Classifying vessel shapes

using automated shape extraction and unsupervised classification

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motivation

previous approaches

Shape Extraction

Shape Analysis 1: PCA & hclust

Shape Analysis 2: t-sne & hdbscan

Case study 1: Bell Beakers of the Iberian Peninsula

Case study 2: Neolithic Swiss Ceramic

Resume

motivation

shape vs. decoration for typology

levels of pottery design

Tendencies:

criteria	shape	decoration
functional dependency	strong	weak
dependency on local ressources	stronger	weak
moment of determination	from the beginning	finished product
ad hoc changes	difficult	easy
more reflecting	practised reality	imagined reality
design decision	more collective	more individual
homogenity	more convergent	more divergent
degrees of freedom	smaller	higher
category of style	more isochrestic	more emblemic
unit of analysis	ideal type	singularity

Phases of ceramic production

Design

- imagined and intended
- concept of a shape (incl. attached parts, eg. handles)
- ideal type
- **social bounded options for creativity**

'style of action'

- learned, habitual movements, manipulations, routines
- at all stages of the *chaîne opératoire*
- instantiation reflecting the characteristics of the material
- **limited or prescribed options for creativity**

'material style'

- physical traces and effects in the material
- Characteristics of the vessel
- finished object
- **material induced alterations of the original design possible**

resume

using vessel shapes to identify underlying large scaled ‘communities of practice’ in production and consumption

- more related to covert communication structures, habitus and similar (economic) practises
- ‘better measurable’ from a practical quantitative perspective

previous approaches

quantitative approaches towards shape-based typology

using specific locations

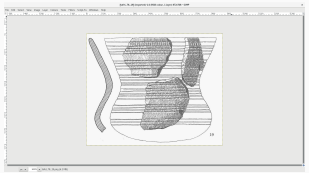
- Koch 1998

'Hollistic' approaches

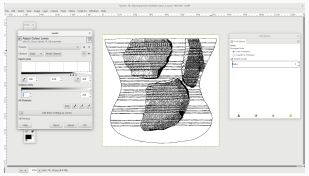
- Mom 2005
- Chapman et al., 2006
- Keogh et al., 2009

Shape Extraction

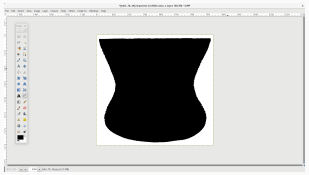
‘by hand’: workflow



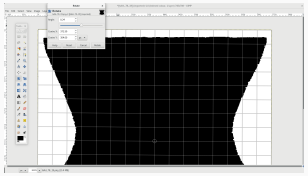
load



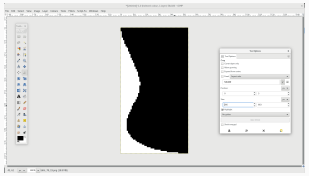
enhance contrast



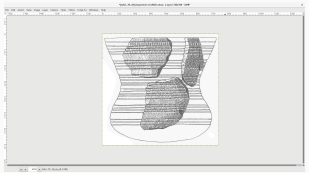
fill inside black



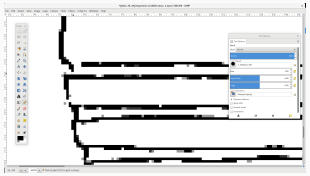
rotate



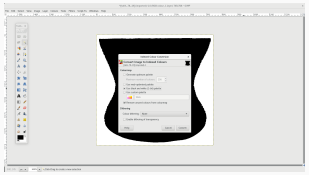
split in half



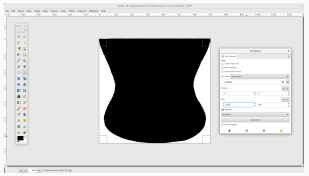
clean



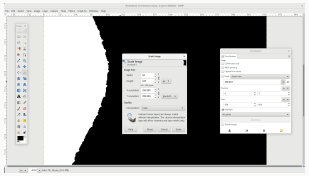
close gaps



turn bw (bitmap)

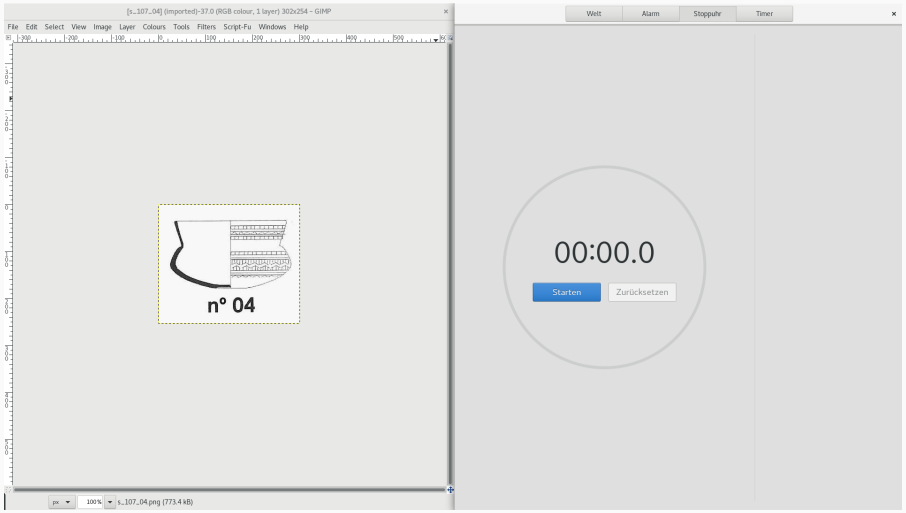


crop

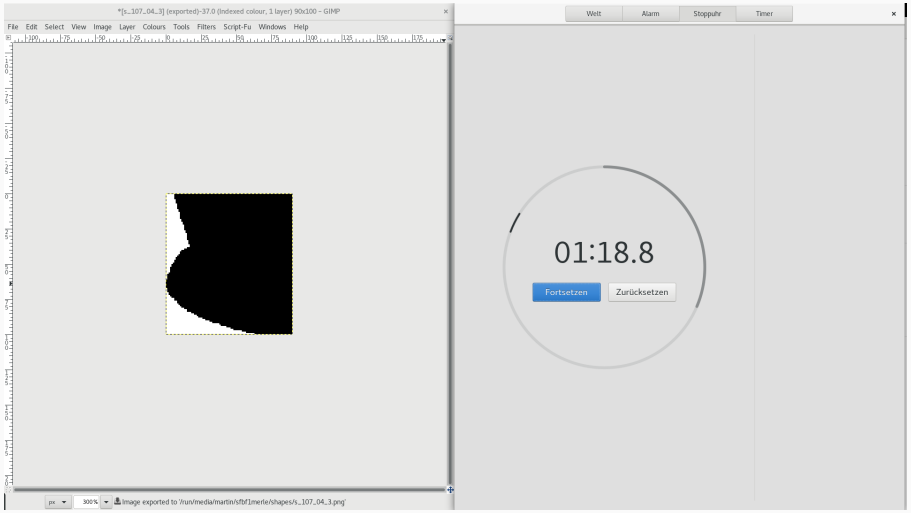


scale to resolution (100px)

‘by hand’: speed



↓



Adaptive Contour Motivation

- 1:30 min for 800 images -> 20 hours
  - automation makes sense!
- scanned vessel drawings not trivial
  - might have holes (dashed lines)
  - might have additional image components beside the vessels
- no simple image segmentation with background color and floodfill possible

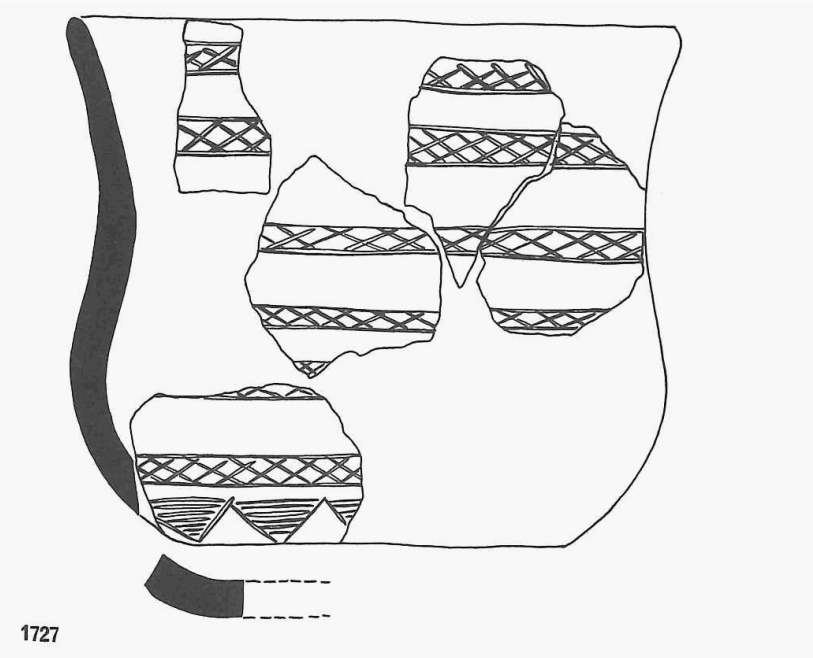


Figure 1: Bell Beaker (Harrison 1977)

Adaptive Contour: what is it

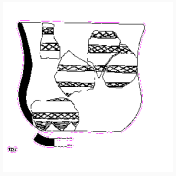
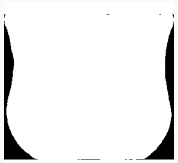
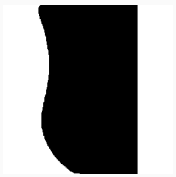
Active contour model, *also called* ***snakes***, *is a framework in computer vision for delineating an object outline from a possibly noisy 2D image. The snakes model is popular in computer vision, and snakes are greatly used in applications like object tracking,* ***shape recognition***, *segmentation, edge detection and stereo matching. Wikipedia*

source: https://github.com/pmneila/morphsnakes

Active contour with Bell Beakers

See shapAAR vignette

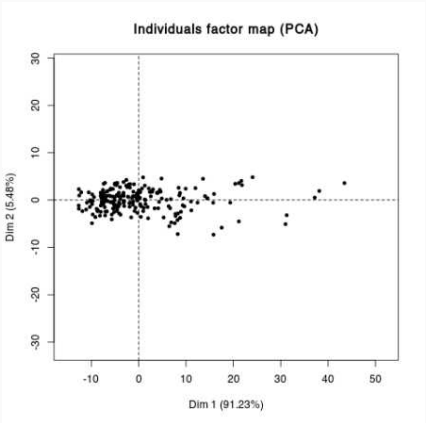
https://github.com/ISAAKiel/shapAAR/blob/master/vignettes/object-extraction.md

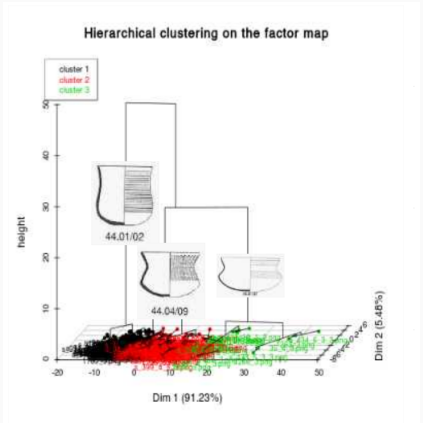
	Image preparation	bw, blur
	Image segmentation	active_contour
	Selecting the biggest object	EBImage
	Rectify and crop	get Bounding box, rotate upright, crop
	half and side mean	split in middle, mean left-right

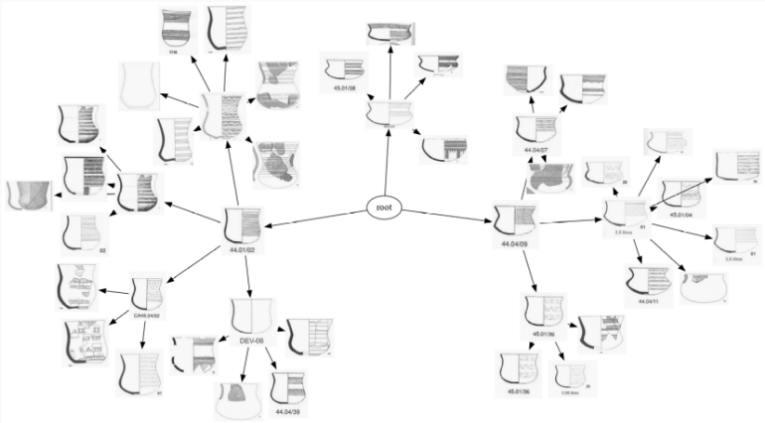
Shape Analysis 1: PCA & hclust

approach/workflow

- using profile distances + additional nominal variables as input
- conduct PCA
- using hclust (euclidean/Ward) to cluster
- package `FactoMinR`: HCPC with automatical cut (number of clusters according to higher relative loss of inertia)
- for individual clusters, repeat with cluster members as new dataset (usually 3 levels)







problems

- non-metric (non-euclidean) variables not considered correctly
- all vessels had to belong to one cluster (hand made ceramics)
- global dissimilarity resulted in suboptimal separation

Shape Analysis 2: t-sne & hdbscan

t-Distributed Stochastic Neighbor Embedding

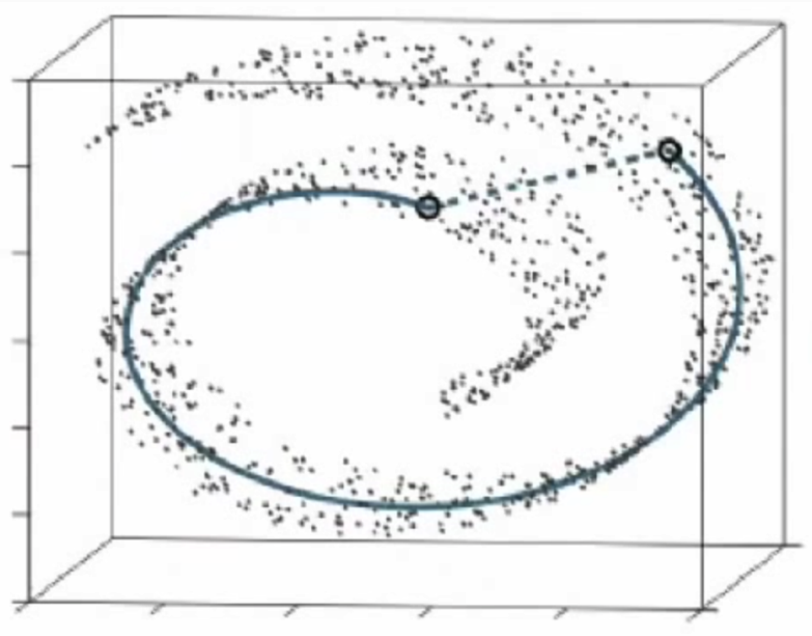
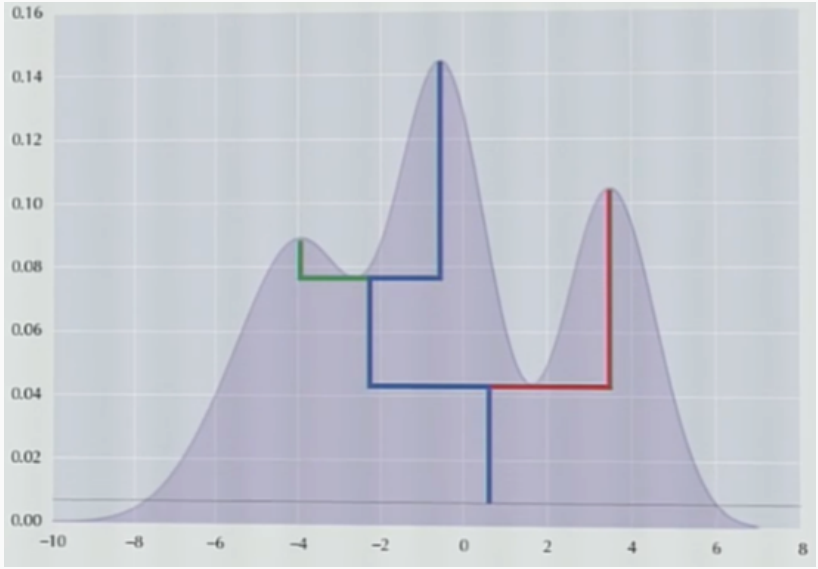


Figure 2: van der Maaten 2008; 2009; 2012; 2014;
https://lvdmaaten.github.io/tsne/
https://www.youtube.com/watch?v=RJVL80Gg3lA

Challenge

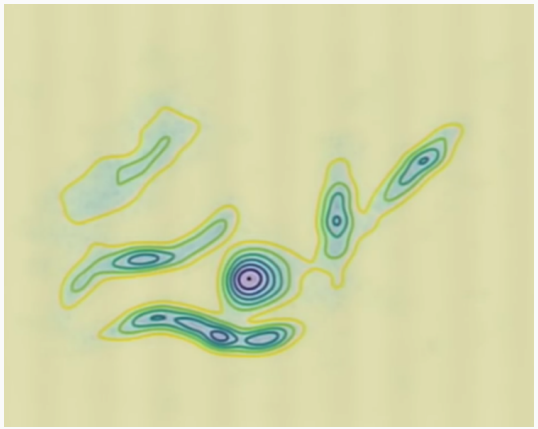
- high dimensional non-linear data distribution
- consider not the global, but the local neighbourhood (contrasting PCA)

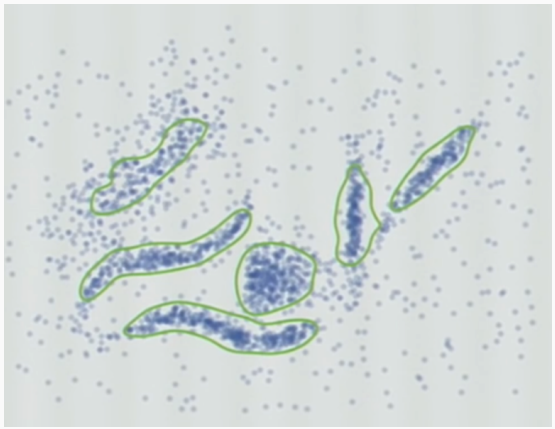
Hierarchical Density-Based Spatial Clustering of Applications with Noise

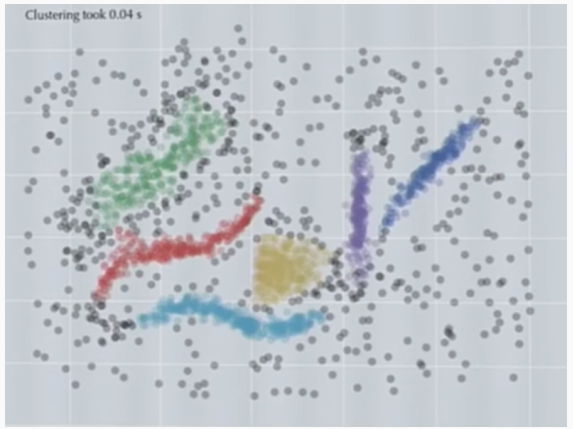


Benefits:

- separating non-circular clusters
- 'identification' and exclusion of noise (hand made ceramics!)

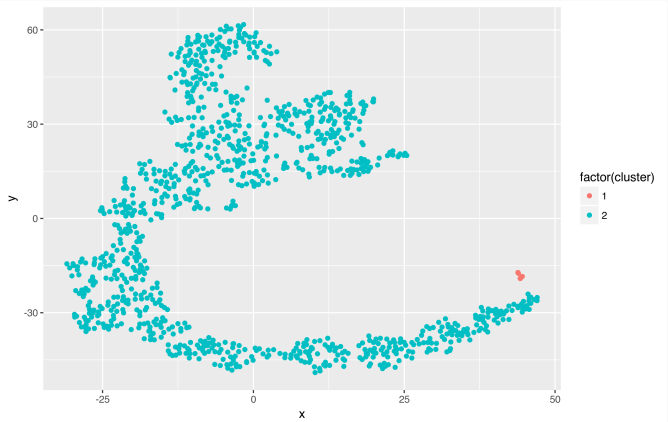


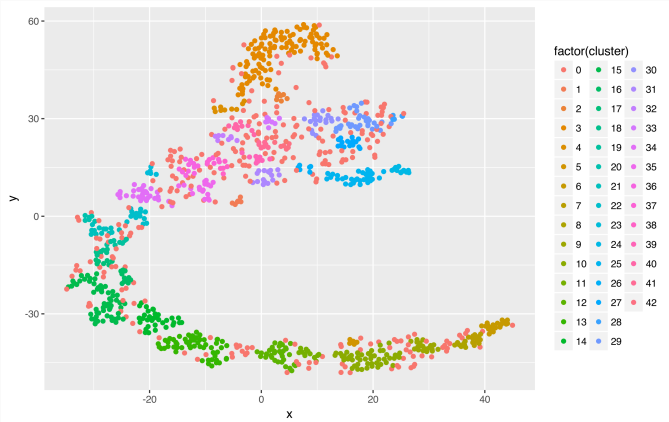




approach/workflow

- using profile distances + additional nominal variables as input
- conduct t-sne
- using hdbscan to cluster
- package `Rtsne`: conduct t-sne
  - `Rtsne(as.matrix(shapes),perplexity=30,dims=2,theta = 0)`
- package `dbscan`: conduct hdbscan on t-sne result
  - `hdbscan(this_res_sne, minPts = 5)`
- for individual clusters, repeat with cluster members as new dataset (usually only 2 levels)





stochastic nature of t-sne

Problem

- t-sne is as stochastic algorithm
  - results from two t-sne runs might differ
  - accordingly clustering might also differ

solution

- consensus clustering
  - repeat clustering for n times (101)
  - mark co-occurence of objects in cluster
  - make final cluster solution on majority voting

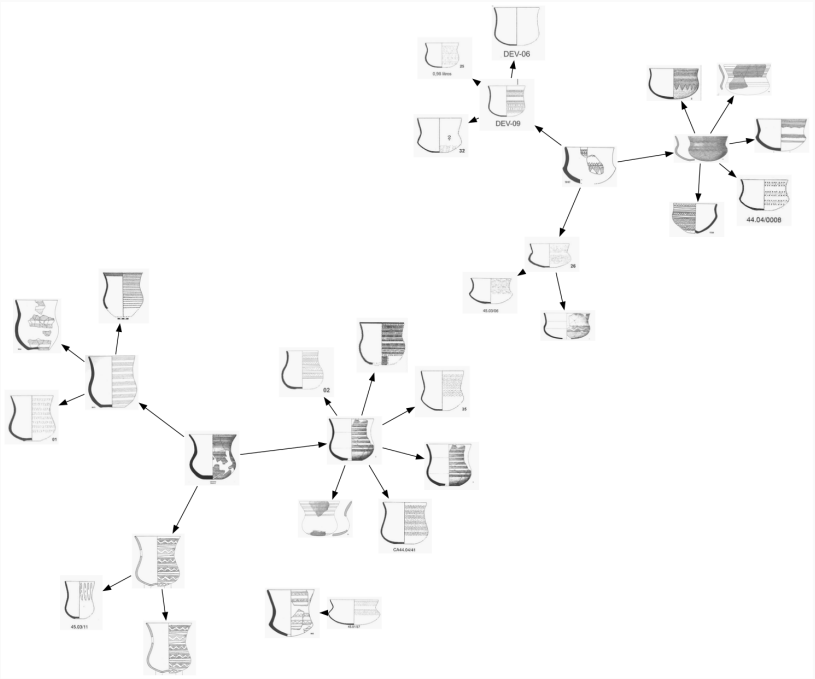
Case study 1: Bell Beakers of the Iberian Peninsula

Dataset

- 213 speciments
- Collected from 5 publications
  - Leisner/Leisner 1956
  - Harrison 1977
  - García Rivero 2008
  - Rojo-Guerra et al. 2005
  - Prieto-martinez/Salanova 2011
- Only ceramics with full (preserved or reconstructed) profiles
- Only beakers and carinated bowls
  - rather low diversity of ceramic shapes

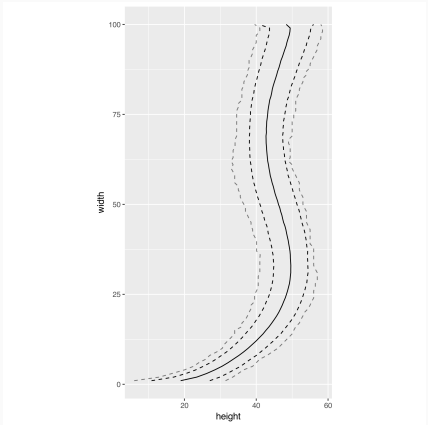
Results HCPC

- Separation Beakers/Carinated Bowls on first Level
- additionally small group with low belly break

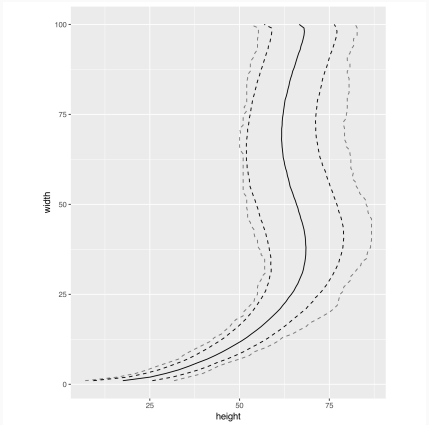


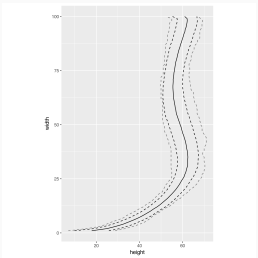
mean profile per cluster HCPC

Cluster 1

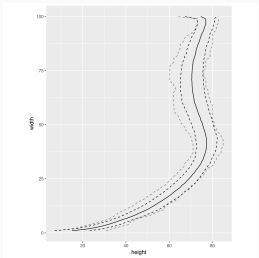


Cluster 2

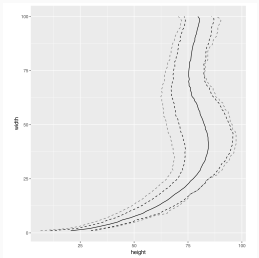




Cluster 2.1



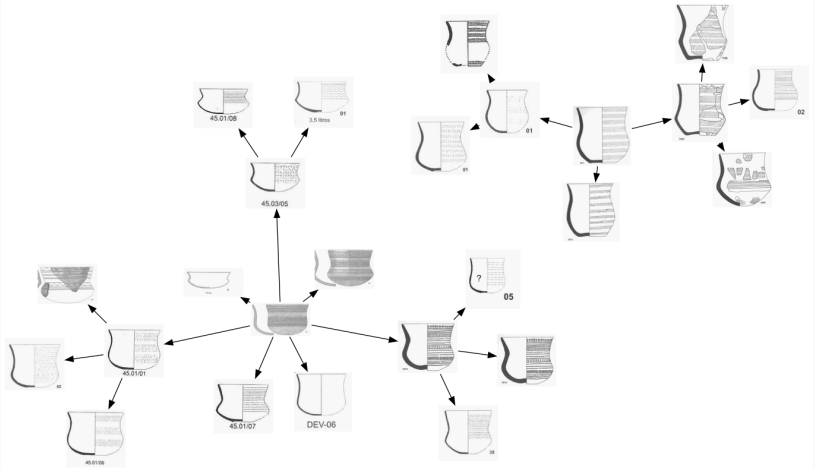
Cluster 2.2



Cluster 2.3

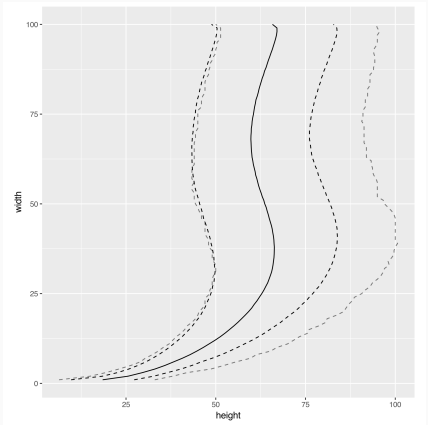
Results tsne_hdbscan

- Separation Slim Beakers/Stout Beakers + Carinated Bowls on first Level
- Separation Beakers/Bowls on second level

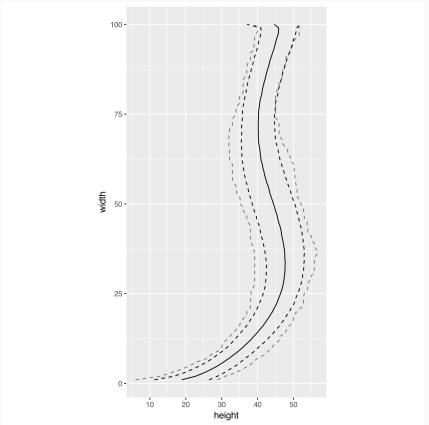


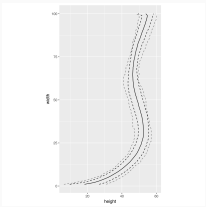
mean profile per cluster tsne_hdbscan

Cluster 1

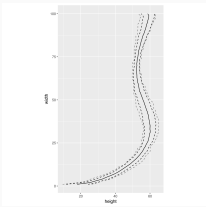


Cluster 2

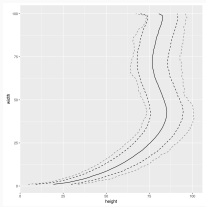




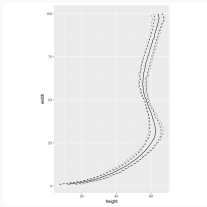
Cluster 1.1



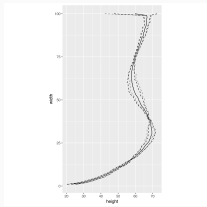
Cluster 1.2



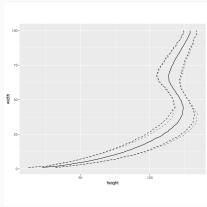
Cluster 1.3



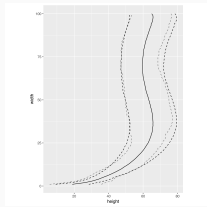
Cluster 1.4



Cluster 1.5



Cluster 1.6



Cluster 1.7

Resume Case Study 1

with t-sne and hdbscan

- finer separation of classes early
- profile curvature has more impact

but in general at this complexity level both approaches are feasible/comparable

Case study 2: Neolithic Swiss Ceramic

Background

Mobilities, **E**ntanglements, **T**ransformations

What can be said about mobility, relationships and transformations in neolithic societies on the basis of ceramics?

- including form, but also nominal characteristics like
  - lugs, handles, eyelet
  - bottom characteristics
  - plastic attachments
  - surface treatment
- much more diverse ceramic shapes

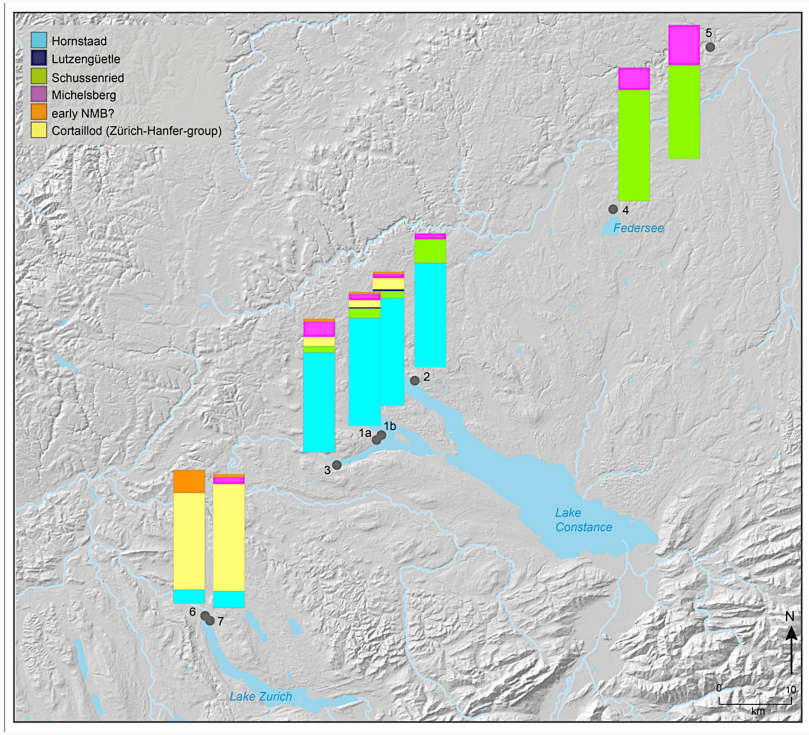
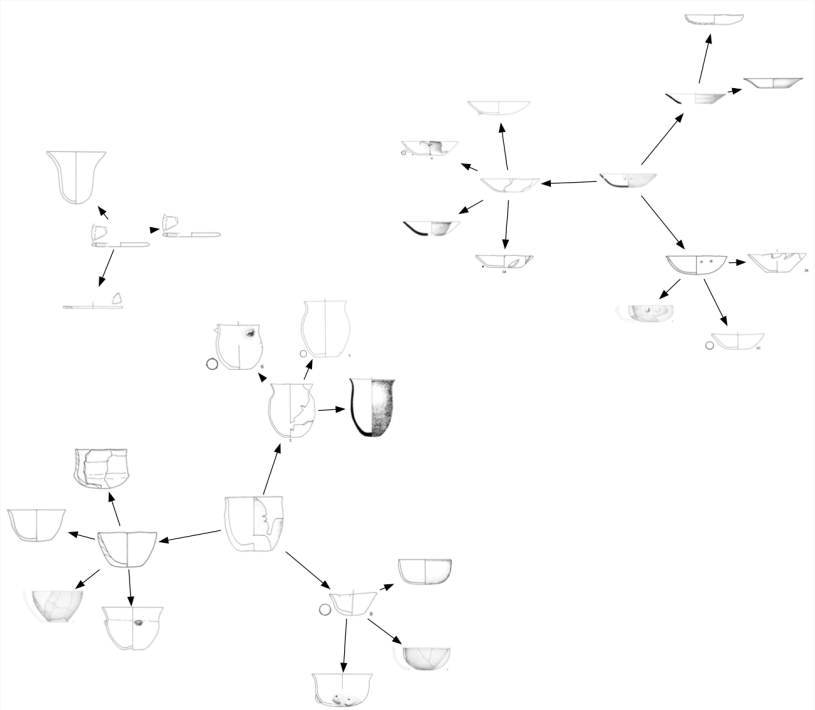


Figure 3: Ceramic spectrum at different Swiss and South German sites, 3950–3900 cal BCE

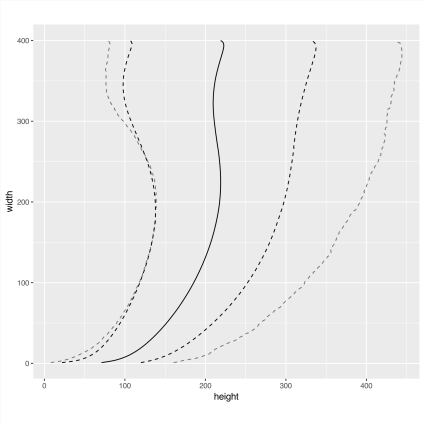
Results HCPC

- Separation first Level
  - bowls
  - higher forms
  - special forms
- second level higher forms
  - beakers
  - higher and flatter bowls
- not bad

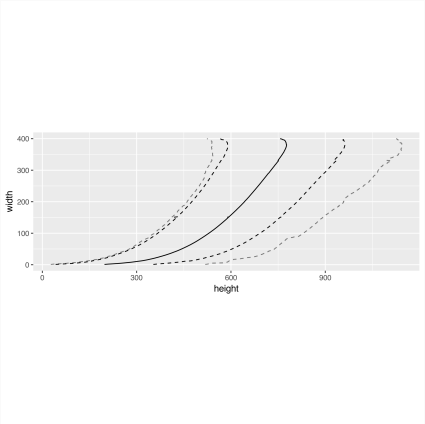


mean profile per cluster HCPC

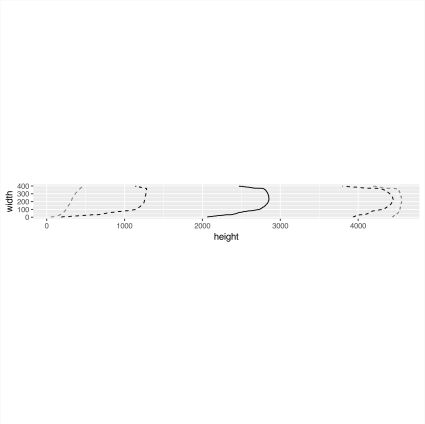
Cluster 1



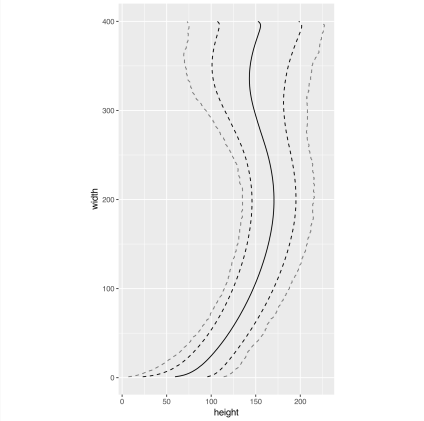
Cluster 2



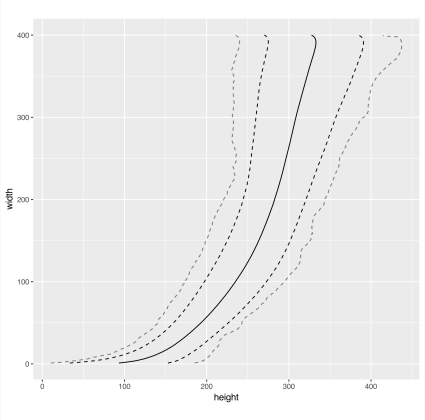
Cluster 3



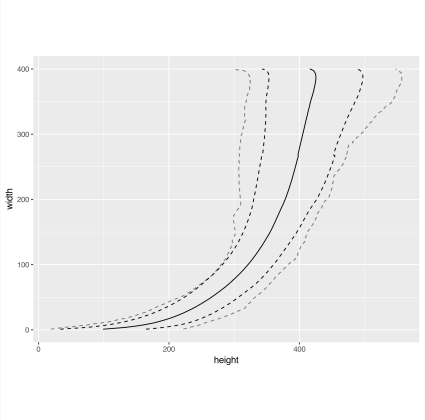
Cluster 1.1



Cluster 1.2

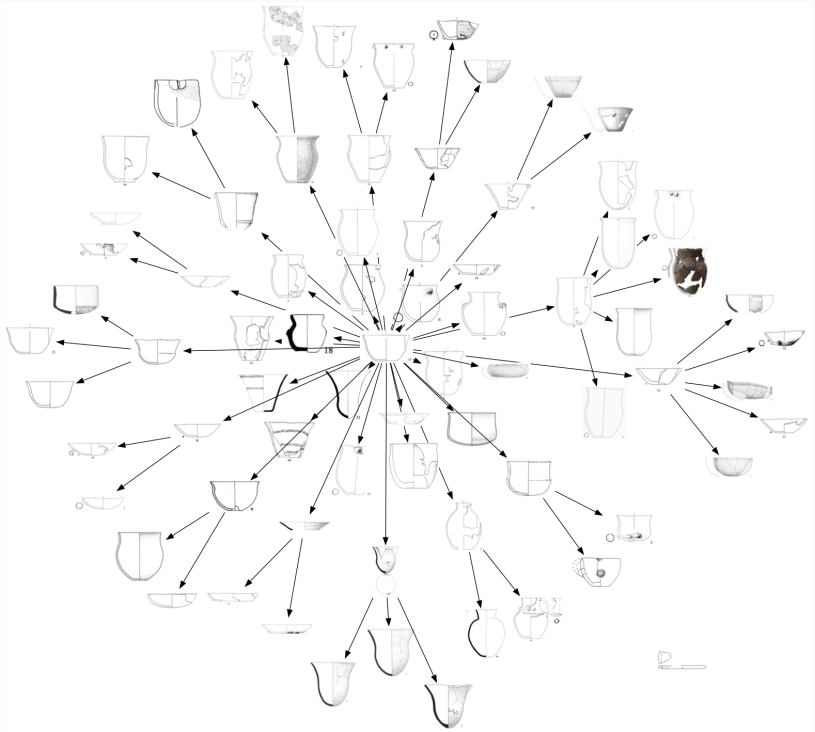


Cluster 1.3



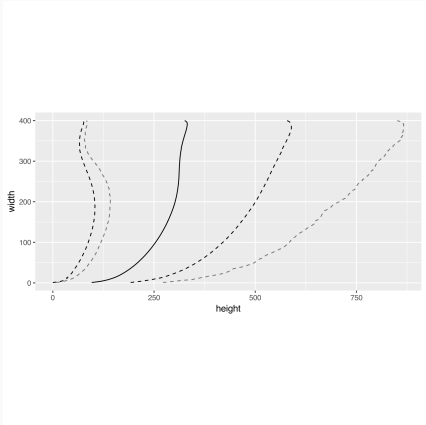
Results tsne_hdbscan

- First Level separation dishes / remainder
- on second level an explosion of 33 different classes

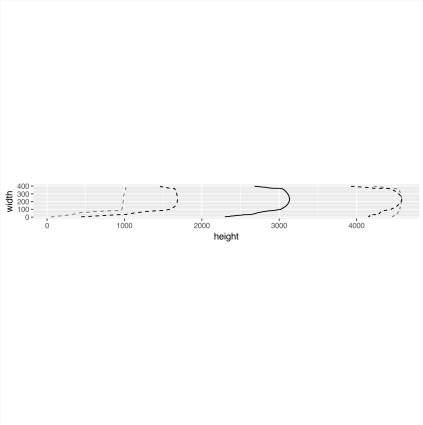


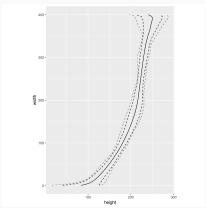
mean profile per cluster tsne_hdbscan

Cluster 1

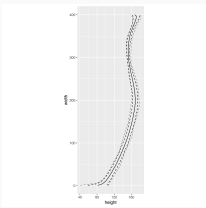


Cluster 2

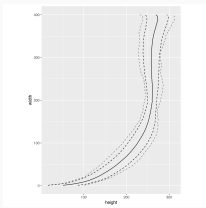




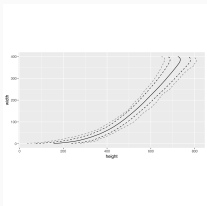
Cluster 1.1



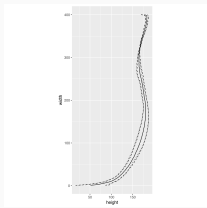
Cluster 1.3



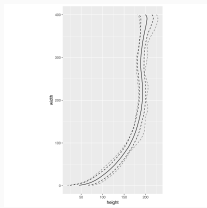
Cluster 1.5



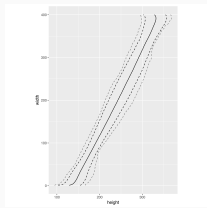
Cluster 1.7



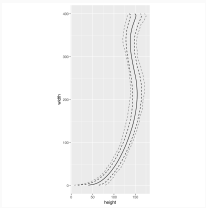
Cluster 1.9



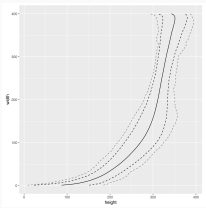
Cluster 1.11



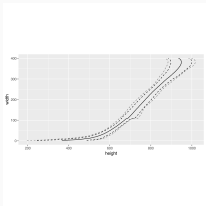
Cluster 1.13



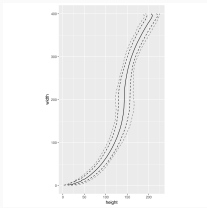
Cluster 1.2



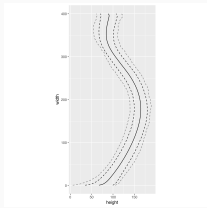
Cluster 1.4



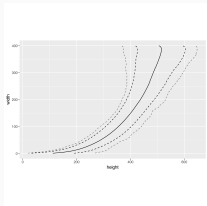
Cluster 1.6



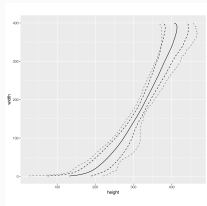
Cluster 1.8



Cluster 1.10



Cluster 1.12



Cluster 1.14

Resume Case Study 2

with t-sne and hdbscan

- much finer separation of classes
- much greater homogeneity within the classes
- Classification clearly more meaningful based on prior archaeological knowledge
  - no mixing up of ‘exotic shapes’ into one class
  - eg. Michelsberg Beakers separated
    - even division between ‘Beutelbecher’ (‘bag beaker’) and ‘Tulpenbecher’ (‘tulip beaker’)

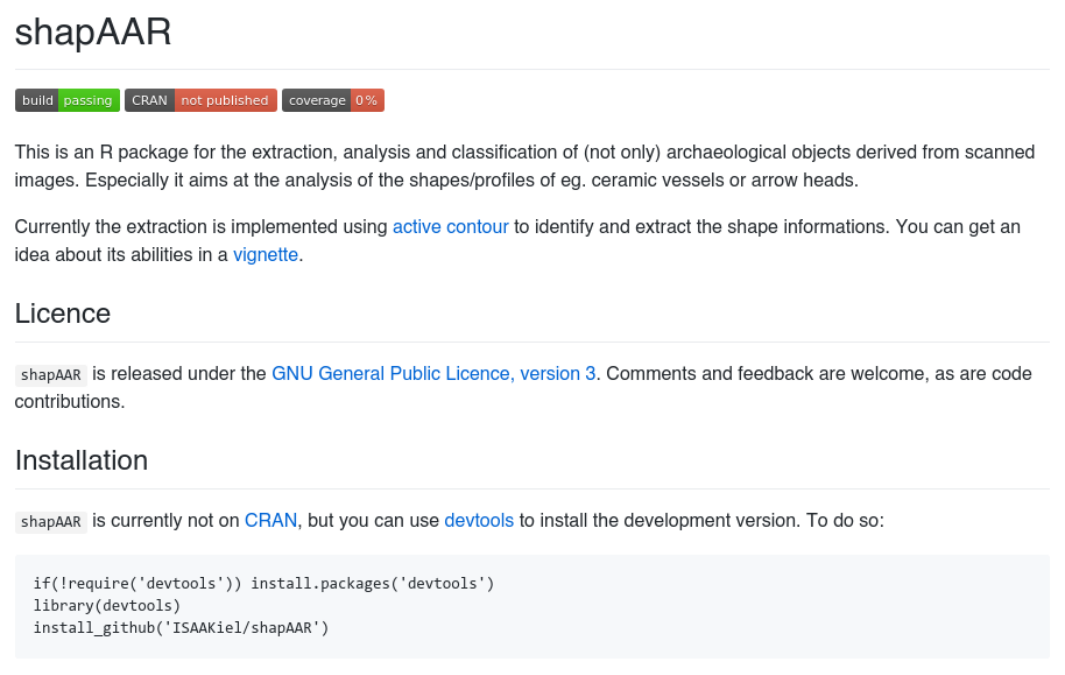
Resume

Results from case studies

- unsupervised classification (also as merely explorative tool) can open up new perspectives in archaeological interpretation
- automated object separation has the potential to speed up the process significantly
- in case of low diversity pca/hclust and t-sne/hdbscan perform similar
- in case of high diversity t-sne/hdbscan results in much more adequate classes

shapAAR as (CRAN) Package

Watch this space: https://github.com/ISAAKiel/shapAAR



shapAAR

build passing | CRAN not published | coverage 0%

This is an R package for the extraction, analysis and classification of (not only) archaeological objects derived from scanned images. Especially it aims at the analysis of the shapes/profiles of eg. ceramic vessels or arrow heads.

Currently the extraction is implemented using active contour to identify and extract the shape informations. You can get an idea about its abilities in a vignette.

Licence

`shapAAR` is released under the GNU General Public Licence, version 3. Comments and feedback are welcome, as are code contributions.

Installation

`shapAAR` is currently not on CRAN, but you can use devtools to install the development version. To do so:

```
if(!require('devtools')) install.packages('devtools')
library(devtools)
install_github('ISAAKiel/shapAAR')
```

- object separation from scanned images already usable
- inclusion of classification in progress
- cran release expected this year (2018)

Thank you

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