Data-Analysis of Environmental Air Pollutant Monitoring Systems in Europe

Kristina Voigt, Gerhard Welzl, [2]Rainer Brüggemann

GSF –National Research Center for Environment and Health

Working Group Biostatistcs,

[2]Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin

GSF – Forschungszentrum für Umwelt und Gesundheit

Content

- Air Pollutant Monitoring Systems
- Objects, Attributes
- Data-analysis Methods
- Evaluation of Data-Matrix 15 x 5
  - Data-analysis by Hasse Diagram Technique
  - Data-analysis by Data Reduction Methods
    - PCA
    - POSAC
- Discussion of Results

GSF – Forschungszentrum für Umwelt und Gesundheit

15 Member States of EEC

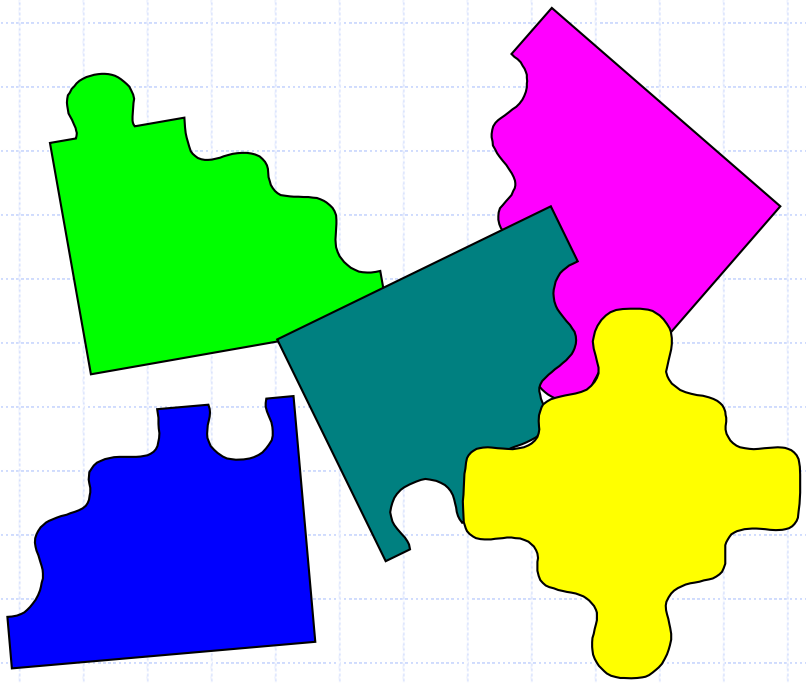
GSF – Forschungszentrum für Umwelt und Gesundheit

Air Pollution Monitoring / EEC

- **Concept of public's right to information**
- Proposal for a Directive of the European Parliament and of the Council on public access to environmental information exists
  - Preserving, protecting and improving the quality of the environment
  - Protecting human health
  - Prudent and rational utilization of natural resources
  - Promoting measures at the international level to deal with regional or world-wide environmental problems

GSF – Forschungszentrum für Umwelt und Gesundheit

Necessity to Find and Analyze Air Pollutant Monitoring IS



- Where on the Internet?
- http://www.stadtklima.de/stuttgart/s-luft/links.htm
- **Quality of the Systems**

GSF – Forschungszentrum für Umwelt und Gesundheit

Search Strategy for Air Pollutant Monitoring Information Systems

- http://www.stadtklima.de/stuttgart/s-luft/links.htm
- Key Air Quality Links http://unr.edu/homepage/daved/airqual.html
- Search in GOOGLE http://www.google.com
  - "air monitoring"
  - "name of European capital"

GSF – Forschungszentrum für Umwelt und Gesundheit

Data-Matrix 15 x 5

- **15 Objects**: Air Pollutant MS in European capitals
- **5 Variables:** Evaluation Criteria
- **Scoring System**:
  - 0 : bad
  - 1: medium
  - 2: good

GSF – Forschungszentrum für Umwelt und Gesundheit

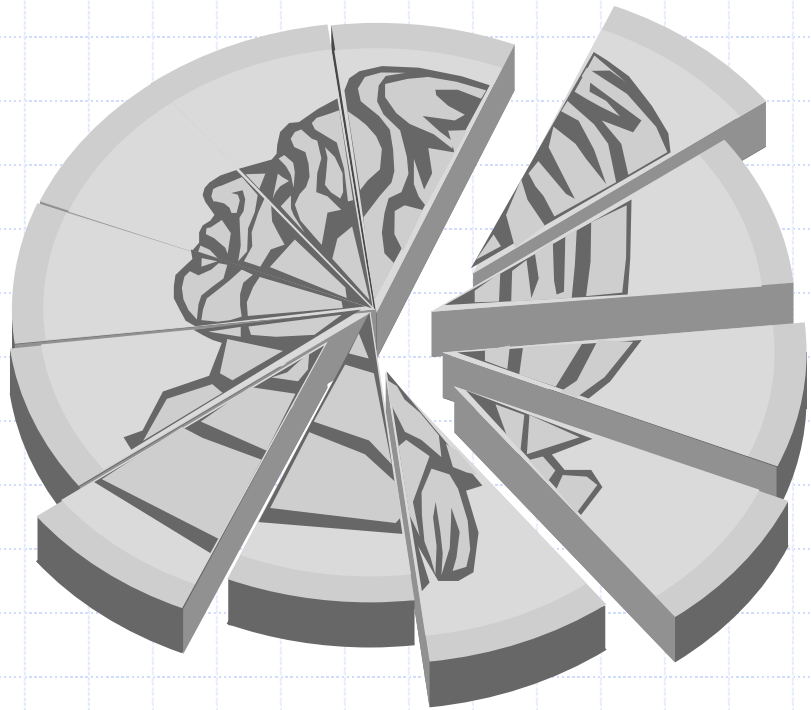
Evaluation Criteria (1)

- NU: Number of chemicals
- ME: Type and duration of measurements
- ST: Measurement stations
- PR: Data presentation
- BM: Background material

GSF – Forschungszentrum für Umwelt und Gesundheit

Evaluation Criteria (2)

- NU: quantitative, type of pollutant
- ME: temporal
- ST: spatial
- PR: descriptive
- BM: descriptive



Evaluation Criterion: NU
Number of chemicals monitored

≤ 4	0
5-7	1
> 7	2

GSF – Forschungszentrum für Umwelt und Gesundheit

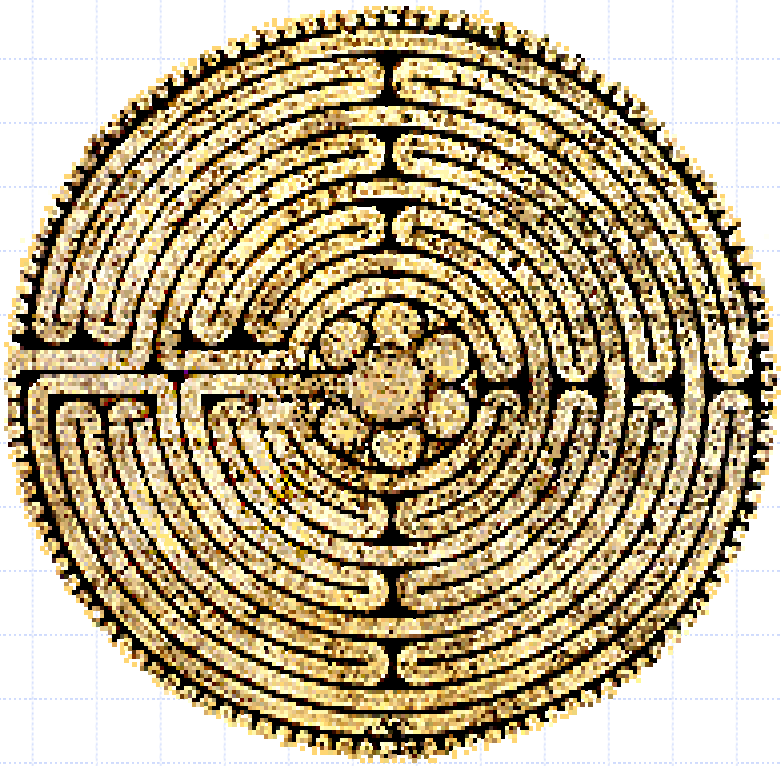
Evaluation Criterion: ST
Measurement stations in capital

1-2 stations	0
3-5 stations	1
> 6 stations	2

Data-Matrix (abbreviated)

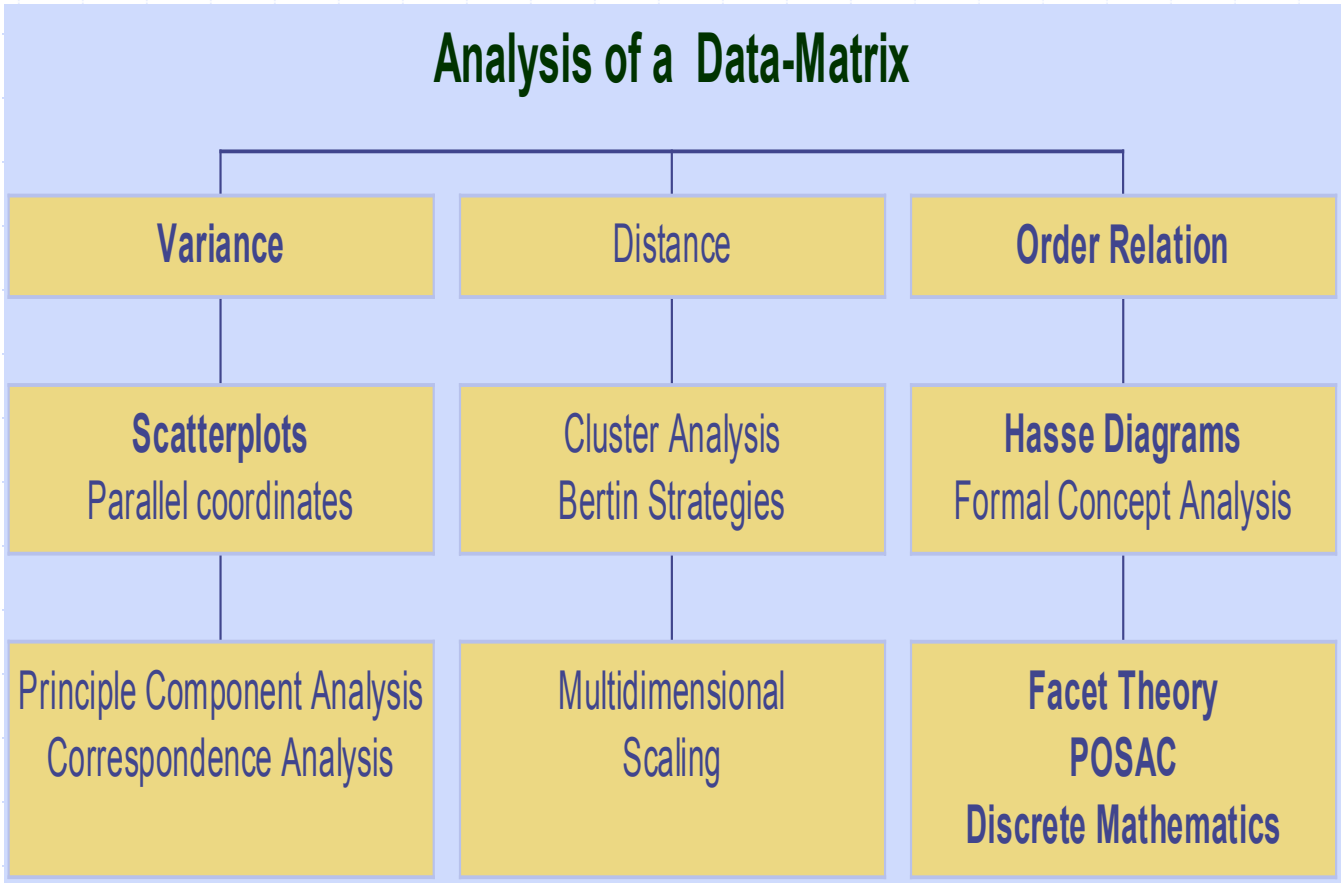
Abb.	NU	ME	ST	PR	BM
AUS	1	2	1	2	1
BEL	1	2	1	2	2
DEN	2	2	0	2	2
FIN	1	1	2	1	1
FRA	1	2	2	2	2

Analysis of Data-Matrix with Different Methods



- Hasse Diagram Technique
- Dimension Reduction Methods
- Similarities and Difference in Methods

Chemical or Environmental Data-Matrix



GSF – Forschungszentrum für Umwelt und Gesundheit

HDT: Four Point Program (1)

- Set of Elements: Ground set *O*
- Information Base IB
- Find a common orientation for all properties
- Analysing x,y $\in$ *O* whether one of the following relations is valid

HDT: Four Point Program (2)

- Analysing $x,y \in O$ whether one of the following relations is valid
  - $x \sim y$ (equivalence)
  - $x \leq y$ or $x \geq y$ (comparability)
  - $x \,||\, y$ (incomparability, there is a "contradiction in the data of x and y").

GSF – Forschungszentrum für Umwelt und Gesundheit

Hasse Diagram: Comparabilities / Characterizing Numbers

- **V: Comparabilities**
- **U:Incomparabilities**
- **Complex with equivalent objects**

- **NECA**: Number of equivalence classes
- **NL:** Number of levels
- **NEL:** Number of elements in the level, which contains the most elements

GSF – Forschungszentrum für Umwelt und Gesundheit

Hasse Diagram Technique (HDT) (1)

- Basis of the HDT is the assumption that we can perform a ranking while avoiding the use of an ordering index
- HDT is very appropriate for a comparative evaluation of objects when a multicriterial assessment is envisaged
- Hasse diagrams visualize so-called partially ordered sets (posets)

Hasse Diagram Technique (HDT) (2)

- **Objects** (elements)
- **Criteria** (attributes, variables)
- **Equivalent objects**: Different objects that have the same data with respect to a given set of attributes
- **Maximal objects** (greatest element)
- **Minimal objects** (least element)
- **Isolated objects**

GSF – Forschungszentrum für Umwelt und Gesundheit

D-Matrix: Analysis of Successors

- Geometrical analysis of a Hasse diagram to investigate substructures
- Preferably a maximal object is chosen
- Key element (k)
- all elements located lower than that of the key element: successors
- $G(k) = O(k) \setminus \{k\}$

GSF – Forschungszentrum für Umwelt und Gesundheit

W-Matrix: Dissimilarity-Matrix

- Describes the influence of the attributes on the Hasse diagram
- **W-matrix** contains the mutual comparisons of the Hasse diagrams
- **Heart of the analysis**
- Dissimilarity-matrix: The larger the matrix-entries are, the greater is the difference between the successor sets for the element k and hence between the Hasse diagrams.

PCA: Principal Component Analysis

- MVSP Statistics Package Kovach Computing Services http://www.kovcomp.co.uk/mvsp/
- Aim: Reduction of the Dimensionality of the Data
- The new variables, the principal components, are defined as linear functions of the original variables

GSF – Forschungszentrum für Umwelt und Gesundheit

POSAC

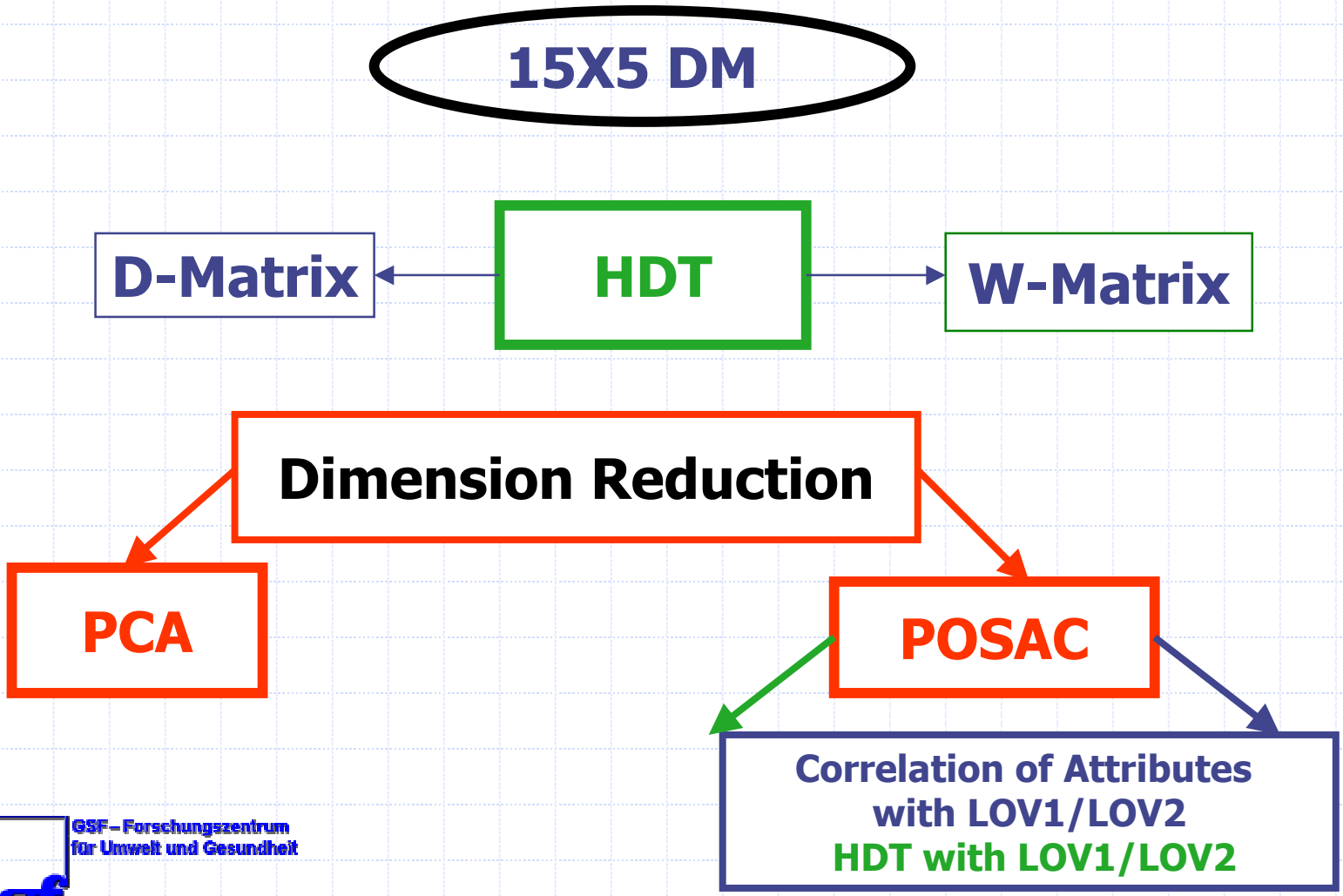
- Partially Ordered Scalogram Analysis with Coordinates
- Systat 10 program
- Iteratively computes a configuration of points in a **two-dimensional** space according to the partial order model
- Order relations are considered as the essential aspect of the data to be preserved in the data-analysis

GSF – Forschungszentrum für Umwelt und Gesundheit

POSAC

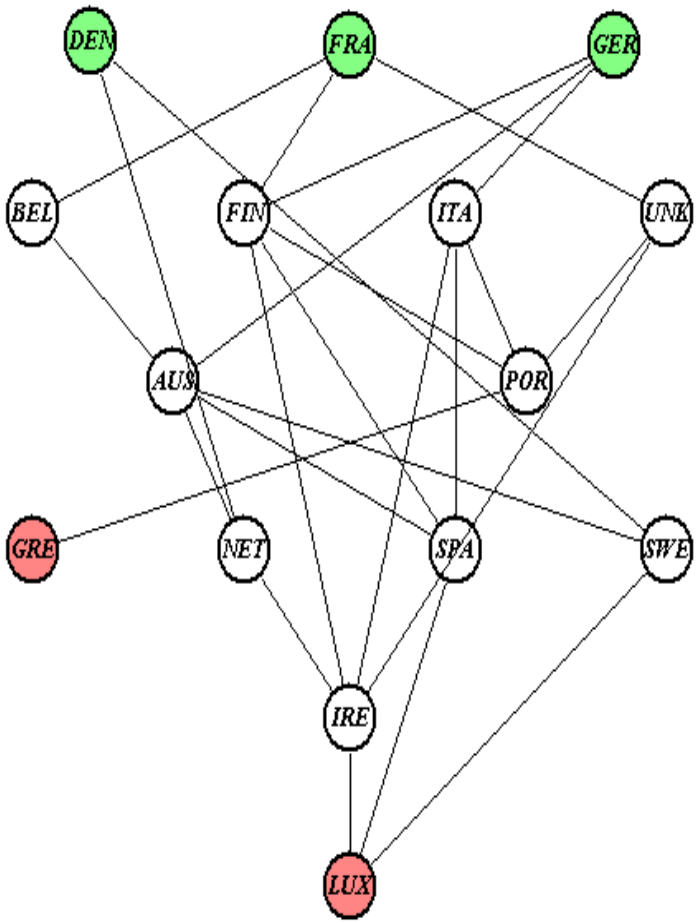
- Data reduction on attribute side
- 2 Dimensions
- LOV (Latent Order Variables)
- Percentage of order relations are kept / lost

Application of Analyses Methods



Hasse Diagram for Data-Matrix 15 X 5

Maximal objects



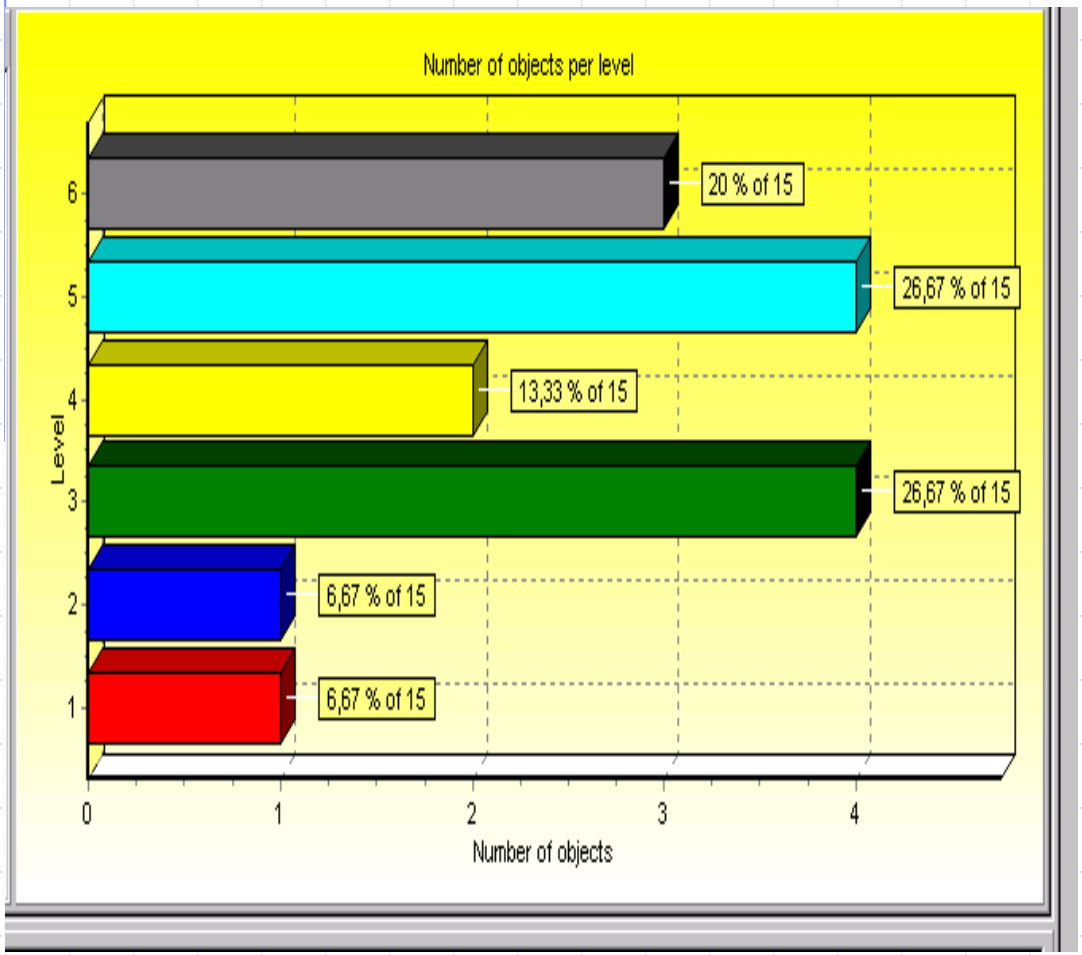
Minimal objects

GSF – Forschungszentrum für Umwelt und Gesundheit

Hasse Diagram Results (1)

- **Maximal Objects**: {DEN}, {FRA}, {GER}
- **Minimal Objects**: {LUX}, {GRE}
- **Comparabilities V(N): 57**
- **Incomparabilities U(N): 48**
- **K = 0**

Hasse Diagram: Levels



6 Levels

4 Objects in largest level

GSF – Forschungszentrum für Umwelt und Gesundheit

D-Matrix: Analysis of Successors

- Maximal objects are taken as key objects
- search of all objects which are located lower than the key object
- GER 10 successors
- FRA 11 successors
- DEN 4 successors

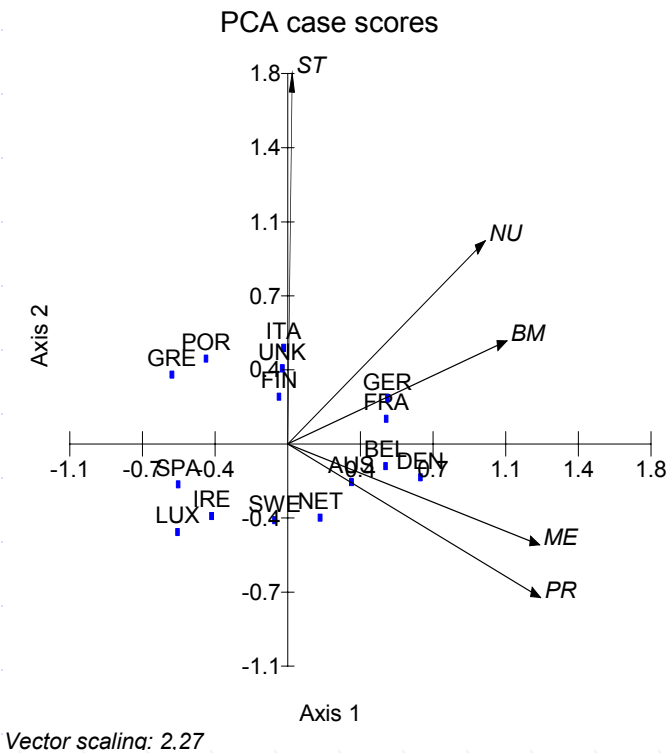
GSF – Forschungszentrum für Umwelt und Gesundheit

W-Matrix: Dissimilarity Matrix

- **Case 3** (leaving out the attribute ST) leads to 26 changes in the original diagram
- Measurement stations in capital is the most important attribute
- Data-matrix: 16 X 4 (NU, ME, PR, BM)
- **ST left out**

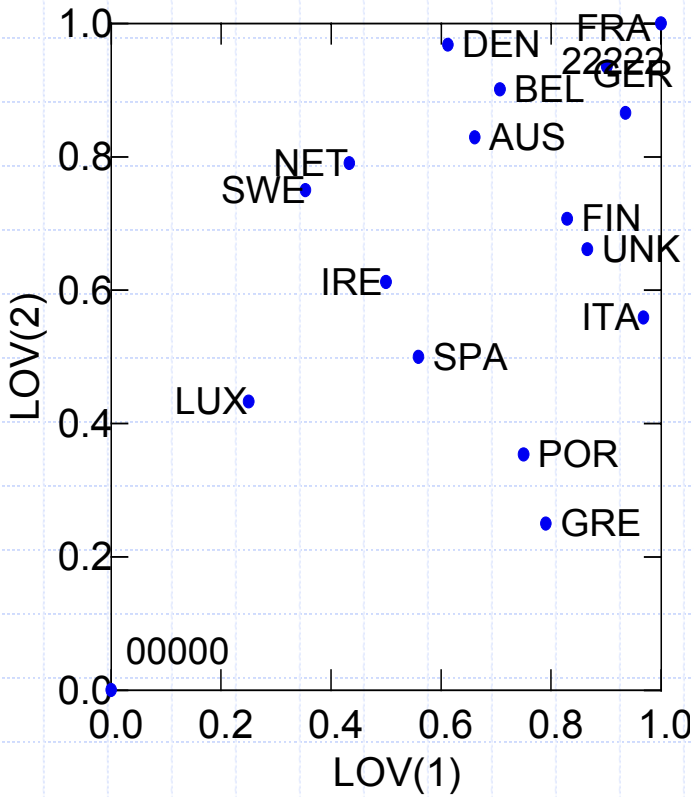
GSF – Forschungszentrum für Umwelt und Gesundheit

Data Reduction Methods



Vector scaling: 2.27

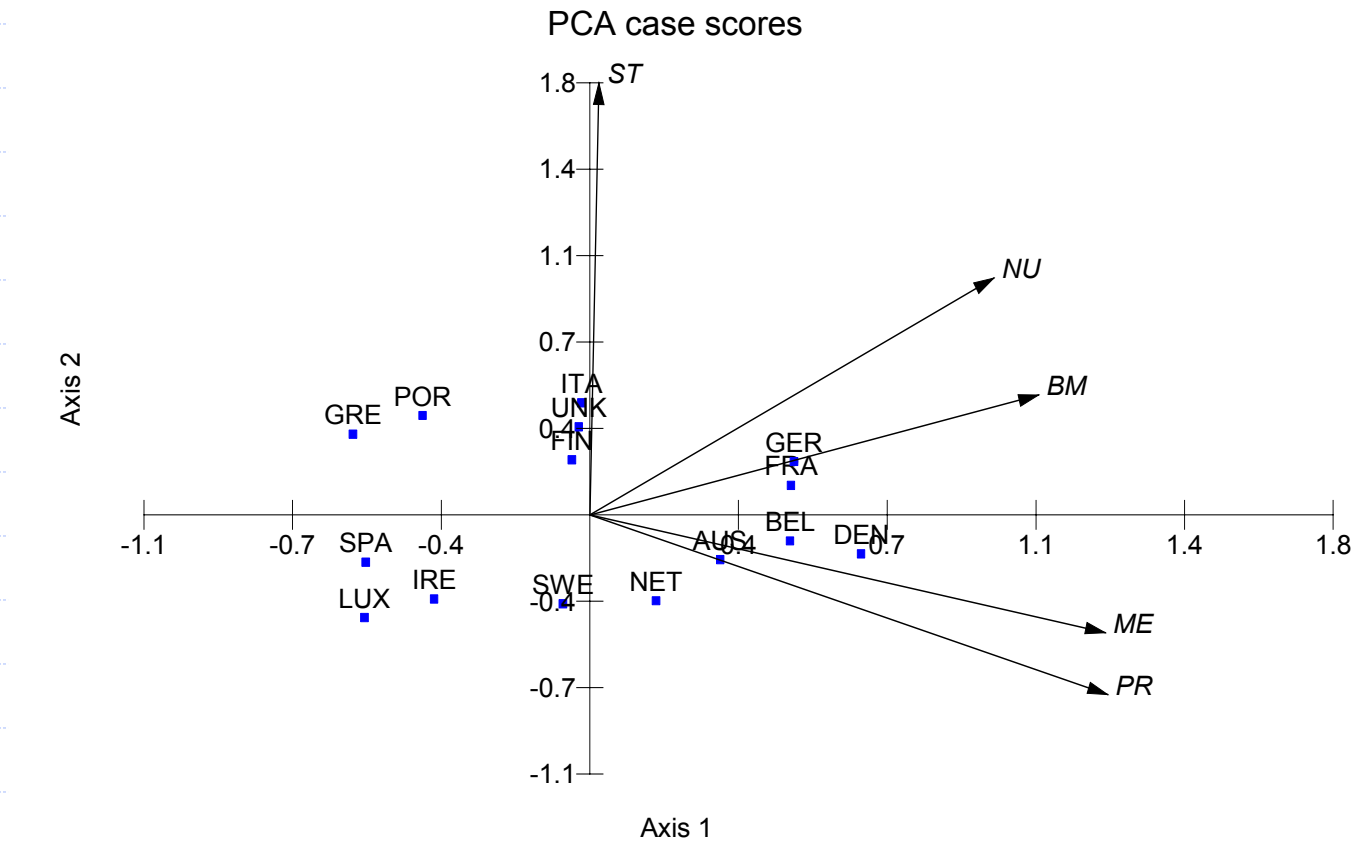
PCA



POSAC

GSF – Forschungszentrum für Umwelt und Gesundheit

PCA Biplot



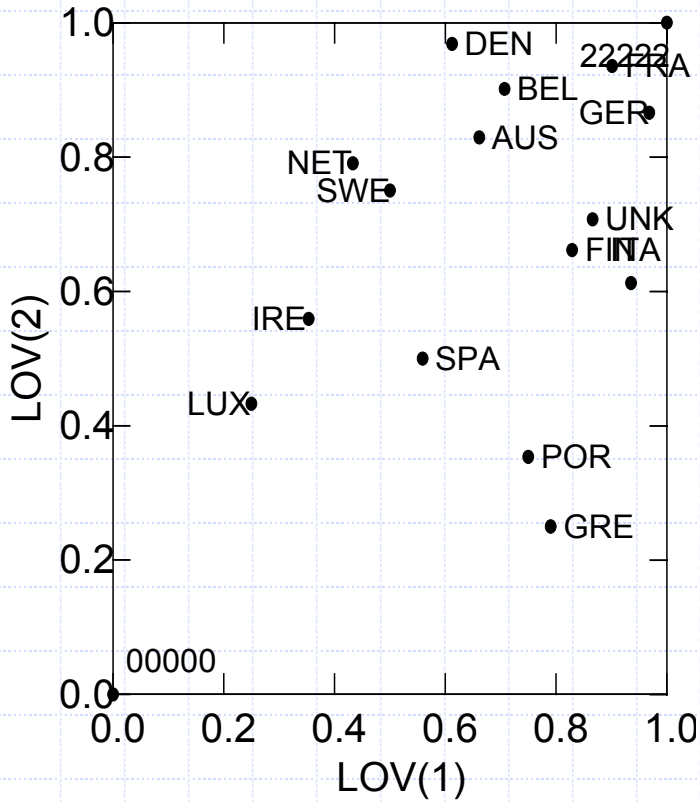
Vector scaling: 2.27

GSF – Forschungszentrum für Umwelt und Gesundheit

PCA Biplot: Interpretation

- Component 1 is influenced by NU, BM, ME, PR
- Component 2 is influenced by ST
- Component 3 has a positive loading 0,754 for BM

POSAC Plot for Data-Matrix 15 x 5



- Dimension reduction
- 2 latent order variables
- 93,4 % correct
- Minimal (00000) and maximal (22222) are added.

GSF – Forschungszentrum für Umwelt und Gesundheit

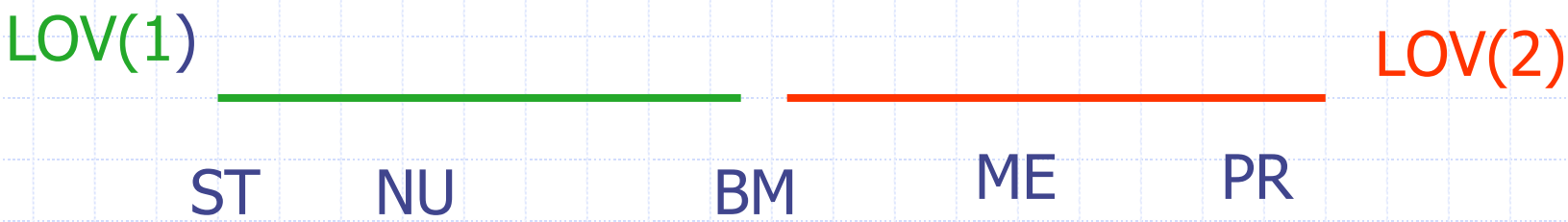
Interpretation of LOVs using ANOVA

- **LOV (1)** is highly correlated with **ST**
  - F-Statistik: 26,556
- **LOV (2)** is highly correlated with **PR (ME)**
  - F-Statistik: 32,7
- **LOV (1)** can be described by **ST**
- **LOV (2)** can be described by **PR**
- **POLAR Items**

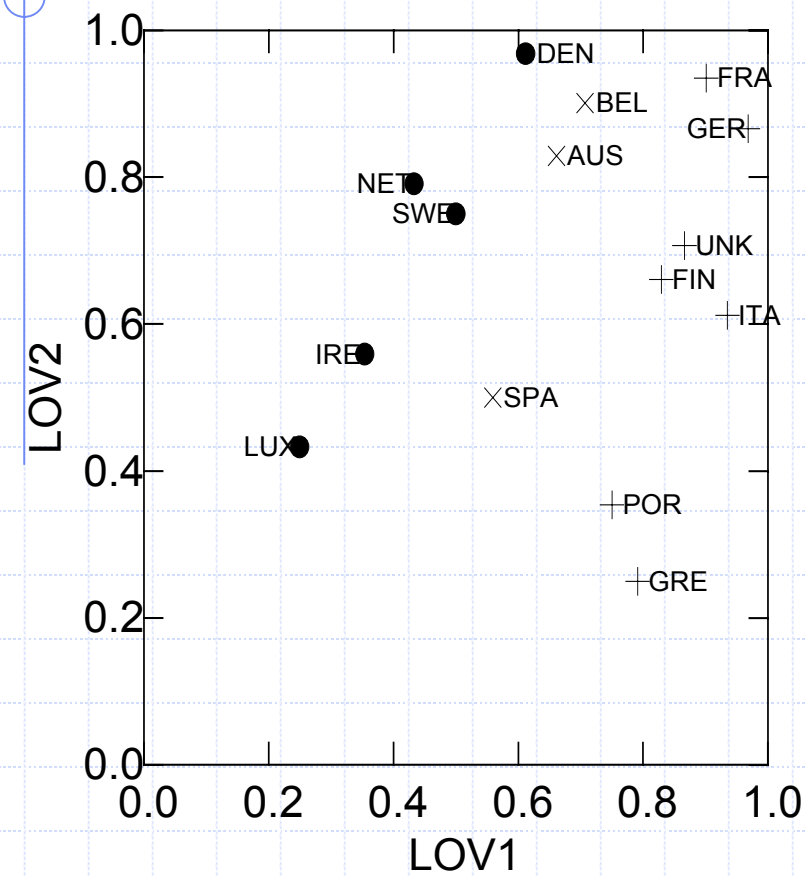
Interpretation of LOVs using ANOVA

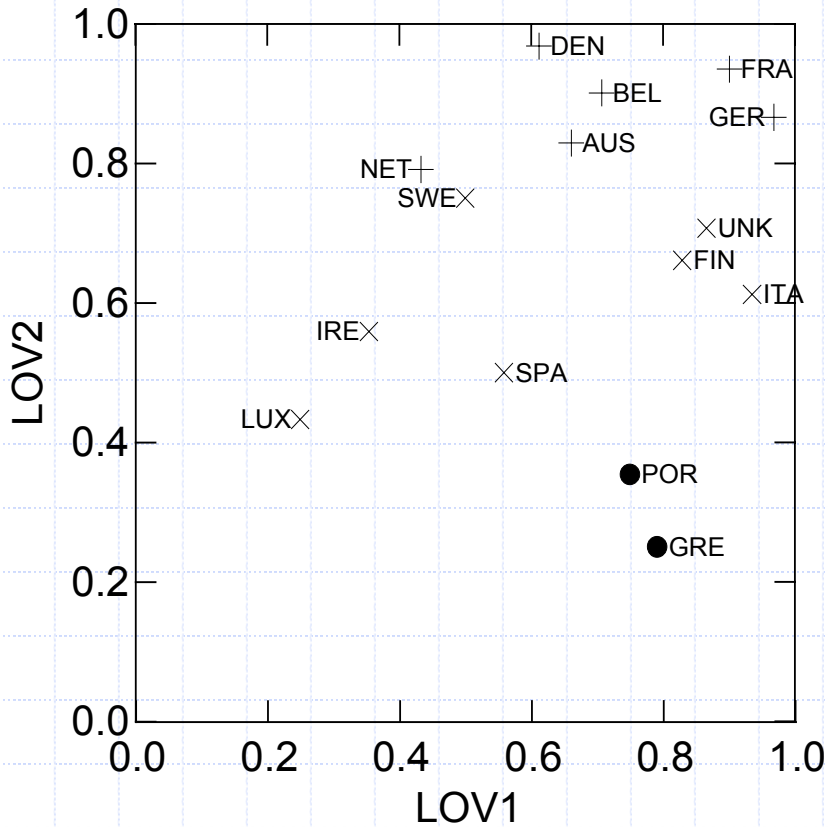
Attribute: Measurement stations in capital is described by LOV(1)

Attributes: Way of presentation on the Internet is described by LOV(2)



Scatter Plots of Variables ST and PR

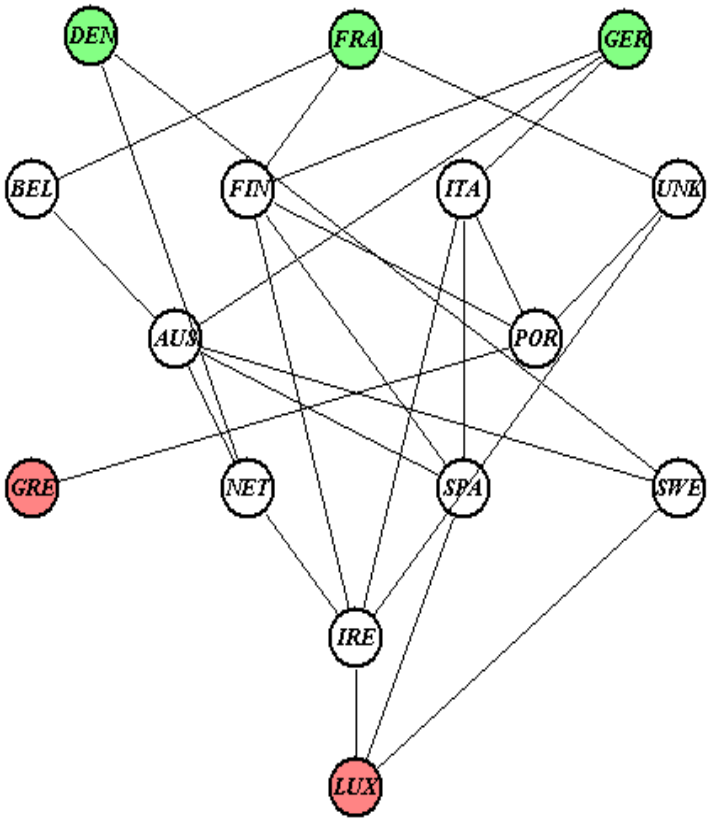




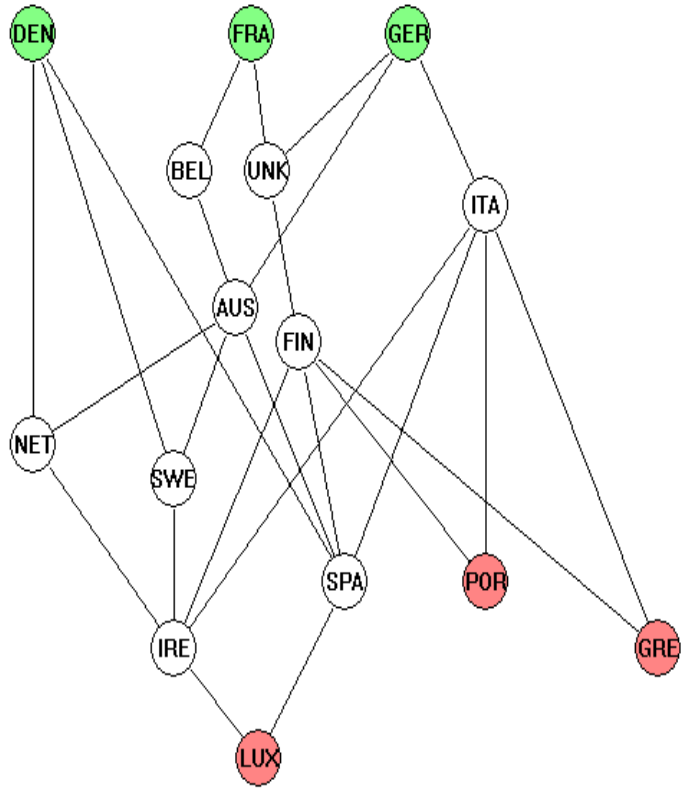
.=0, x=1, +=2

GSF – Forschungszentrum für Umwelt und Gesundheit

Comparison of Hasse Diagrams

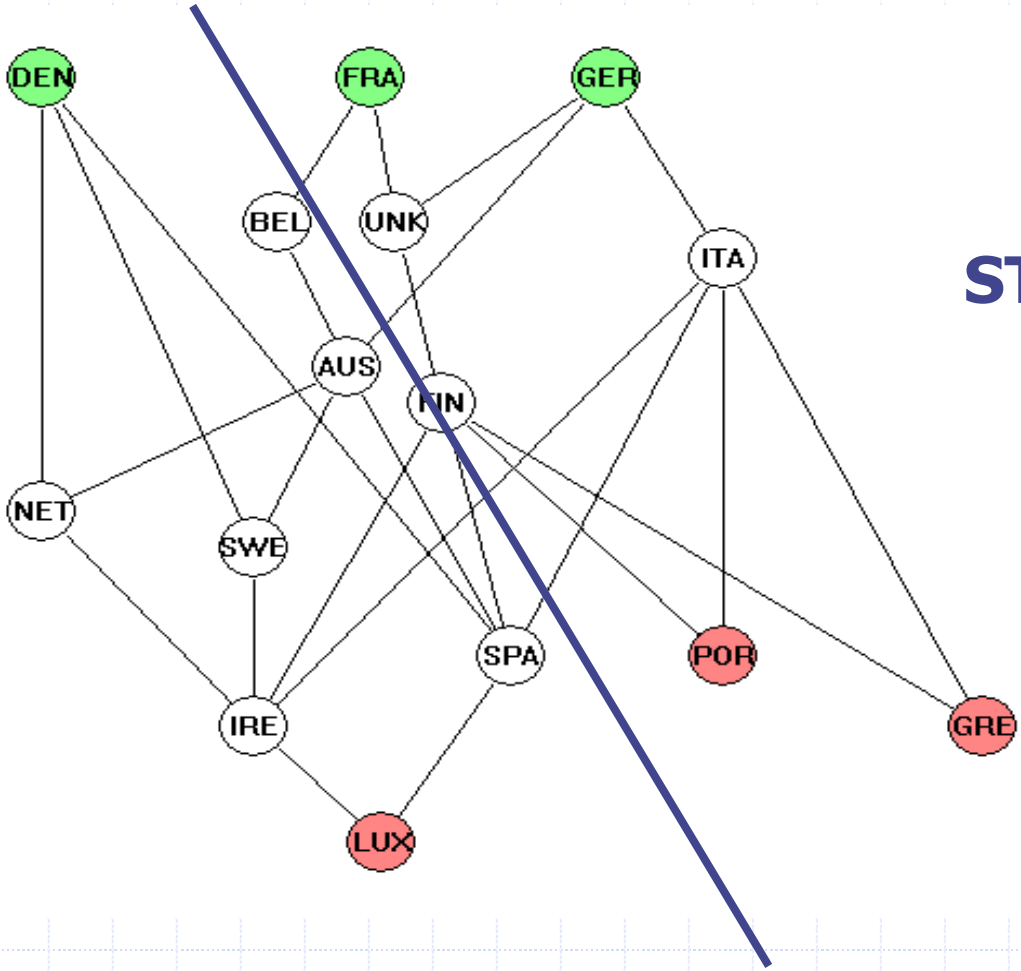


15x5



15x2

Hasse Diagram of the reduced Data-matrix 15 X 2



ST = 2

ST = 0,1

Interpretation POSAC/HASSE

- **Maximal objects: same, Minimal objects: plus {POR}**
- **More V, less U**
- Generation of HD from POSAC plot leads to clearer structures
- Better interpretation
- Two parts:
  - Right: ST = 2
  - Left: ST = 0,1
- Still further research necessary

POSAC - MPOSAC

- Maybe 2 dimensions insufficient
- higher dimensions proposed
- MPOSAC = Multidimensional POSAC
- Not available (yet) in Systat
- Available in HUDAP
- Instead: Subgroups according to the influences of PCA (Variable BM) are looked upon

Discussion of Results: Objects

- Germany, Denmark, France offer valuable data on air pollution monitoring (HDT, POSAC)
- Luxembourg, Greece show rather low information (HDT)

Discussion of Results: Objects

- POSAC analysis supports the results of the initial Hasse diagram technique approach
- initial data-matrix 15 x 5 can be reduced to 15 x 2 (latent order variables)
- Very few changes but improvement for interpretations (ST =2, ST = 0,1)

Discussion of Results: Attributes

- ST (measurement stations): highly correlated with LOV1: POSAC
- PR (way of presentation): highly correlated with LOV2: POSAC
- ST: highly correlated with Component 1: PCA
- BM: highly correlated with Component 2: PCA
- ST: W-Matrix (HDT)
- Importance of spatial aspect of air monitoring information systems

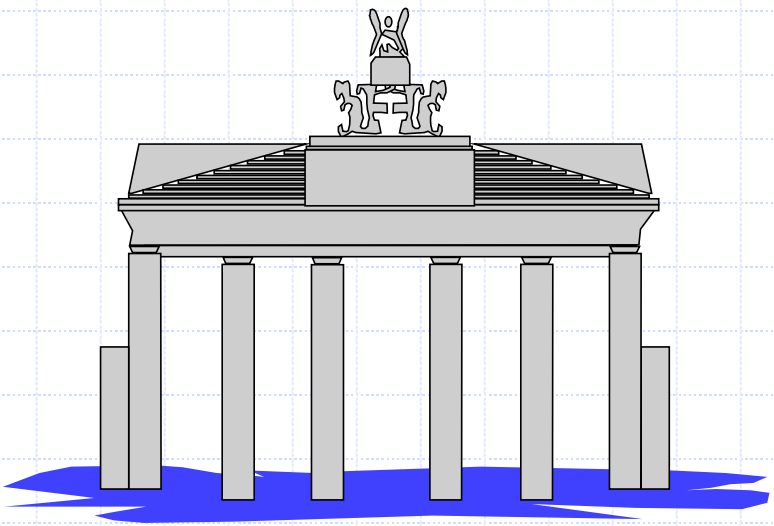
Outlook

- More and different Evaluation Criteria
- Combination of HDT with other MVS methods
- POSAC – MPOSAC
- 2 Dimensions – more Dimensions

Further Research

- Multivariate explorative statistical methods offfer simple and effective tools for graphical analysis of data-matrices
- Ranking using Hasse Diagram Technique
- Choice and Preference of Method(s) is problem-driven
- Combination of Methods is the Aim of future research

Collaboration between MVS und HDT



Rainer Brüggemann, Stefan Pudenz

IGB, Berlin, Criterion Berlin

Kristina Voigt, Gerhard Welzl

München, GSF-IBB

GSF – Forschungszentrum für Umwelt und Gesundheit

Data-Analysis of Environmental Air Pollutant Monitoring Systems in Europe

Dr. Kristina Voigt
GSF - National Research Center for Environment and Health
Institute for Biomathematics and Biometry
Ingolstaedter Landstrasse 1
85764 Neuherberg
Germany
Tel: ++49 (0)89/3187-4029
Fax: ++49(0)89/3187-3127
e-mail: **kvoigt@gsf.de**
URL: http://www.gsf.de/institute/ibb/voigt
http://www.wiz.uni-kassel.de/dain

GSF – Forschungszentrum für Umwelt und Gesundheit