Exploratory Hierarchical Clustering for Management Zone Delineation in Precision Agriculture

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Precision Agriculture

- GPS technology used in site-specific, sensor-based crop management
- combination of agriculture and information technology
- data-driven approach to agriculture
- lots of data analysis tasks

Data Details – Example Field

Figure: F550 field, depicted on satellite imagery, source: Google Earth

Data Details – Features

- collect a number of geo-coded, high-resolution features such as:
  - N1, N2, N3: nitrogen fertilizer application rates in 2004
  - REIP32, REIP49: vegetation index (red edge inflection point) in 2004
  - Yield: corn yield 2003, winter wheat yield in 2004 and 2007
  - EC25: electrical conductivity of soil in 2004
  - pH, P, K, Mg: soil sampling in 2007
- one field available, 1080 records in $25 \times 25m$-resolution on a hexagonal grid

Data Details – Temporal Aspects

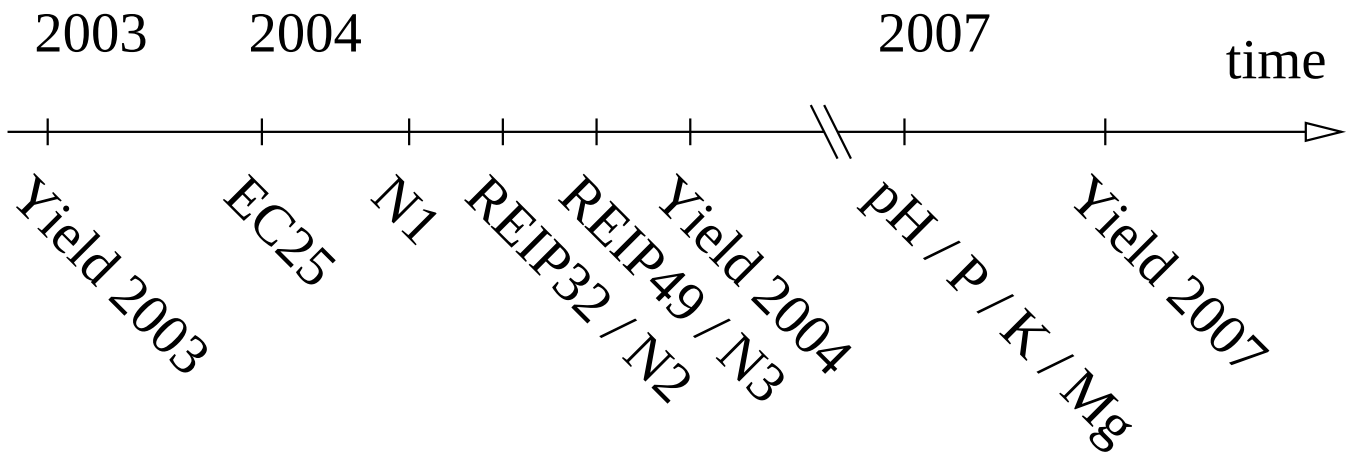


Figure: timeline of data acquisition

Spatial Autocorrelation

Are (spatial) data records independent of each other?
(Do we have spatial autocorrelation?)

(a) EC25 (b) Magnesium content

Figure: F550, EC25 and Magnesium readings

Management Zone Delineation

- A common task in agriculture:
  - subdivide the field into smaller zones
  - zones are rather homogeneous
  - zones are spatially mostly contiguous
  - similarity between zones is low
- $\longrightarrow$ spatial clustering

Literature Approaches

- mostly non-spatial algorithms are used
  - no spatial contiguity
  - small islands, outliers, etc.
  - black-box models
  - fuzzy c-Means, k-Means, etc.
- spatial contiguity is not always required, but desirable
- spatial autocorrelation is usually neglected rather than exploited

Spatial Contiguity Constraint

- spatial clustering = clustering with a spatial contiguity constraint
- $\longrightarrow$ constrained clustering
- Keep it simple and understandable:
  - hierarchical clustering
  - agglomerative clustering
- Idea:
  1. split field into small zones which are homogeneous
  2. iteratively merge these zones obeying similarity and spatial constraint

Spatial Tessellation

- k-Means clustering on the data points' coordinates
  - due to spatial autocorrelation, adjacent points are likely to be similar
  - this ensures homogeneity of these small zones
  - k is user-controllable and easy to understand
    - homogeneous field: smaller k
    - heterogeneous field: higher k

Spatial Tessellation

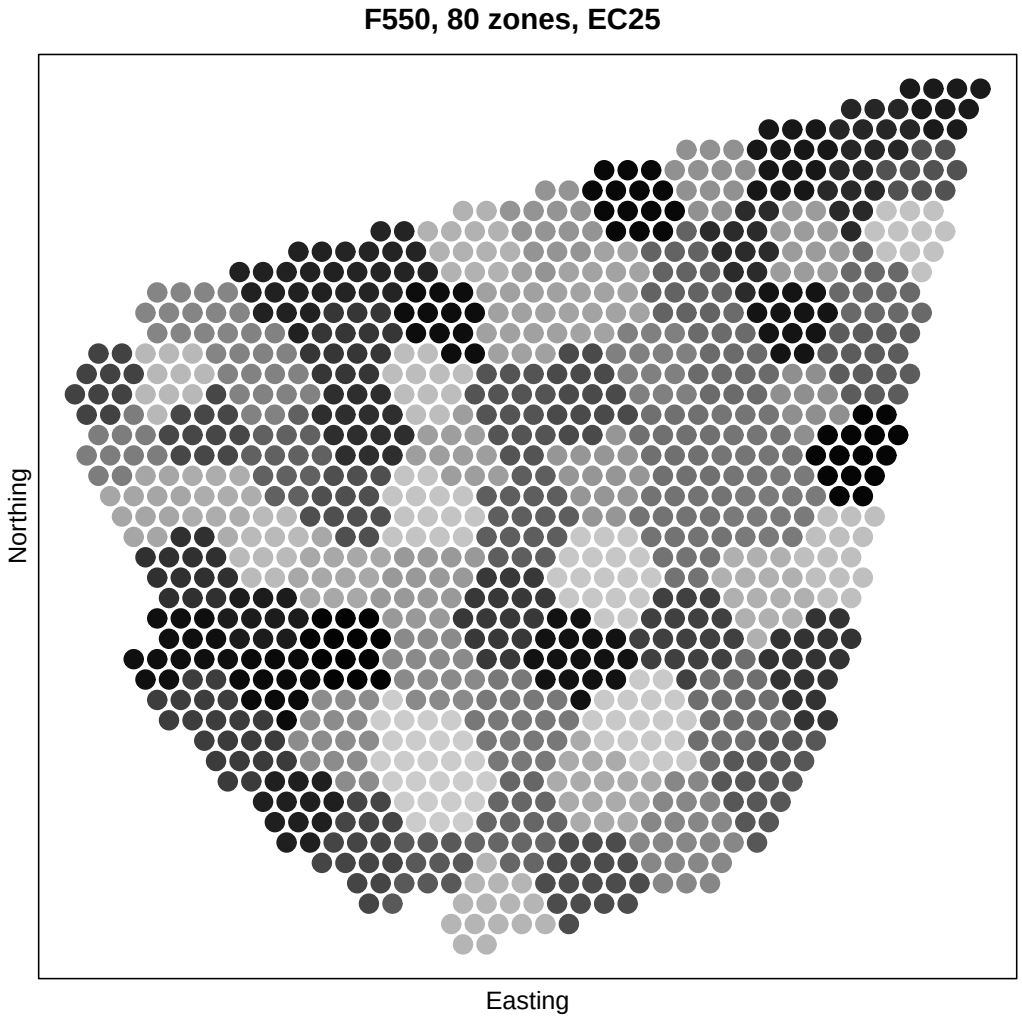
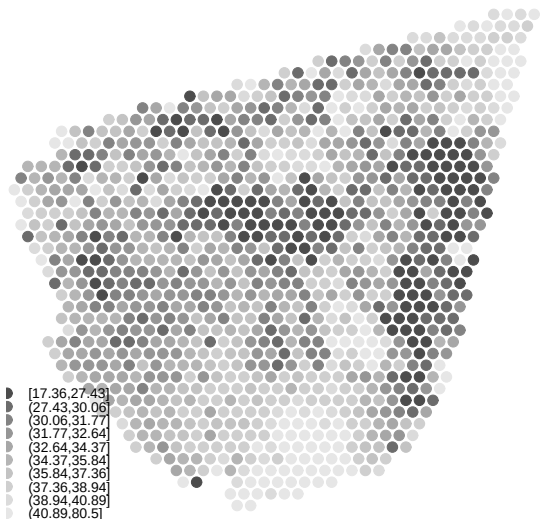


Figure: Tessellation of F550 using k-means, $k = 80$ (grey shades are for illustration only, no further meaning here)

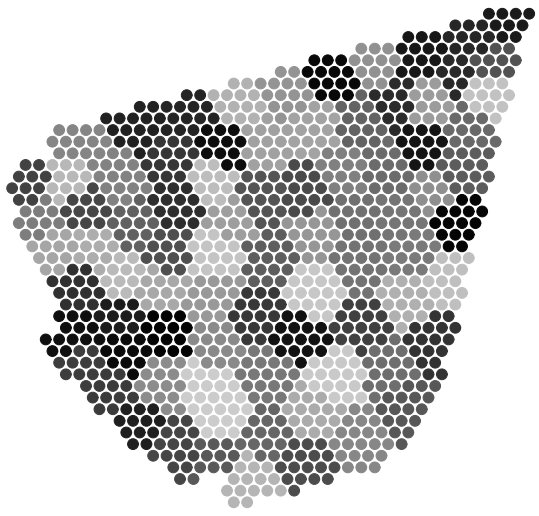
Hierarchical Agglomerative Constrained Clustering

- principle: merge only adjacent objects/clusters, if they are similar enough
  - this ensures spatial contiguity
  - $\rightarrow$ spatial constraint, non-adjacent clusters *cannot link*
- once non-adjacent clusters become much more similar than adjacent ones, they may be merged
  - introduce a user-controllable *contiguity factor cf*
  - $cf \geq 2$: high contiguity
  - $cf \in [1, 2]$: low contiguity
  - $cf \leq 1$: no contiguity

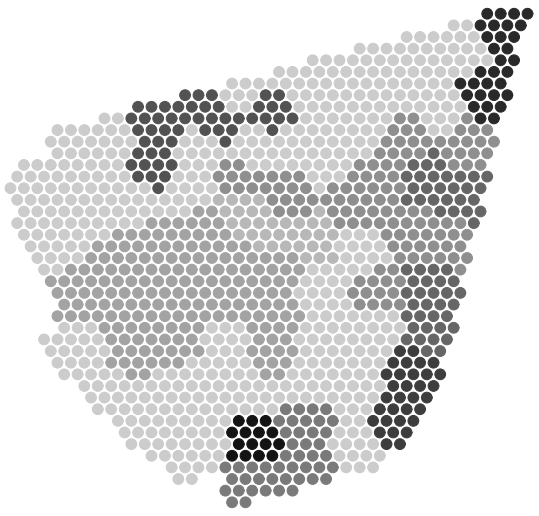
HACC – 1D example



(a) EC25 plot



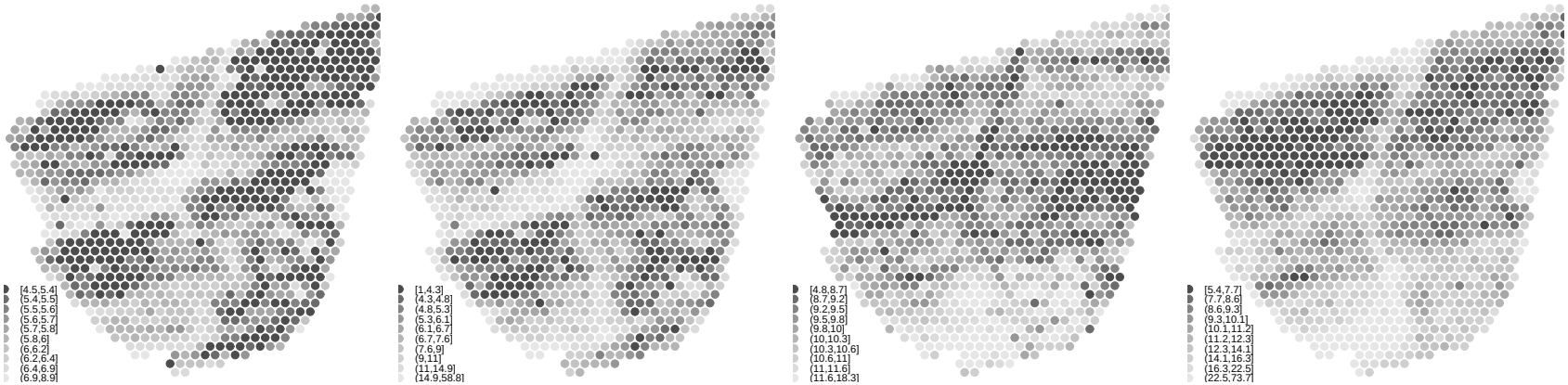
(b) EC25, 80 zones



(c) EC25, final zones

Figure: F550, EC25 clustering

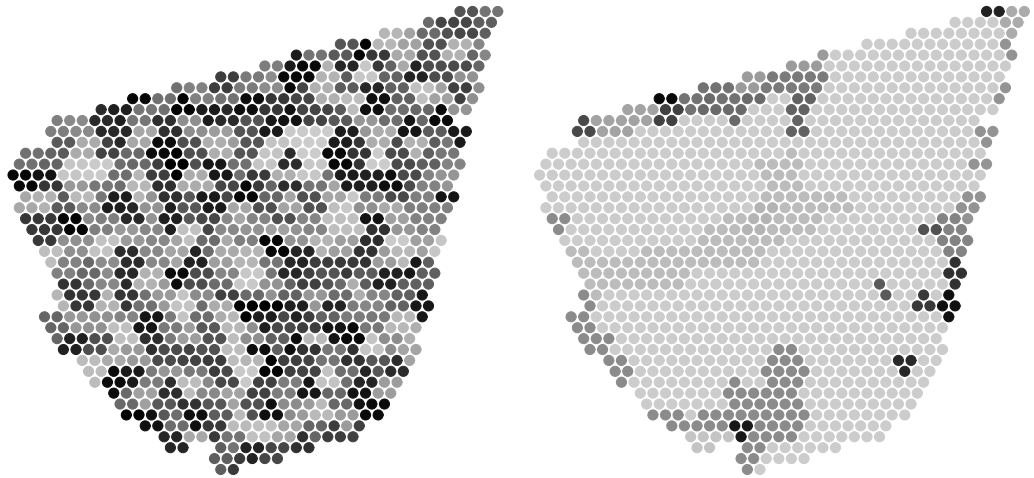
HACC – 4D example



(a) pH plot (b) P plot (c) Mg plot (d) K plot

Figure: F550, four attributes

HACC – 4D example (cont.)



(a) F550-4D, beginning (b) F550-4D, ten zones

Figure: F550, management zones

- actually, 3 zones (when comparing attribute values)
  - low pH, low P, low Mg, low K (largest zone)
  - high pH, high P, high Mg, high K (border zones)
  - high pH, high P, low Mg, high K (middle, from left)

Summary

- precision agriculture as a data-driven approach
- spatial, geo-referenced data records in large amounts
- management zone delineation solved as a spatial clustering approach
- important difference between spatial and non-spatial data treatment $\Rightarrow$ use models which are fit for spatial tasks

Time for ...

Questions?

Workshop *Data Mining in Agriculture* on Saturday (after ICDM)

- contact: `russ@dma-workshop.de`
- slides, R scripts and further info at `http://research.georgruss.de`