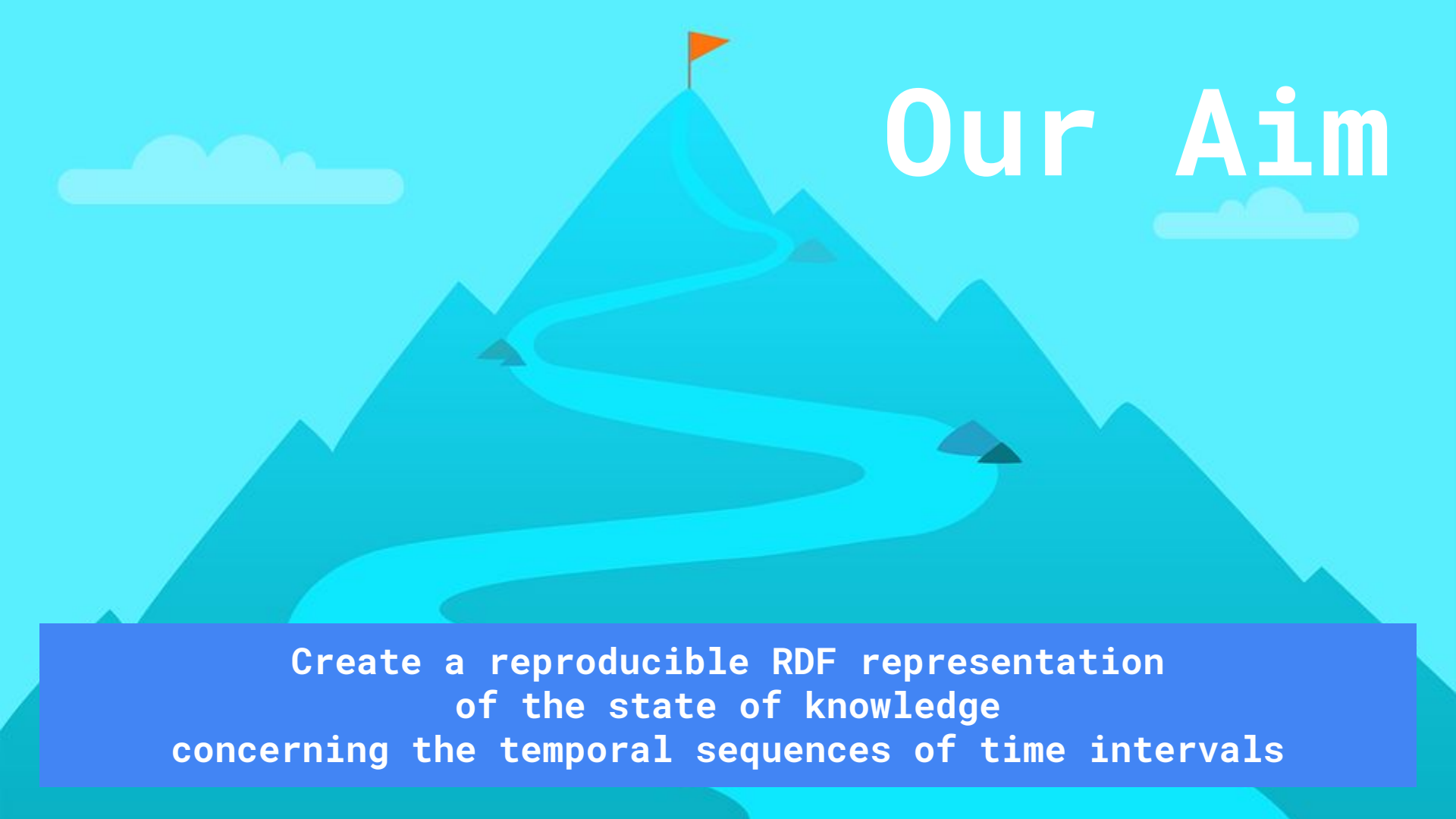
RDF BASED MODELING OF RELATIVE AND ABSOLUTE CHRONOLOGICAL DATA:

EXAMPLES FROM THE CENTRAL AFRICAN RAINFOREST AND ROMAN PERIODISATION

Dirk Seidensticker[1], Florian Thiery[2], Allard Mees[2] and Clemens Schmid[3]

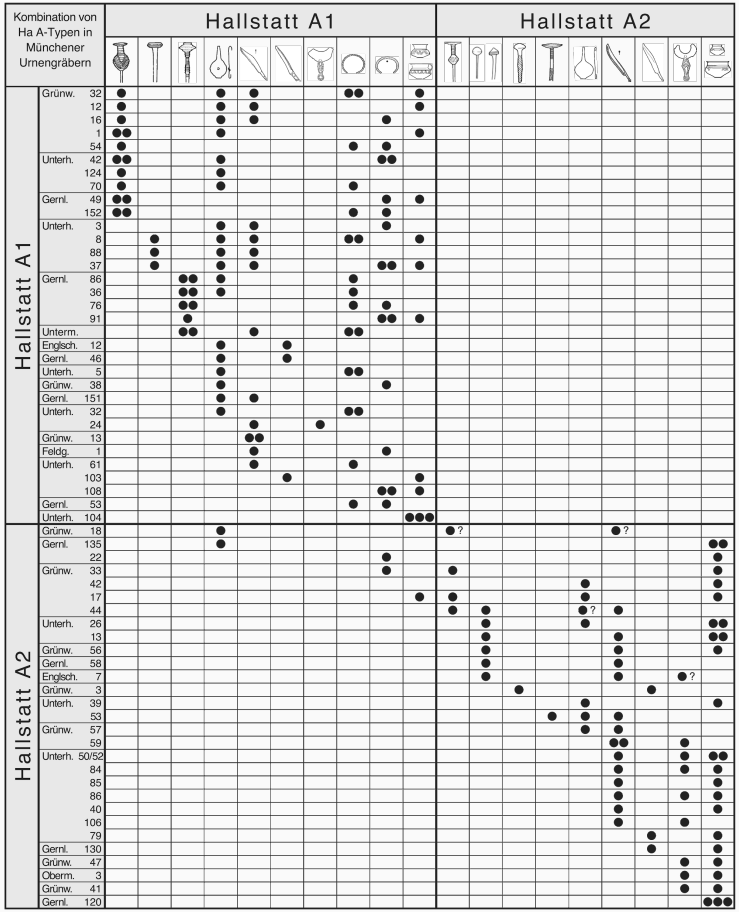
1 Ghent University
2 Römisch-Germanisches Zentralmuseum - Leibniz Forschungsinstitut für Archäologie, Mainz
3 University of Kiel

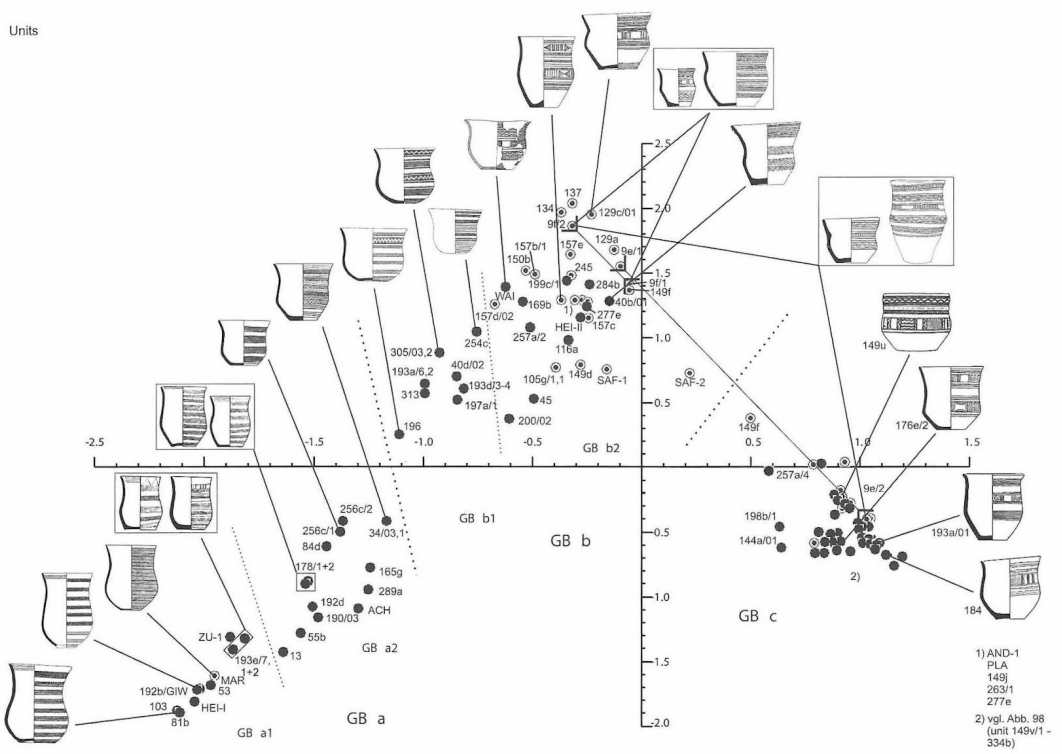
Our Aim



Create a reproducible RDF representation
of the state of knowledge
concerning the temporal sequences of time intervals

Correspondence analysis and chronology

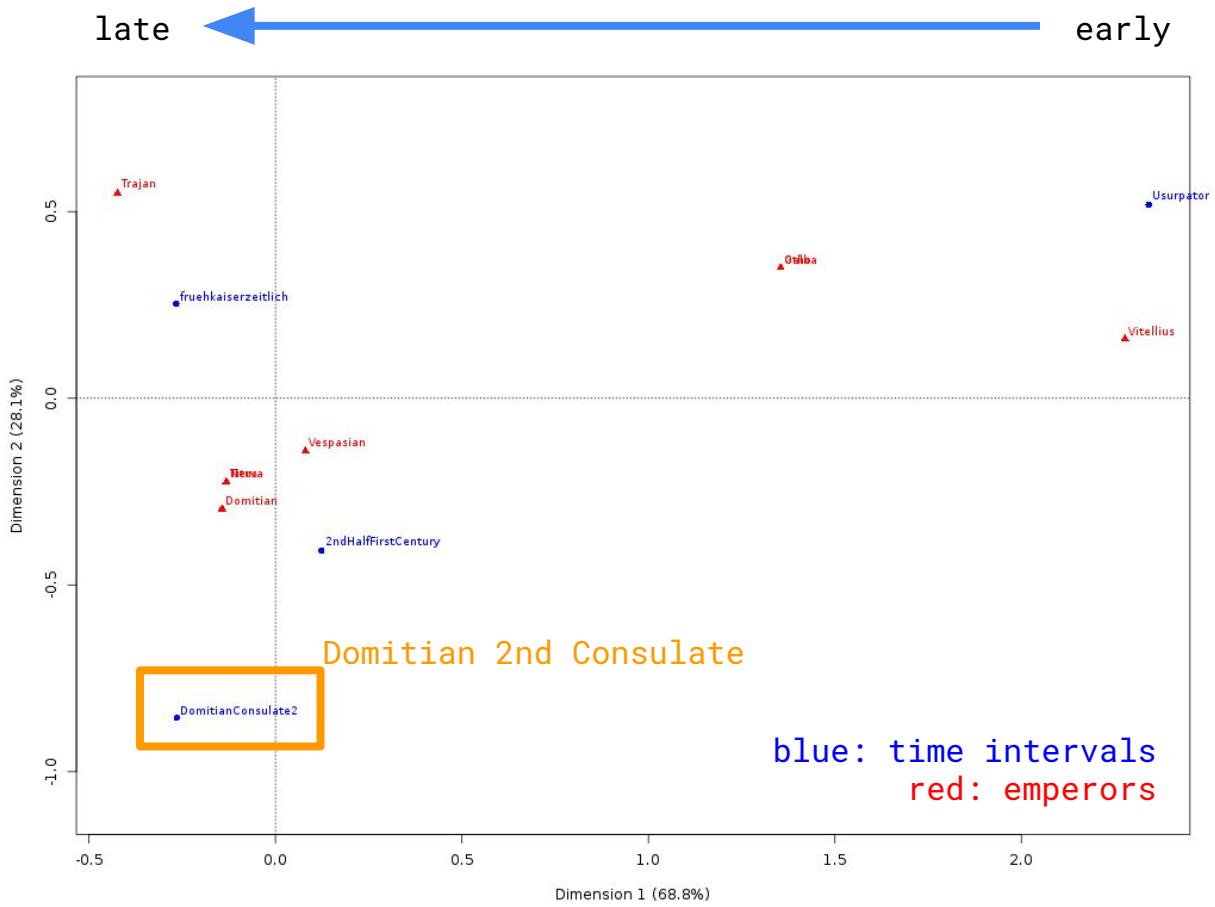




⬆ CA of bell beakers of the Rhine-Main-Necker complex (Müller/Hinz/Ullrich 2015: 59 Fig. 6.2)

⬅ Seriation of the Hallstatt A period in the region of Munich (Eggert 2008: 208 Fig. 49)

Method test with Roman emperors



timeinterval emperor years

	A	B	C
1	fruehkaiserzeitlich	Vitellius	1
2	fruehkaiserzeitlich	Galba	1
3	fruehkaiserzeitlich	Otho	1
4	fruehkaiserzeitlich	Vespasian	10
5	fruehkaiserzeitlich	Titus	2
6	fruehkaiserzeitlich	Domitian	15
7	fruehkaiserzeitlich	Nerva	2
8	fruehkaiserzeitlich	Trajan	19
9	2ndHalfFirstCentury	Vitellius	1
10	2ndHalfFirstCentury	Galba	1
11	2ndHalfFirstCentury	Otho	1
12	2ndHalfFirstCentury	Vespasian	10
13	2ndHalfFirstCentury	Titus	2
14	2ndHalfFirstCentury	Domitian	15
15	2ndHalfFirstCentury	Nerva	2
16	2ndHalfFirstCentury	Trajan	2
17	Usurpator	Galba	1
18	Usurpator	Otho	1
19	Usurpator	Vitellius	1
20	Usurpator	Vespasian	1
21	DomitianConsulate2	Domitian	1

Results in 3D and 2D of a CA of Roman Emperors and reigning years

The Alligator Method (Part 1)

github.com/RGZM/alligator

- Each emperor has a starting and end year (e.g. Traian: 98-117 AD)
- Most - but not all - time intervals have a starting and end year (e.g. 2nd Half First Century: 50-100 AD)
- Some intervals have unknown floating (=schwebend) starting and/or end years (e.g. the unknown time period of the 2nd Domitian consulate)
- The horizontal CA dimension axis defines the amount of overlap between the time intervals

- **Step 1:** All 3D distances between the CA time periods are calculated
- **Step 2:** The nearest 3D CA neighbours for start and end years of the floating intervals towards intervals with fixed values are located
- **Step 3:** the result is stored as a “calculated virtual fuzzy year”
- **Step 4:** the intermediate result of the fixed and floating time intervals is stored as a list of “virtual fuzzy start and end years”

	A	B	C	D	E	F	G
1	name	x	y	z	von	bis	fixed
2	fruehkaiserzeitlich	-0.2660	0.2530	0.0072	1	150	fixed
3	2ndHalfFirstCentury	0.1235	-0.4078	-0.0481	50	100	fixed
4	Usurpator	23.415	0.5180	0.0610	69	69	fixed
5	Galba	13.550	0.3500	0.0580	69	69	fixed
6	Otho	13.550	0.3500	0.0580	69	69	fixed
7	Vespasian	0.0810	-0.1420	-0.1450	69	79	fixed
8	Titus	-0.1320	-0.2240	-0.1790	79	81	fixed
9	Domitian	-0.1430	-0.2960	0.1180	81	96	fixed
10	Nerva	-0.1320	-0.2240	-0.1790	96	98	fixed
11	Trajan	-0.4230	0.5490	0.0170	98	117	fixed
12	Vitellius	22.780	0.1590	0.0560	69	69	fixed
13	DomitianConsulate2	-0.2646	-0.8560	10.336	0	0	schwebend

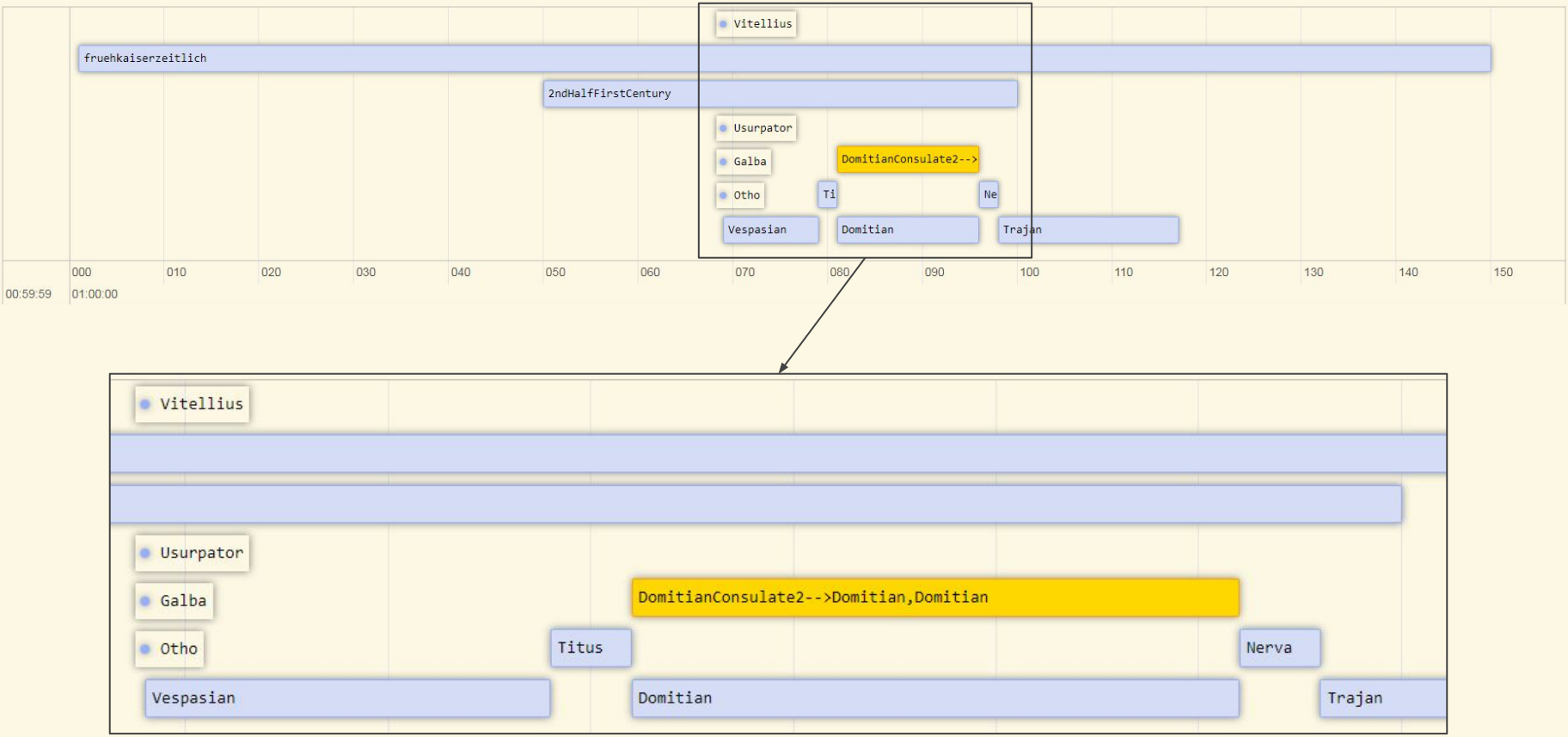
Aim: date “Domitioan Consulate2” and get the “virtual fuzzy start and end years”

	A	B	C	D	E	F	G
1	name	x	y	z	von	bis	fixed
2	fruehkaiserzeitlich	-0.2660	0.2530	0.0072	1	150	fixed
3	2ndHalfFirstCentury	0.1235	-0.4078	-0.0481	50	100	fixed
4	Usurpator	23.415	0.5180	0.0610	69	69	fixed
5	Galba	13.550	0.3500	0.0580	69	69	fixed
6	Otho	13.550	0.3500	0.0580	69	69	fixed
7	Vespasian	0.0810	-0.1420	-0.1450	69	79	fixed
8	Titus	-0.1320	-0.2240	-0.1790	79	81	fixed
9	Domitian	-0.1430	-0.2960	0.1180	81	96	fixed
10	Nerva	-0.1320	-0.2240	-0.1790	96	98	fixed
11	Trajan	-0.4230	0.5490	0.0170	98	117	fixed
12	Vitellius	22.780	0.1590	0.0560	69	69	fixed
13	DomitianConsulate2	-0.2646	-0.8560	10.336	81	96	schwebend

Result: “virtual fuzzy start and end years” for “Domitioan Consulate2”

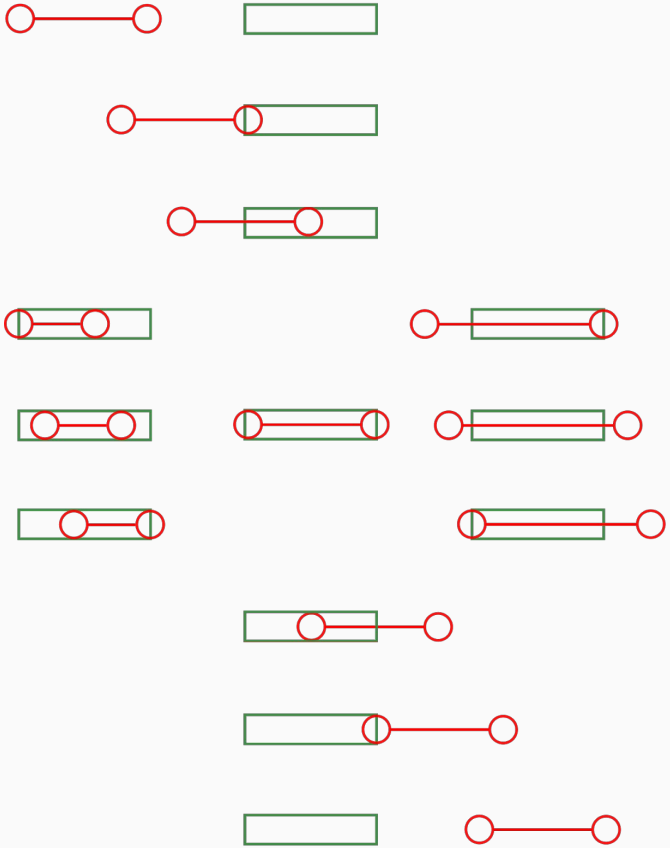
	A	B	C	D	E	F	G
1	name	x	y	z	von	bis	fixed
2	fruehkaiserzeitlich	-0.2660	0.2530	0.0072	1	150	fixed
3	2ndHalfFirstCentury	0.1235	-0.4078	-0.0481	50	100	fixed
4	Usurpator	23.415	0.5180	0.0610	69	69	fixed
5	Galba	13.550	0.3500	0.0580	69	69	fixed
6	Otho	13.550	0.3500	0.0580	69	69	fixed
7	Vespasian	0.0810	-0.1420	-0.1450	69	79	fixed
8	Titus	-0.1320	-0.2240	-0.1790	79	81	fixed
9	Domitian	-0.1430	-0.2960	0.1180	81	96	fixed
10	Nerva	-0.1320	-0.2240	-0.1790	96	98	fixed
11	Trajan	-0.4230	0.5490	0.0170	98	117	fixed
12	Vitellius	22.780	0.1590	0.0560	69	69	fixed
13	DomitianConsulate2	-0.2646	-0.8560	10.336	81	96	schwebend

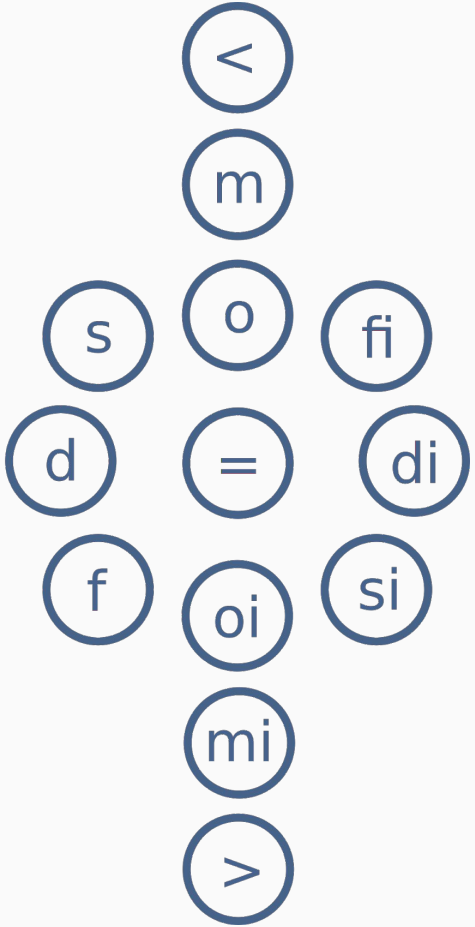
Result: fixed and floating time intervals as a full list of “virtual fuzzy start and end years”



Result: virtual fuzzy years of Roman emperors in a virtual timeline

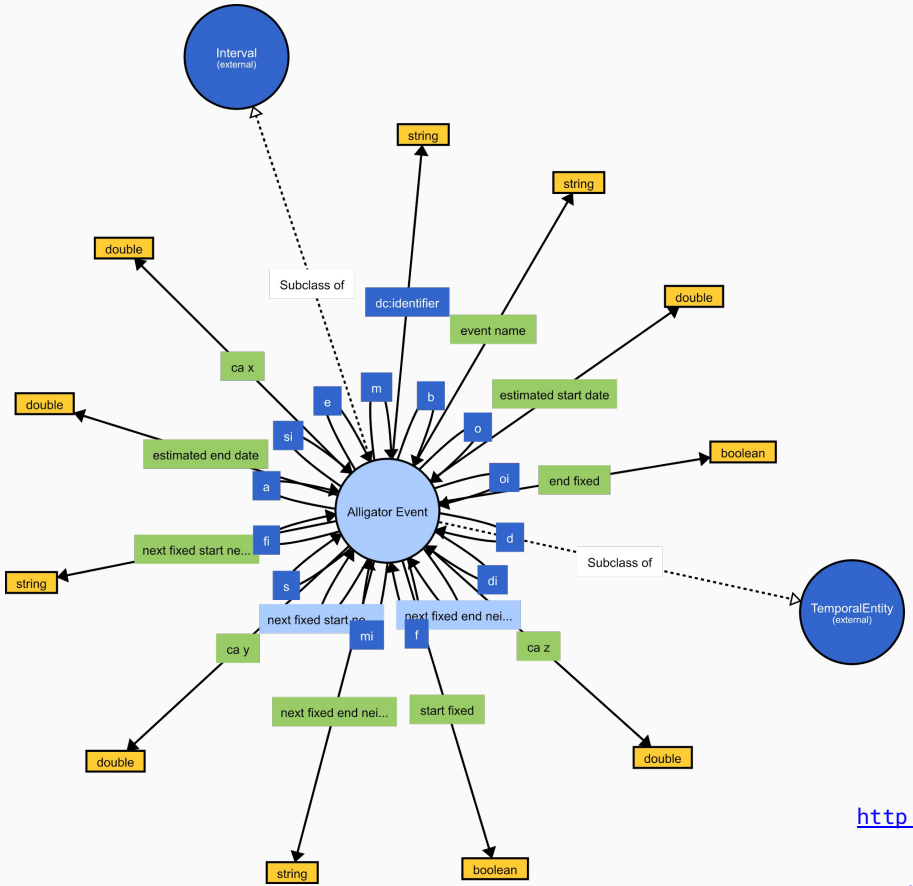
Allen Interval Algebra





<	before
>	after
d	during
di	contains
o	overlaps
oi	overlapped-by
m	meets
mi	met-by
s	starts
si	started-by
f	finishes
fi	finished-by
=	equals

Alligator Ontology
https://rgzm.github.io/alligator/vocab



ALLIGATOR VOCABULARY

Authors: Florian Thiery (Römisch-Germanisches Zentralmuseum Mainz)

Version: Vättern Edition

Date: 2018-08-19

Abstract: A vocabulary for Alligator.

Copyright: This work is licensed under a Creative Commons Attribution 4.0 International License.

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

https://rgzm.github.io/alligator/vocab/

http://www.visualdataweb.de/webvowl/#iri=https://raw.githubusercontent.com/RGZM/alligator/master/docs/vocab/alligator.rdf

https://github.com/RGZM/alligator/blob/master/docs/vocab/alligator.rdf

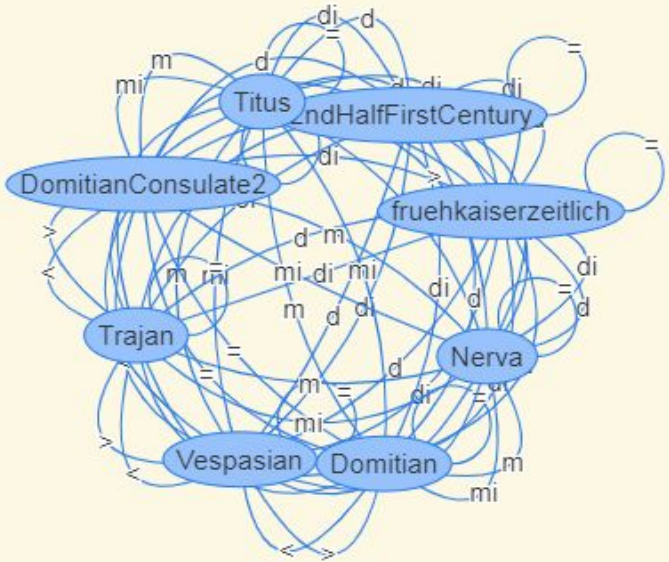
The Alligator Method (Part 2)

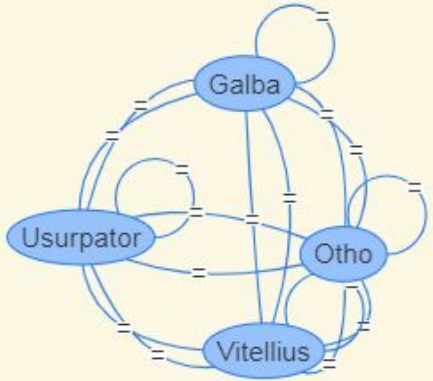
github.com/RGZM/alligator

- **Step 5:** the “virtual fuzzy years” are transformed to relative time intervals using Allen interval algebra
- **Step 6:** create a RDF representation in order to achieve a representation of the state of knowledge concerning the temporal sequences of time intervals, which is transparent, interoperable, semantically described and machine readable
- **Step 7:** visualisation of the results
- **Step 8:** look for contradictions
- **Step 9:** resolve them and start with step 1

		1	2	3	4	5	6	7	8	9	10	11	12
1	fruehkaiserzeitlich	e	di				di	di	di	di	di		di
2	2ndHalfFirstCentury	d	e				di	di	di	di	o		di
3	Usurpator			e	e	e						e	
4	Galba			e	e	e						e	
5	Otho			e	e	e						e	
6	Vespasian	d	d				e	m	b	b	b		b
7	Titus	d	d				mi	e	m	b	b		m
8	Domitian	d	d				a	mi	e	m	b		e
9	Nerva	d	d				a	a	mi	e	m		mi
10	Trajan	d	oi				a	a	a	mi	e		a
11	Vitellius			e	e	e						e	
12	DomitianConsulate2	d	d				a	mi	e	m	b		e

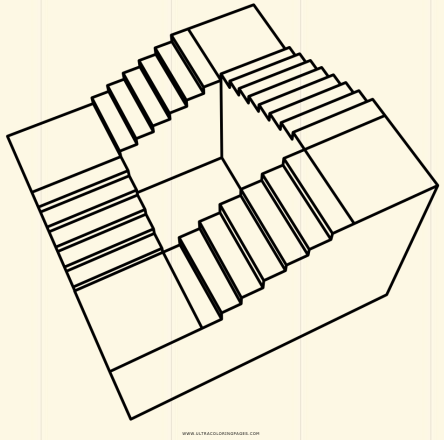
Result: relative Allen time intervals of Roman emperors





Result: relative Allen time intervals of Roman emperors as RDF graph

Chester-extra-mural-->*,Inchtuthil-gutter
Chester-outside fortress-->*,Inchtuthil-gutter
Zwammerdam-Per.1-->*,Pompeii-Hoard
Chesterholm-Vindola
Fishbourne-Per.1b-->Gloucester-Kingsholm,Pompeii-
Chesterholm-Vindola
Carlisle-fort-->*,Inchtuthil-gutter
Doncaster-fort-->Carlisle-fort,Inchtuthil-gutter
Cardiff-fort-->*,Inchtuthil-Gutter
Fishbourne-Per.2 construction-->Nijmegen-fortress,In
Geislingen-Häsenbühl-->Cardiff-fort,Inchtuthil-Gutte
Heddernheim-fort-->*,Inchtuthil-Gutter
Wimborne-Lake Farm fortress-->Wroxeter-baths,Zurzach-fort
Heidelberg-Neuenheim cemetery-->*,Incht
Pompeii-Hoard-->Zwammerdam-Per.1,*
Ilkley-fort-->Chest
Chester-Delamere St. Gorse Stacks-->*,Inchtuthil-gut
Chester-cemetery-->*,Inchtuthil-Gutter
Caerleon-canabae-->*,Inchtuthil-gutter
Nijmegen-canabae-->*,Inchtuthil-Gutter
Fishbourne-Per.1-->Zwammerdam-Per.1,Pompeii-Hoard
Inchtuthi
Verulamium-Per.1-->Wroxeter-b
Inchtuthi
Colchester-Pottery Shop I-->W
Castlefor
Gloucester-Kingsholm-->*,Pompeii-Hoard
Verulamium-Boudiccan burning-->Wroxeter-baths,Zurzach-fort
Rottweil-Hochmauren fort-->*,Hofheim-II
Oberwinterthur-Keramiklager-->Caernarfon-Segontium fort,Zurzach-fort
Rottweil-Altstadt-->*,Hofheim-II vicus

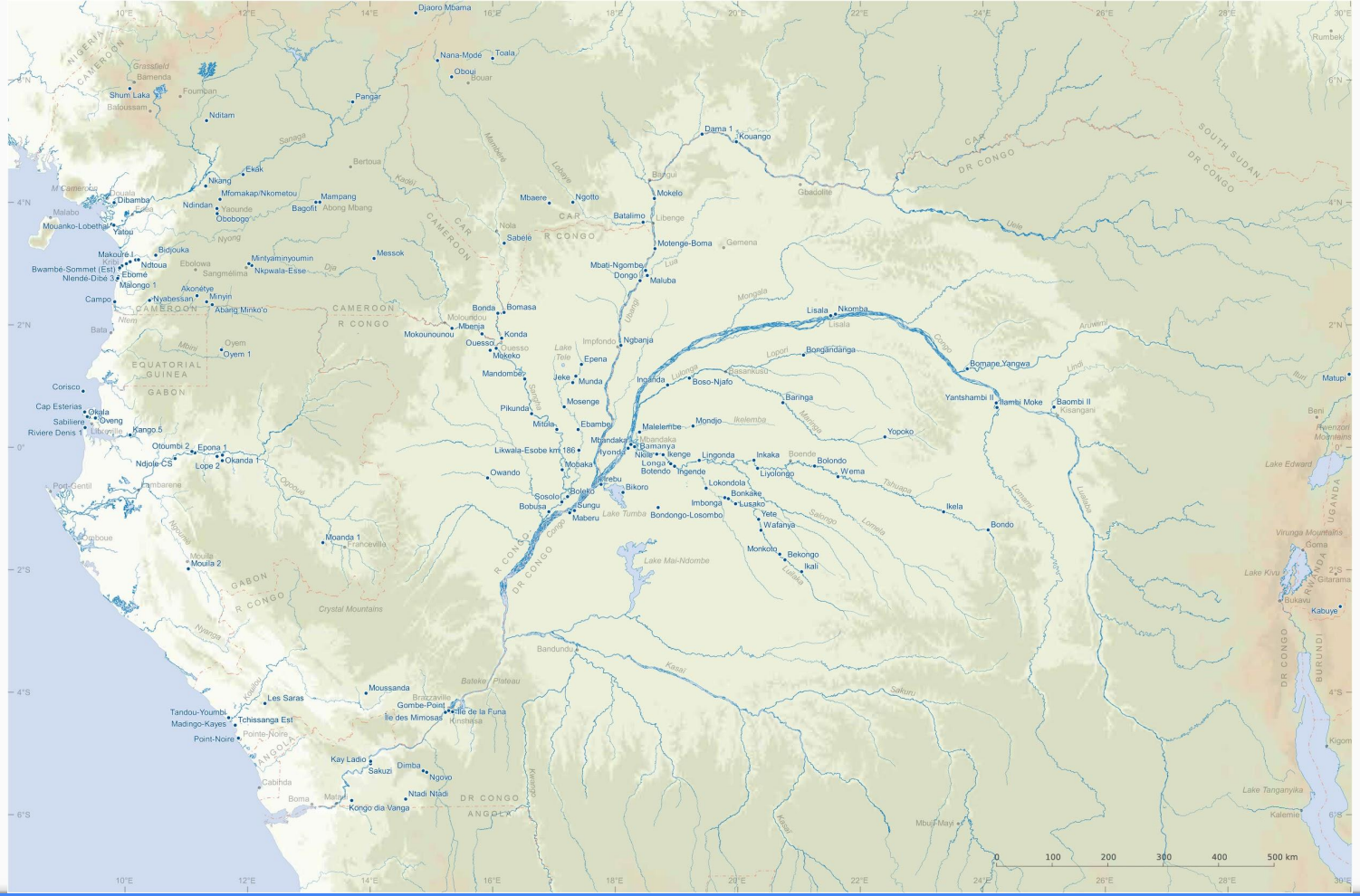


by http://www.ultracoloringpages.com

Burghöfe-Geschirrde
Saalburg-Erdkastel
Hanau-Salisberg-Ke
Butzbach-Degerfeld
Arnsburg-Muschenhei
Cannstatt-fort-->*,Inchtuthil-gutter

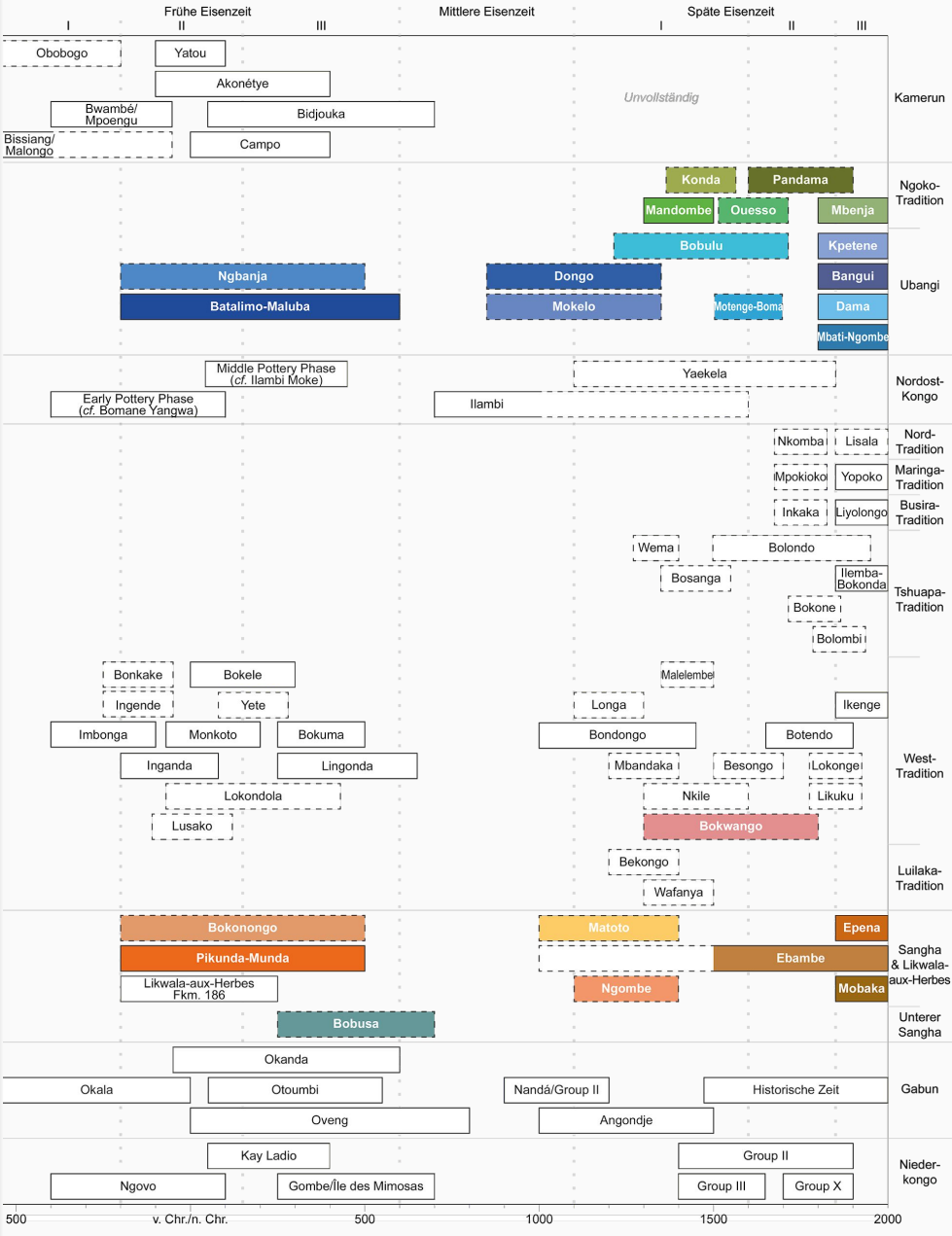
Use of the virtual timeline for detecting contradictions

Alligator for ‘ChronoCongo’
github.com/dirkseidensticker/ChronoCongo

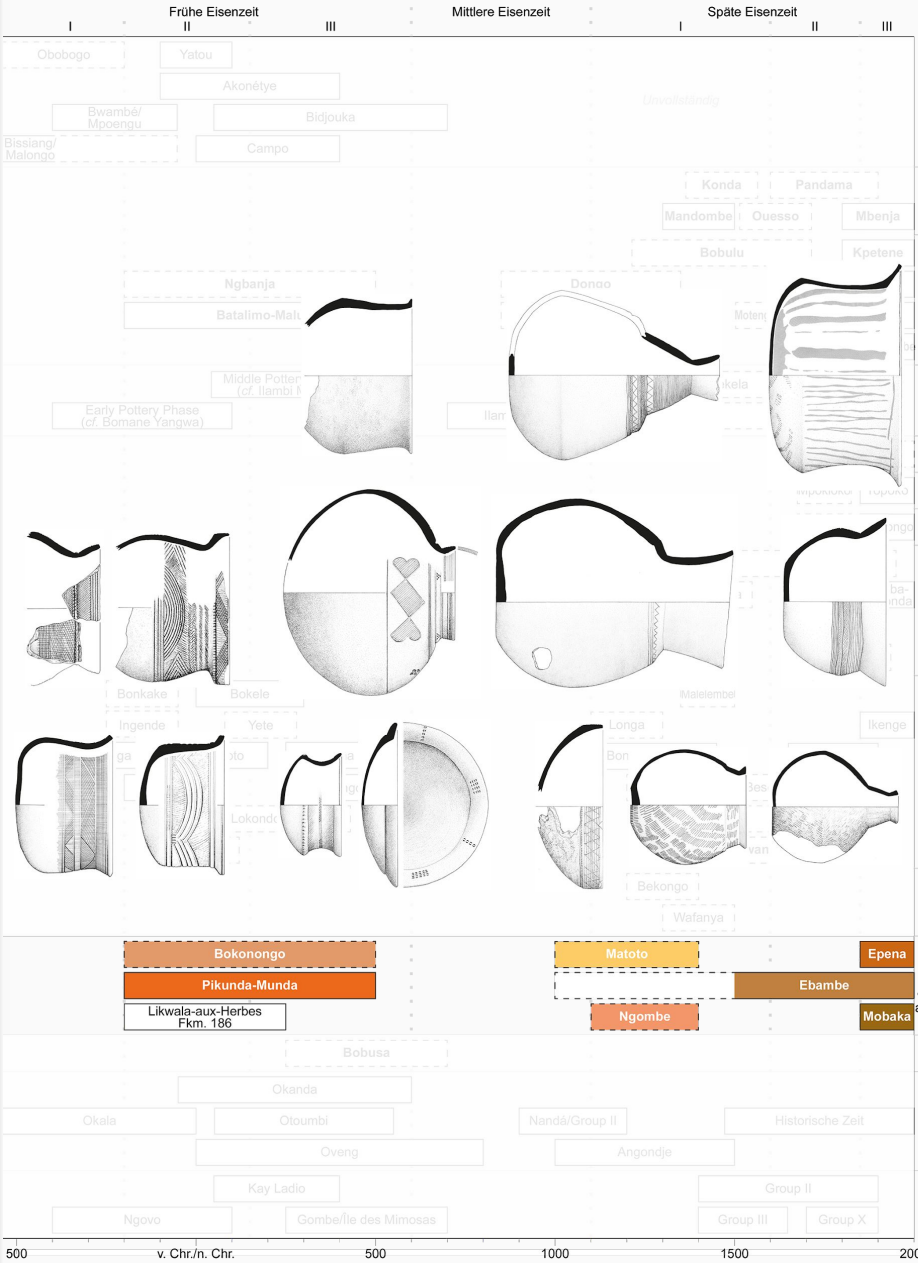


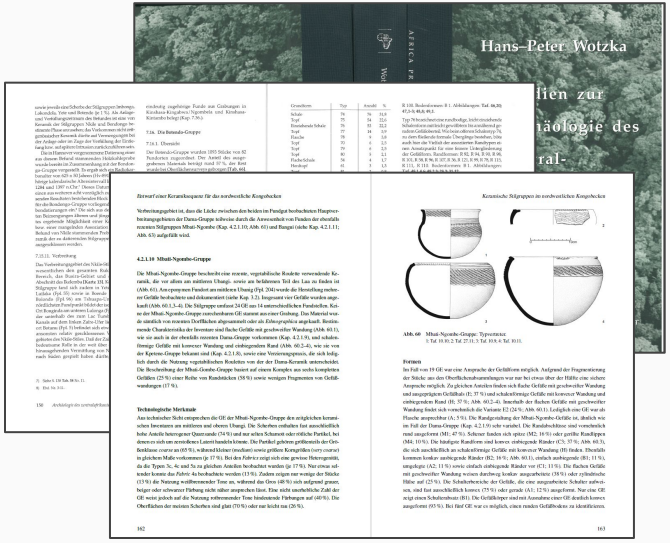
Study Area: Map of important sites in Central Africa

Pottery sequences for the Iron Age in western Central Africa



Pottery sequence for the Sangha region in the north-western Congo Basin





	STYLE	ATTR	META
1	IMB	Fabric.1	Wotzka 1995:59 „Die Keramik des Imbonga-Stiles ist aus weiß-brennenden Tonen hergestellt, denen keinerlei Zuschläge beigemengt wurden."
2	IMB	GefTyp.1	Wotzka 1995:60 „Als charakteristische Form der Imbonga-Gruppe ist Typ 1 anzusehen knapp 80 % aller morphologisch zuweisbaren Stücke gehören d
3	IMB	GefTyp.2	Wotzka 1995:60 Tab. 5 = 4,3 %
4	IMB	RandTyp.1	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
5	IMB	RandTyp.2	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
6	IMB	RandTyp.3	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
7	IMB	RandTyp.4	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
8	IMB	RandTyp.5	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
9	IMB	RandTyp.6	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
10	IMB	RandTyp.7	Wotzka 1995:62 „Wichtig für die Charakterisierung dieser Stilgruppe sind aber nur die häufigsten sieben Typen, die zusammen rund 91 % des zugewie
11	IMB	BodenTyp.B4	Wotzka 1995:63 „Von den sechs unterschiedenen Typen sind vor allem der einfache Flachboden (B 4) und der abgesetzte Flachboden (B 11) von Bedeu
12	IMB	BodenTyp.B11	Wotzka 1995:63 „Von den sechs unterschiedenen Typen sind vor allem der einfache Flachboden (B 4) und der abgesetzte Flachboden (B 11) von Bedeu
13	IMB	VerzTech.02	Wotzka 1995:63 „Nach Riefung und Wiegebandverzierung treten vor allem Ritz- und Stempeltechnik auf." = Riefung
14	IMB	VerzTech.04-1	Wotzka 1995:63 „Nach Riefung und Wiegebandverzierung treten vor allem Ritz- und Stempeltechnik auf." = Wiegeband
15	IMB	VerzTech.01	Wotzka 1995:63 „NachRiefung und Wiegebandverzierung treten vor allem Ritz- und Stempeltechnik auf." = Ritzung
16	IMB	VerzTech.04	Wotzka 1995:63 „Nach Riefung und Wiegebandverzierung treten vor allem Ritz- und Stempeltechnik auf." = Stempel
17	IMB	VerzTech.09	Wotzka 1995:63 „Seltener, aber sehr charakteristisch für d iese Stilgruppe sind Applikationen."

fcn.r × analysis.Rmd* ×

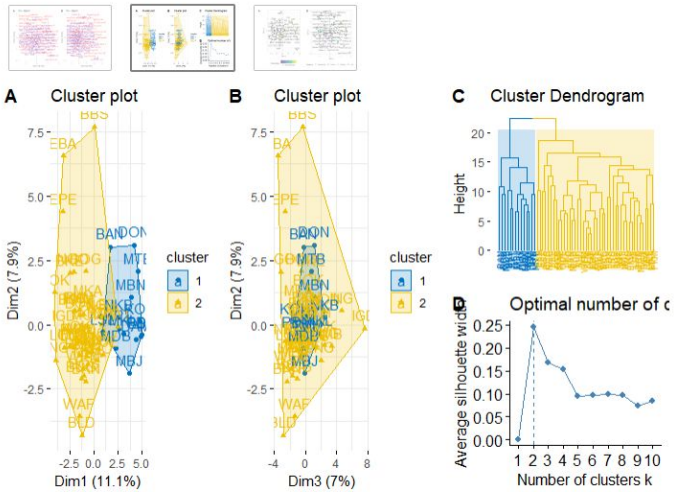
Preview

```
### filter out rims as there is no universal typolgy jet
```{r}
d <- filter(d, !grepl("Rand", ATTR))

# filter out fabrics as no thorough analysis has been performed jet
#d <- filter(d, !grepl("Fabric", ATTR))
```

Analysis of all styles and attributes

```{r}
plt <- anlys(d, 2, '1')
plt$basicPlot
plt$clustPlot
plt$ggplot
```
```




```
# Iterative filtering based on the initial CA
```

53:1 Chunk 4

Console

```
# CA & Cluster Analysis

anlys <- function(d = data,
                  t = threshold,
                  n = name){

  # setup filepath for output
  p <- "output/"

  c <- dcast(d, STYLE ~ ATTR,
             value.var = "STYLE",
             fun.aggregate = length)
  rownames(c) <- c[,1]
  c$STYLE <- NULL

  # convert all summed values to 0/1 abundance
  c[c != 0] <- 1

  # threshold >2
  c <- quantAAR::itremove(c,t)

  # write out the abundance table
  write.csv(c, paste(p, n, "_crosstab.csv", sep = ""))

  plt5 <- plot_grid(plt3,
                    plt4,
                    ncol = 2,
                    labels = c("A", "B"),
                    rel_heights = c(1, 1))

  ggsave(paste(p, n, "_ggplot.png", sep = ""),
         plot = plt5, width = 20, height = 10)

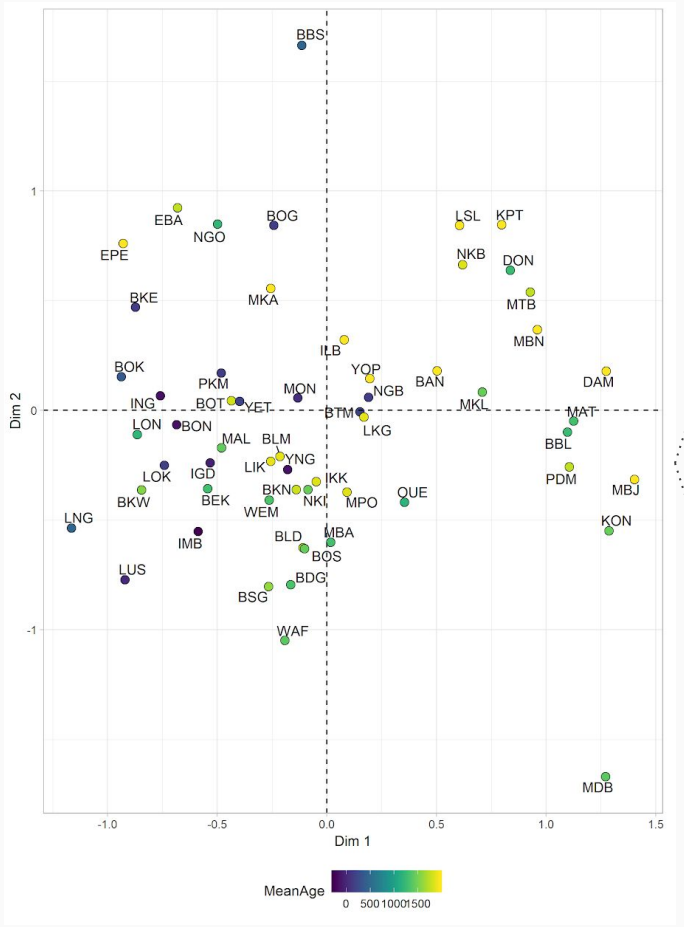
  # Build returned list
  # ===================

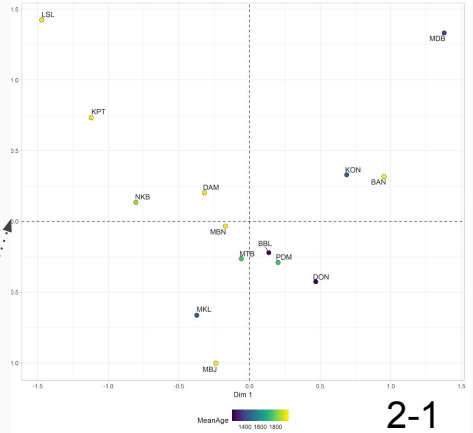
  pltList <- list("basicPlot" = plt1,
                  "clustPlot" = plt2,
                  "ggplot" = plt5,
                  "hclust" = res)

  return(pltList)

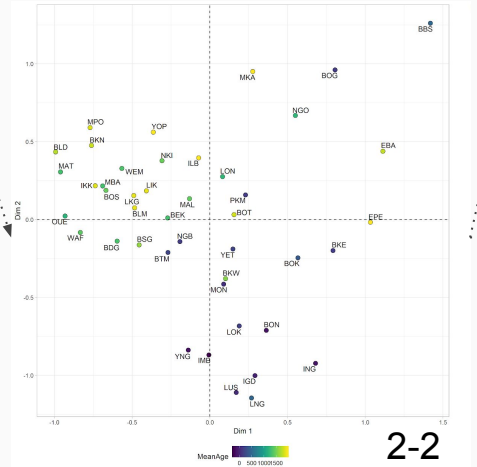
}
```

From the literature into the data world

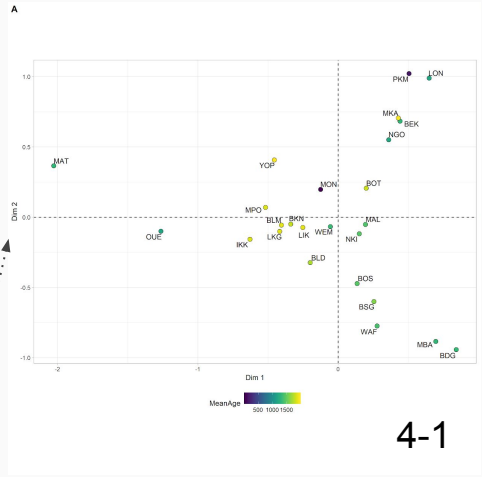




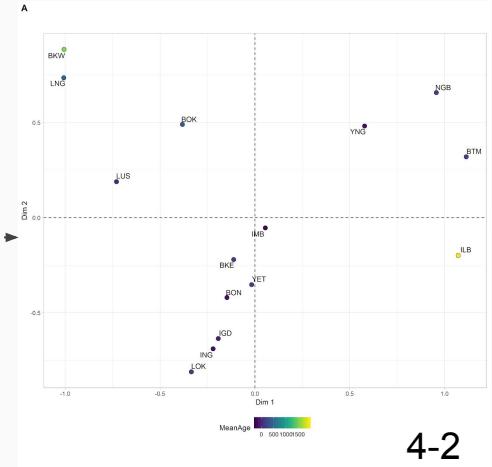
2-1



2-2

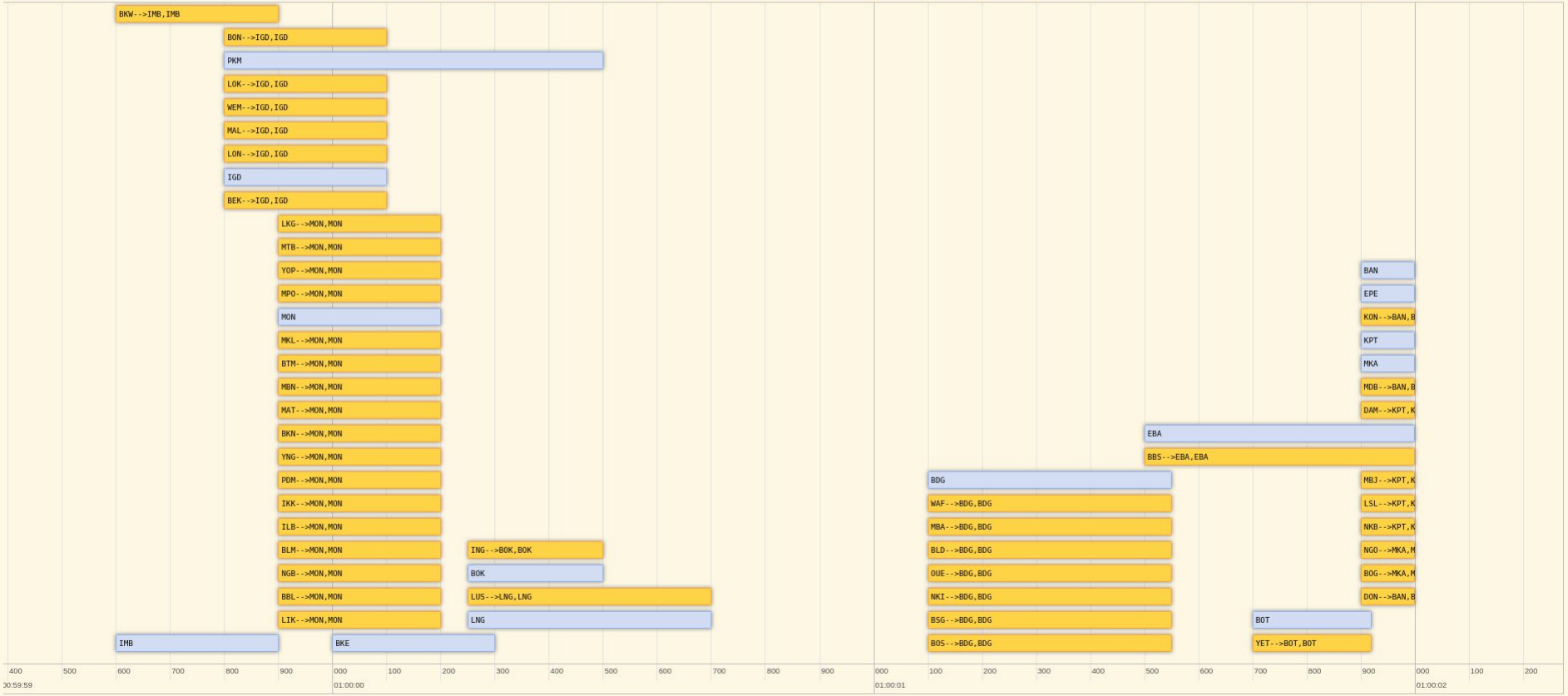


4-1

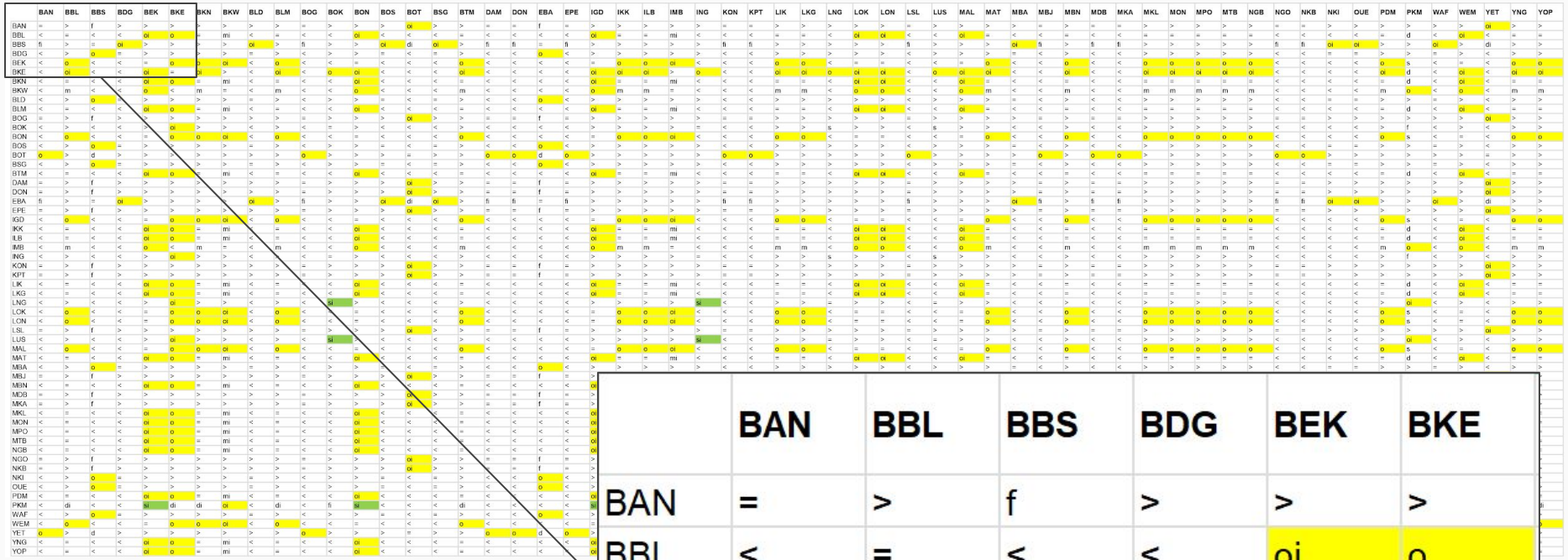


4-2

Correspondence analysis in multiple iterations

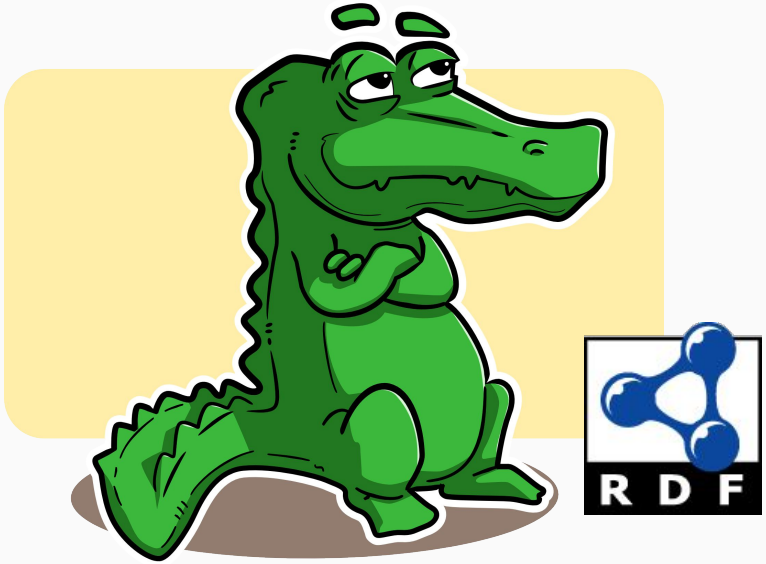


Alligator Output of the virtual fuzzy years based on the ‘ChronoCongo’ data as a virtual timeline

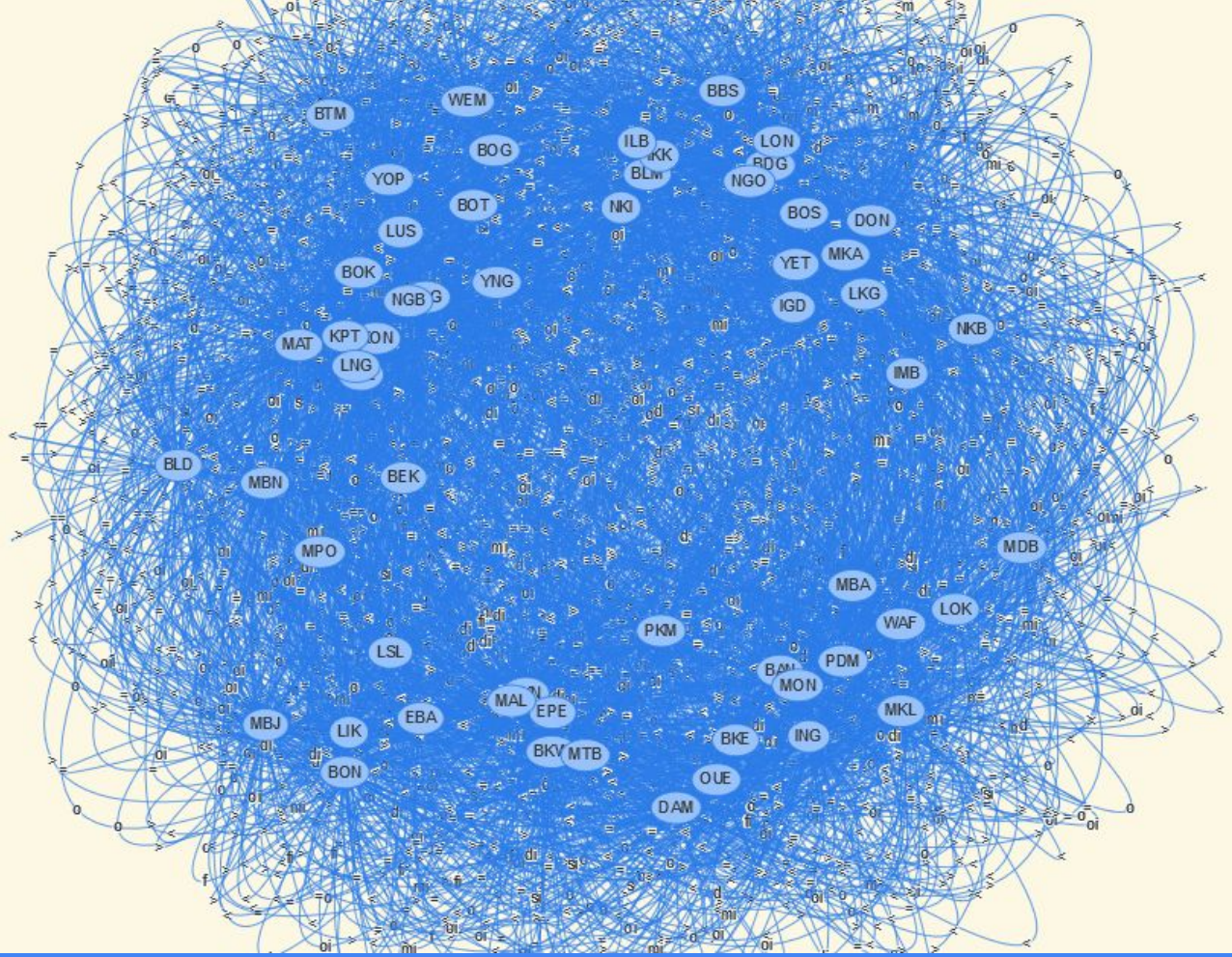


	BAN	BBL	BBS	BDG	BEK	BKE
BAN	=	>	f	>	>	>
BBL	<	=	<	<	oi	o
BBS	fi	>	=	oi	>	>
BDG	<	>	o	=	>	>
BEK	<	o	<	<	=	o
BKE	<	oi	<	<	oi	=

Alligator Output of the Allen relations based on the ‘ChronoCongo’ dataset



RDF based modelling of relative and absolute chronological data is now reproducible and machine readable, but ...



… visualizations that are a meaningful representation of the data are hard to come by.

Dirk Seidensticker, Florian Thiery
Allard Mees, Clemens Schmid
¡gracias!