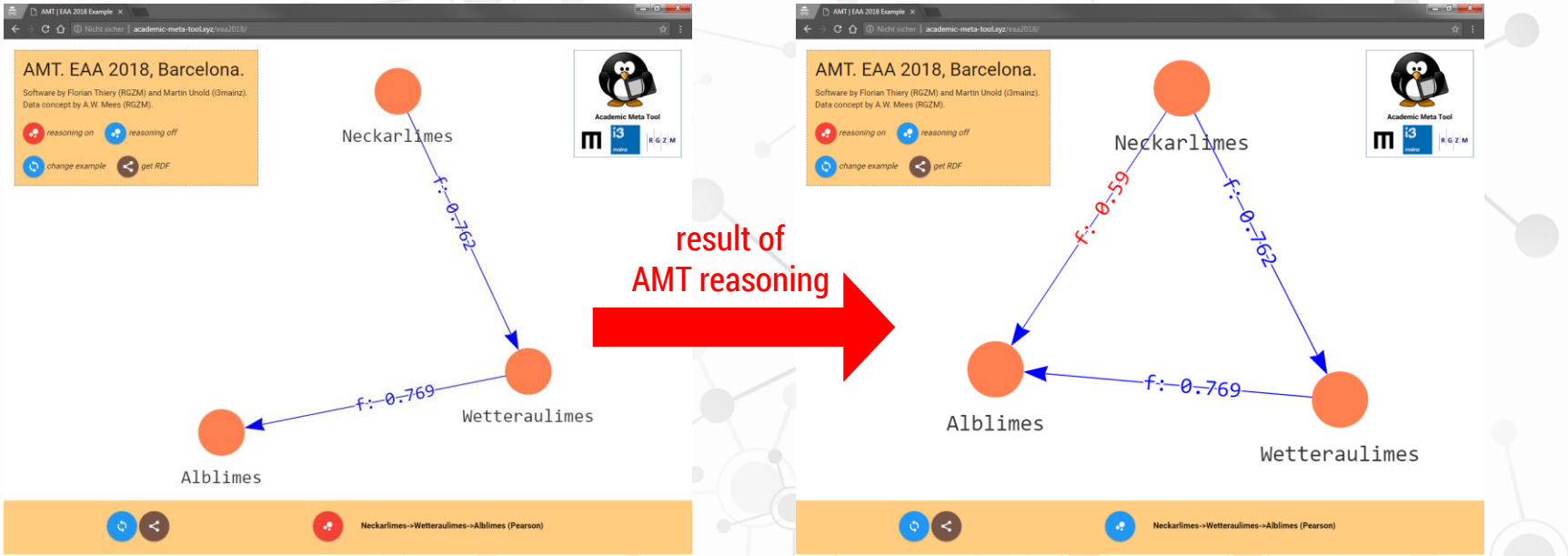
http://academic-meta-tool.xyz/eaa2018/

Example 3: Hadrian‘s Wall and Pearson coefficient with other Limes parts and the inferred reasoning results using AMT.



http://academic-meta-tool.xyz/eaa2018/

Example 3: Neckarlimes and Pearson coefficient with other Limes parts and the inferred reasoning results using AMT.



http://academic-meta-tool.xyz/eaa2018/

Note: It is extremely important to use the „right“ direction and the „correct“ degree of connection!

RGZM

Leibniz-Gemeinschaft

mainzed

Example:

Hadrian's Wall->Wetteraulimes->Elisabethenstraße

Question:

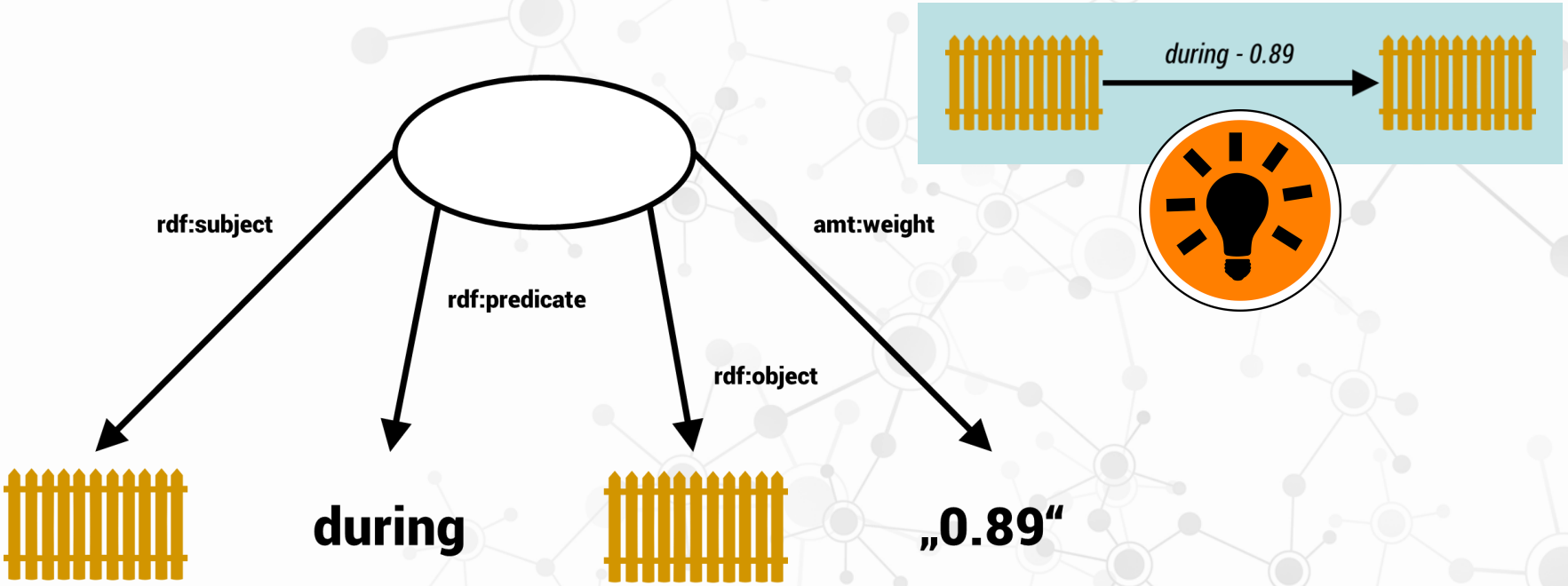
p for Hadrian's Wall-[after]->Elisabethenstraße

p for Elisabethenstraße-[before]->Hadrian's Wall

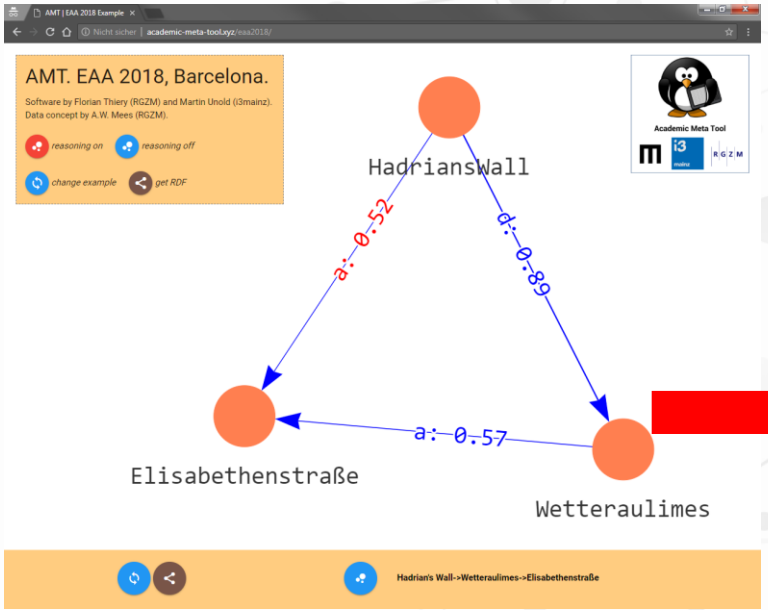
Results:

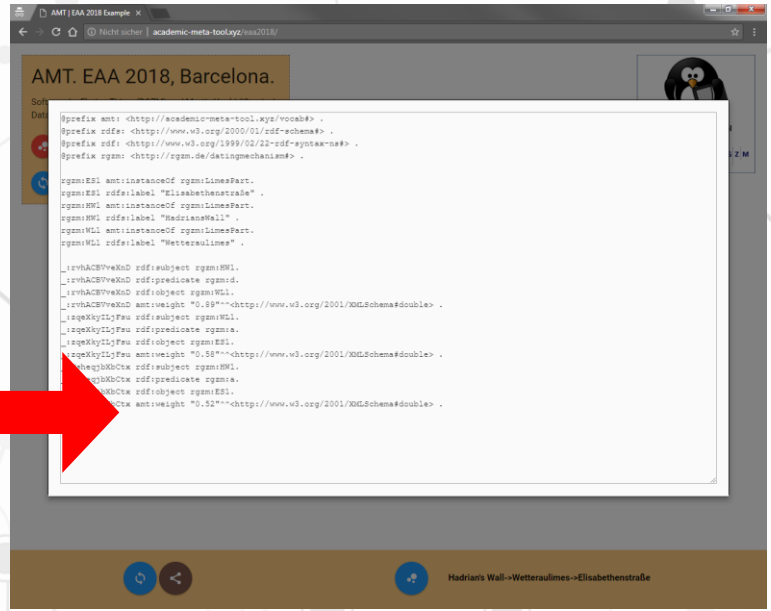
- **weighted:** HW->ES=>**0.52** [0;1]
- **weighted^{-1}:** ES->HW=>**0.03** [0;1]
- **PearsonNormalized:** HW->ES=>**0.59** [0;1]
- **PearsonNormalized^{-1}:** ES->HW=>**0.59** [0;1]

The data and reasoning results can be exported as reproducible Linked Open Data in so called ‘quadruples’.



The data and reasoning results can be exported as reproducible Linked Open Data in so called ‘quadruples’.





http://academic-meta-tool.xyz/eaa2018/

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Römisch-Germanisches Zentralmuseum
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Taming Time

Modelling uncertainty as reproducible Linked Open Data

thiery@rgzm.de & mees@rgzm.de

online references

- Github Repository
  - http://rgzm.github.io/amt-eaa2018/
- Academic Meta Tool Live Demo
  - http://academic-meta-tool.xyz/eaa2018
- RGZM Samian Online-Database
  - http://rgzm.de/samian
- Alligator
  - https://github.com/RGZM/alligator
- RGZM Archaeological Data Processing Web Service (ADP)
  - http://rgzm.de/adp
- Academic Meta Tool
  - http://academic-meta-tool.xyz/
  - http://academic-meta-tool.xyz/vocab/
  - http://academic-meta-tool.xyz/ontology/

publications

- Freksa 1992, Temporal Reasoning Based on Semi-Intervals, Artificial Intelligence 54 (1992), 199-227.
  - https://doi.org/10.1016/0004-3702(92)90090-K
- Allen 1983, Maintaining knowledge about temporal intervals, Magazine Communications of the ACM CACM Homepage archive Volume 26 Issue 11, Nov. 1983 Pages 832-843.
  - https://doi.org/10.1145/182.358434
- Kuhnen H.-P. 1992 (Ed.), Gestürmt – Geräumt – Vergessen?. Der Limesfall und das Ende der Römerherrschaft in Südwest-deutschland. Württembergisches Landesmuseum Stuttgart, Archäologische Sammlungen, Führer und Bestandskataloge II.
- Madsen T. 1988, Multivariate statistics and archaeology. In: Madsen T. (Ed.), Multivariate Archaeology. Numerical Approaches in Scandinavian Archaeology. Jutland Archaeological Socity Publications XII. Aarhus University Press, 7-27.