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Σ joint 2011
Taipei Symposium

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7th Conference of the Asian Regional Section of the IASC

Exploring Symbolic Data Structure using Matrix Visualization

Yin-Jing Tien, Chun-houh Chen, Chiun-How Kao, Junji Nakano, Sheau-Hue Shieh, Chuan-kai Yang

Institute of Statistical Science, Academia Sinica

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Outline

- Matrix Visualization and related techniques
- Symbolic data Matrix Visualization
- Examples
- Summary

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Exploratory Data Analysis
EDA, John Tukey (1977)

1915~ 2000

It is important to understand what you **CAN DO** before you learn to measure how **WELL** you seem to have **DONE** it.

allow the **data to speak** for themselves before standard assumptions or formal modeling

Data

Graphics/visualization interface

Human Mind

The Iris Data

Sepal Length	Sepal Width	Petal Length	Petal Width
5.1	3.5	1.4	0.2
4.9	3.0	1.4	0.2
4.7	3.2	1.3	0.2
4.6	3.1	1.5	0.2
5.0	3.6	1.4	0.2
⋮	⋮	⋮	⋮

Scatterplot Matrices

Sepal.Length

Sepal.Width

Petal.Length

Petal.Width

Iris Virginica

Iris Versicolor

Iris Setosa

Pet É   Pet É   Sep É   Sep É

Species name

- I. Setosa
- I. Verginica
- I. Versicolor

Data

Series

30 60 90 120

Species name

I.S   I.V   I.V

Pet É   Pet É   Sep É   Sep É

max

min

var1 var2 var3 var4

Petal width

nscores
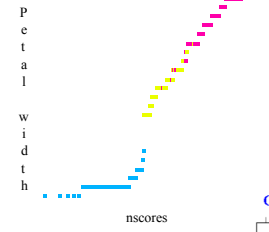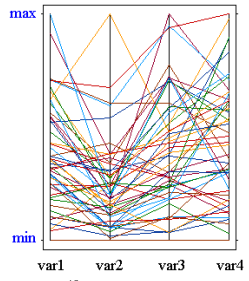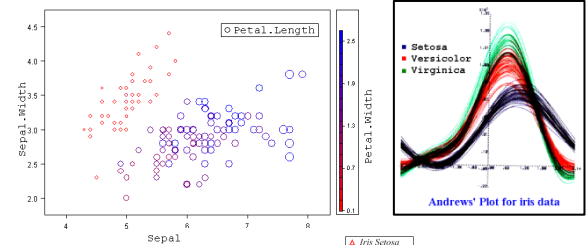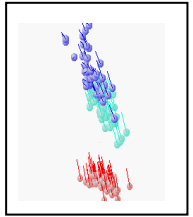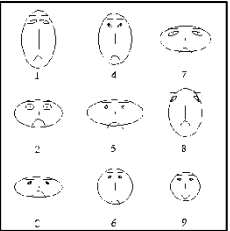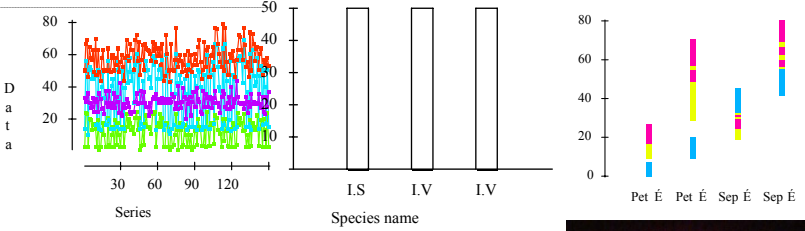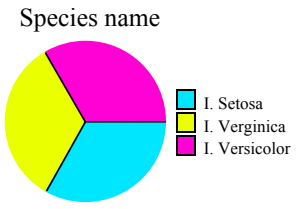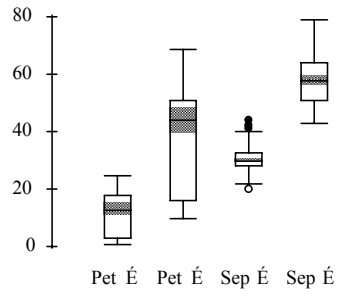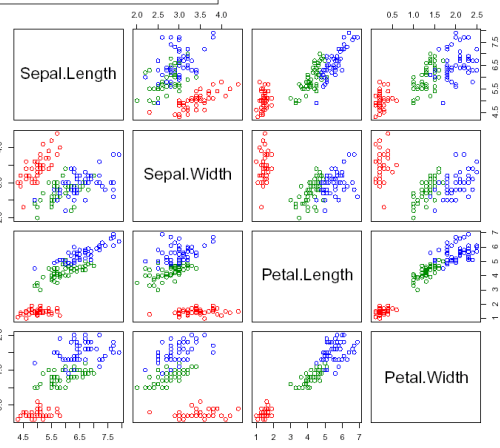
O. Bin origin at 120, bin widths of 20.

Percent of Total

Medical Program Quality Score
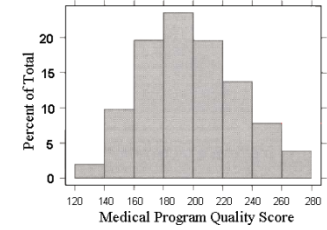
Star plot of Automobile Data

−Log₁₀ (p-value)

Log2(Fold Change)

O Petal.Length

Sepal Width

Sepal

Petal.Width

Setosa
Versicolor
Virginica

Andrews' Plot for iris data

△ *Iris Setosa*
· *Iris Versicolor*
+ *Iris Virginica*

Sepal.Width

Sepal.Length

Petal.Length

Sepal.Width

Sepal.Length

Rectangular   **Gaussian**

Triangular   **Epanechinkov**

Physics
Chemistry
Biology

Achievement Scores in three classes of eleven subjects.

Educ

Highways
WY

Health

Corrects
law_Enf

DE
ND
IA
MT
CT
NY
CA
MS
MO
MA
Welfare

NH

Biplot of 1992 State Policy Spending

Basic Scatterplot   Scatterplot with Loess Curve

Original basis   Basis of *M*
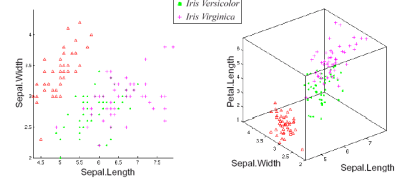
$$M = \log_2\left(\frac{Y}{X}\right)$$
$$A = \frac{1}{2}\log_2(XY)$$

Oligo	cDNA
$X = PM_1$,	$X = Cy3$
$Y = PM_2$	$Y = Cy5$
$X = PM_1 \cdot MM_1$,	
$Y = PM_2 \cdot MM_2$	

Y

X

M

A

linear
loess

linear
loess

Continuous GAP

Binary GAP
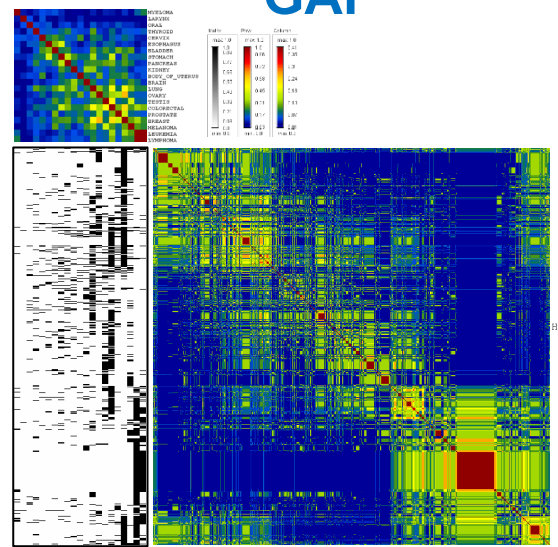
Categorical GAP
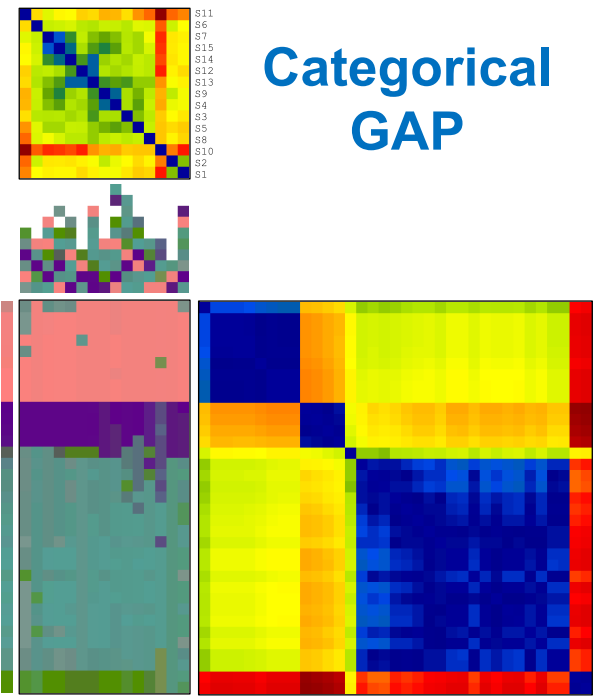
Cartography GAP
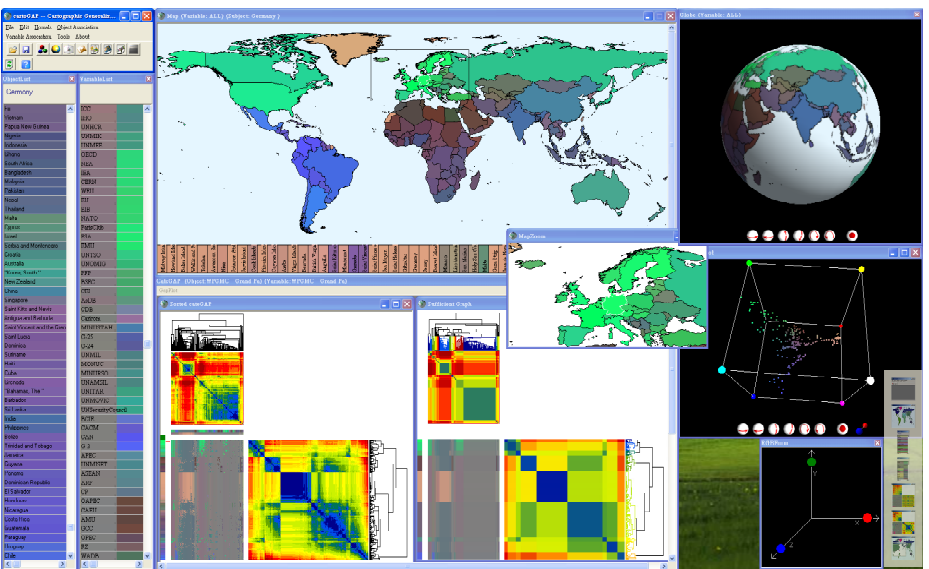
GAP with Covariate-Adjust

GAP for MANOVA

Data Matrix
Continuous
ordinal
Binary
nominal

1.presentation   4.sufficient

GAP

2.permutation   3.partition
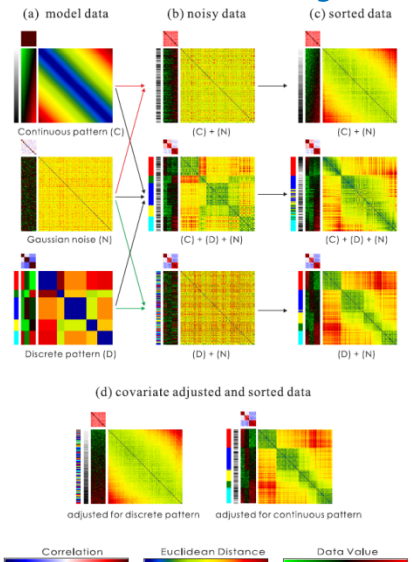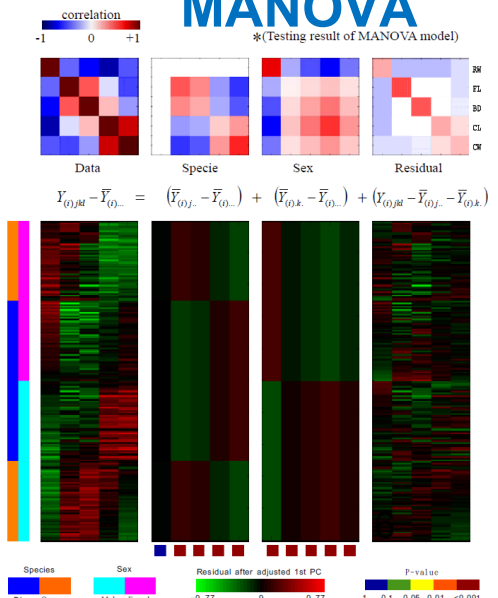
Some essential elements in a GAP MV procedure

3. Proximity (Variable *p* * *p*)
Continuous
Ordinal
Binary
Nominal

4. Permutation (variable)

1. Data Matrix (*n* * *p*)

(w/ Color coding)
Continuous
Ordinal
Binary
Nominal
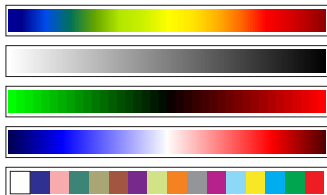
2. Proximity Matrix for Subject (*n* * *n*)

Continuous
Ordinal
Binary
Nominal

4. Permutation (subject)

BMC Bioinformatics
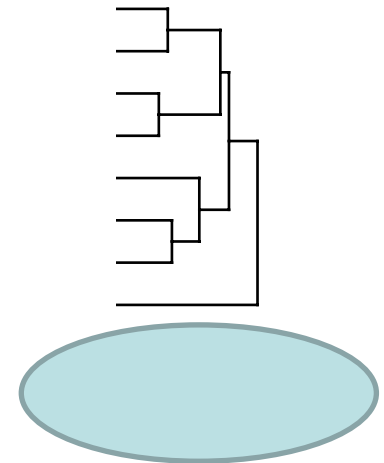
Methodology article

Methods for simultaneously identifying coherent local clusters with smooth global patterns in gene expression profiles

Yin-Jing Tien[1], Yun-Shien Lee[2,3], Han-Ming Wu[4] and Chun-Houh Chen*[5]
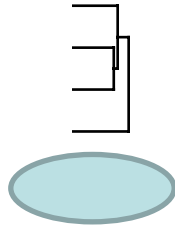
Address: [1]Institute of Statistics, National Central University, Tao-Yuan, 32001, Taiwan, [2]Genomic Medicine Research Core Laboratory, Chang Gung Memorial Hospital (CGMH), Tao-Yuan, 33305, Taiwan, [3]Department of Biotechnology, Ming Chuan University, Tao-Yuan, 33348, Taiwan, [4]Department of Mathematics, Tamkang University, Tamsui 25137, Taiwan and [5]Institute of Statistical Science, Academia Sinica, Taipei, 11529, Taiwan

Local + Global = Local/Global

HCT   R2E   HCT$_{R2E}$
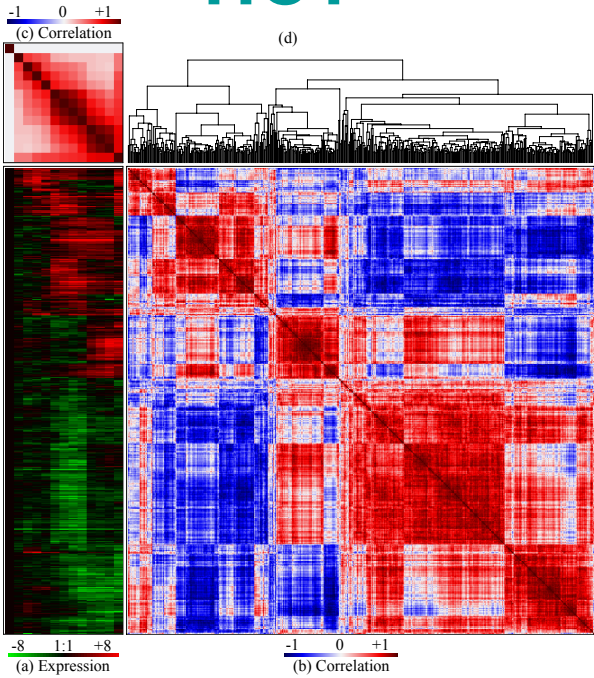
Hierarchical Tree Seriation   GAP Elliptical (R2E) Seriation   Tree guided by (R2E)
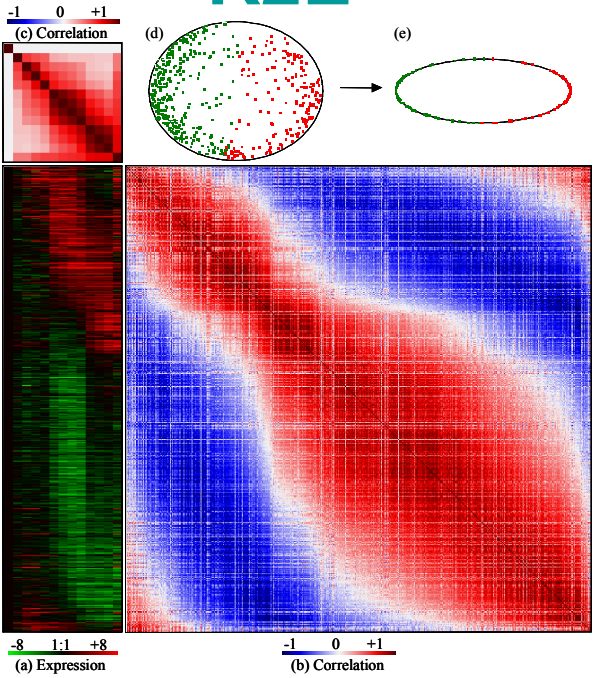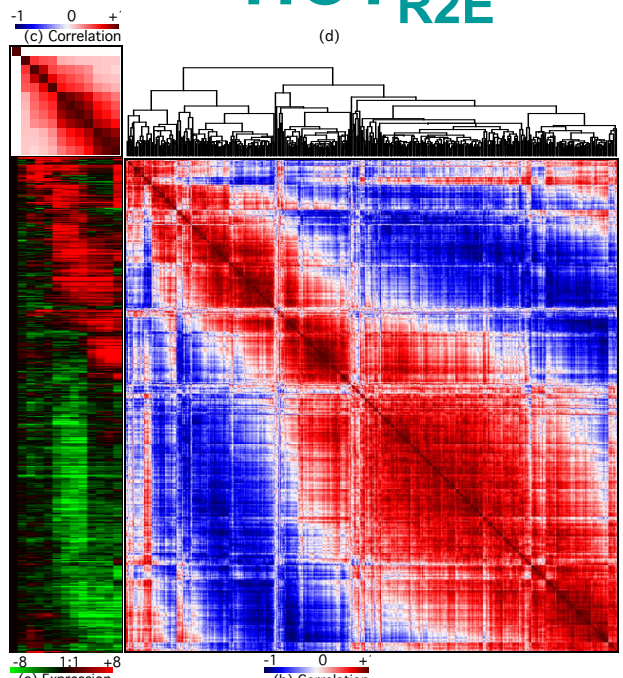
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Symbolic data

- Classical Data : Individuals: single value

  Single player

  age = 25, eye color = blue

- Symbolic Data : Symbolic units (groups/classes)

  Team

  interval : age range = [20, 36]

  multiple values: eye color = {blue,brown,black}

(Billard and Diday (2006))

Symbolic data analysis
When?

- When we are interested the higher level units (groups/classes).

- When the initial data are composed by Symbolic data tables

Symbolic data types

$$\text{Symbolic data} \begin{cases} \text{quantitative} \begin{cases} \text{multi} - \text{valued} \begin{cases} \text{continuous} \\ \text{ordinal} \end{cases} \\ \text{modal multi} - \text{valued} \\ \text{interval} - \text{valued} \\ \text{modal interval} - \text{valued(histogram)} \end{cases} \\ \text{qualitative} \begin{cases} \text{multi} - \text{valued} \\ \text{modal multi} - \text{valued} \end{cases} \\ \text{Mixed} - \text{valued data} \end{cases}$$
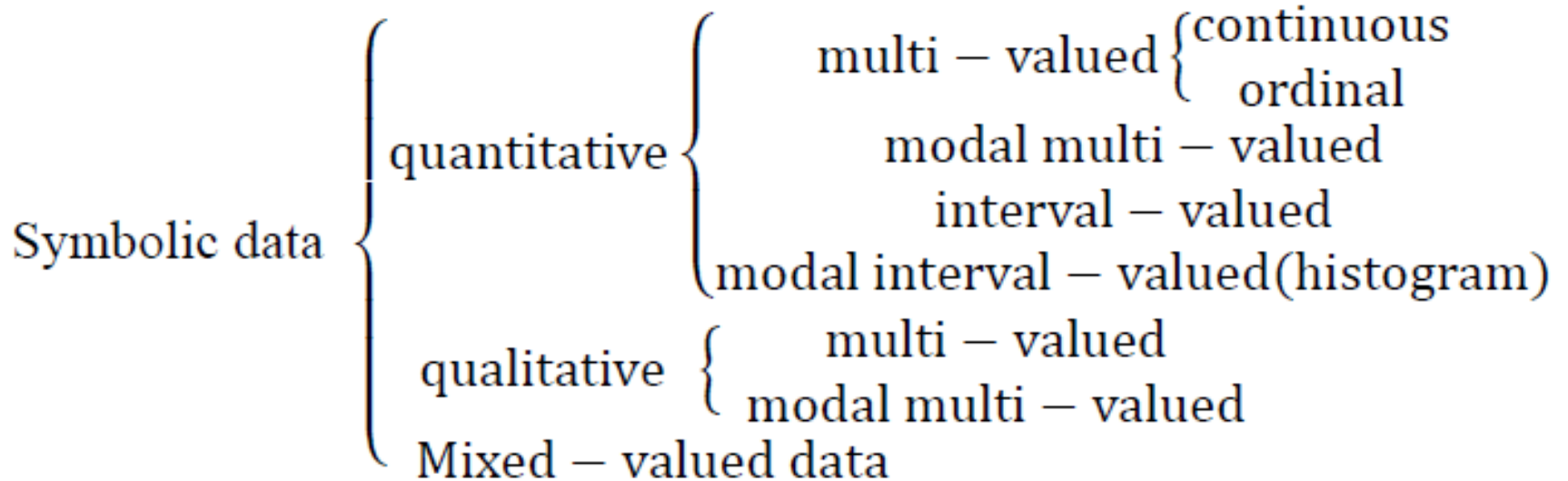
Symbolic data types

Multi-valued symbolic random variable Y is one or more values

{12,23,20}

Interval-valued symbolic random variable Y is one that takes values in an interval

[17, 25]

Modal multi-valued

{single, 3/8, married, 5/8}

$$Y(u) = \{\eta_k, \pi_k ; k = 1,2,...,s_u\}$$

Modal interval-valued (Histogram)

{[12,40), 1/7, [40, 60), 2/7, [60, 80], 4/7}

$$Y(u) = \{[a_{uk}, b_{uk}), p_{uk} ; k = 1,2,...,s_u\}$$
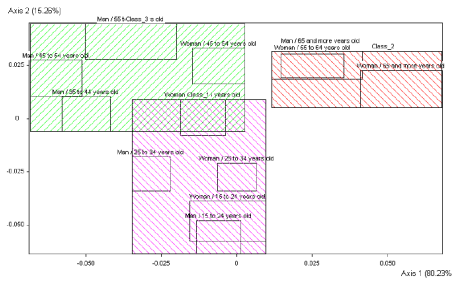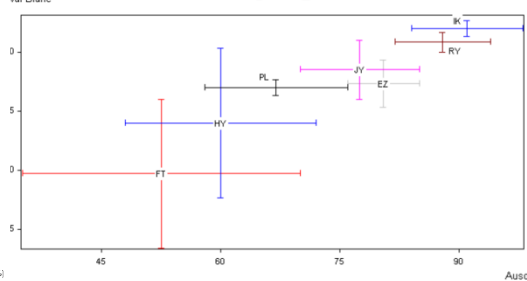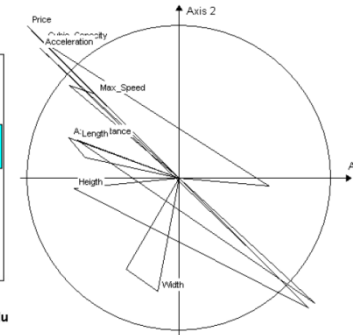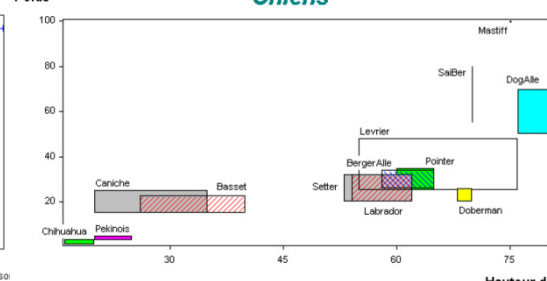
Figure 4: Graphical output of SFDA

SYR software with the TABSYR & STATSYR modules

Figure 23.5   Pyramidal representation of symbolic objects.
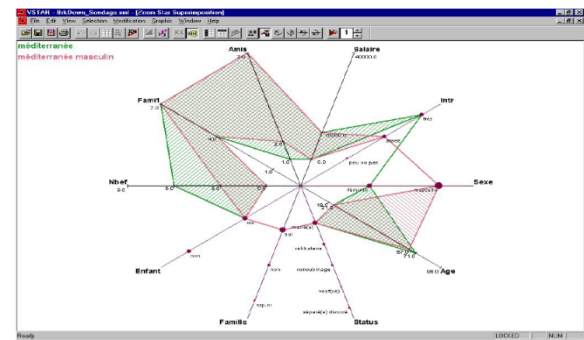
Figure 56: Breakdown - Superimposition of the new and the old objects
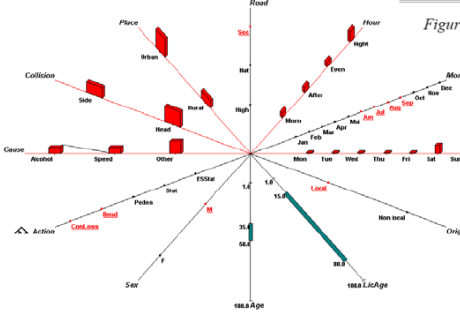
Figure 51: Example of 3D Zoom Star
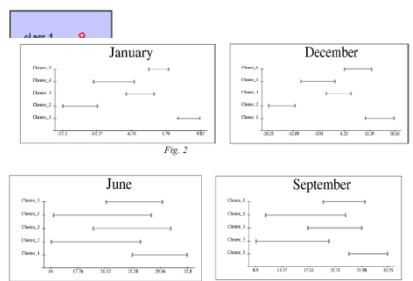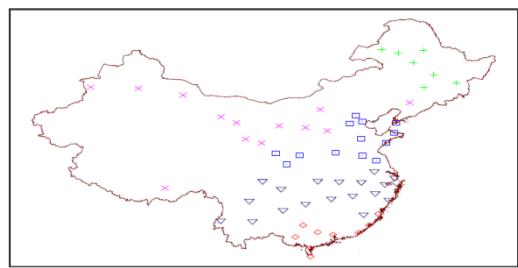
Fig. 1: Visualization on the Map of the China of the 5 Classes of the partition of the 60 meteorological stations
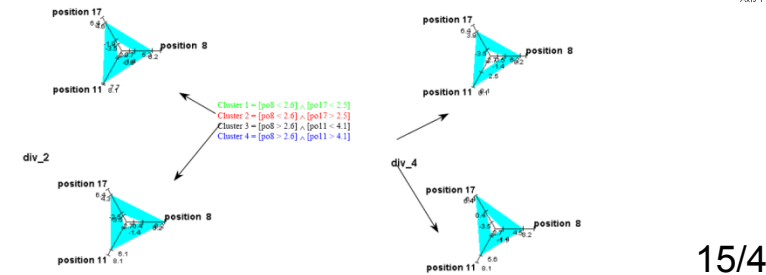
FIG9. Stars of the symbolic interpretation of each cluster

Essential elements in a GAP MV procedure?

Classical

Symbolic

3. Variable Proximity

Correlation
Covariance
polychoric
Correlation . . .

3. Variable Proximity

?

2. Subject Proximity

Euclidean Distance
Manhattan Distance
Correlation …

1. Data Matrix

1. Data Matrix

?
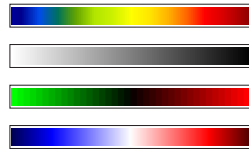
2. Subject Proximity

?

1. Computation of proximity matrix for variables

Notations :

ω_u : The symbolic units (observations), $u = 1, 2, \cdots, m$.

$d_u = (\xi_{u1}, \xi_{u2}, \cdots, \xi_{up})$: The symbolic description of an observation $\omega_u \in E$, $u = 1, 2, \cdots, m$.

Consider two variables there are some association measures for different symbolic data type (Billard, and Diday 2006)

Multi-valued data :
For quantitative multi-valued variables Z_1 and Z_2, the **empirical covariance function** $Cov(Z_1, Z_2)$ is given by

$$Cov(Z_1, Z_2) = \frac{1}{m}\left[\sum_{\xi_1 \in Z_1} \sum_{\xi_2 \in Z_2}(\xi_1 \times \xi_2)\ O_{Z_1 Z_2}(\xi_1, \xi_2)\right] - \bar{Z}_1 \bar{Z}_2$$

Interval data :
For interval-valued variables Z_1 and Z_2, the **empirical covariance function** $Cov(Z_1, Z_2)$ is given by

$$Cov(Z_1, Z_2) = \frac{1}{3m}\sum_{u \in E} G_1 G_2 [Q_1 Q_2]^{1/2}$$

Where, for $j = 1, 2$, $Q_j = (a_{uj} - \bar{Z}_j)^2 + (a_{uj} - \bar{Z}_j)(b_{uj} - \bar{Z}_j) + (b_{uj} - \bar{Z}_j)^2$, $G_j = \begin{cases} 1, & \text{if } \bar{Z}_{uj} \leq \bar{Z}_j \\ -1, & \text{if } \bar{Z}_{uj} > \bar{Z}_j \end{cases}$

Correlation coefficient $\quad r(Z_1, Z_2) = Cov(Z_1, Z_2)/S_{Z_1} S_{Z_2}$

Where $\bar{Z}_{uj} = (b_{uj} + a_{uj})/2$, $\bar{Z}_j = \frac{1}{2m}\sum_{u \in E}(b_{uj} + a_{uj})$, $S_{Z_j} = \frac{1}{3m}\sum_{u \in E}(b_{uj}^2 + b_{uj}a_{uj} + a_{uj}^2) - \frac{1}{4m^2}\left[\sum_{u \in E}(b_{uj} + a_{uj})\right]^2$

Histogram data :
For modal interval-valued (i.e., histogram-valued) variables Z_1 and Z_2, the **empirical covariance function** is given by

$$Cov(Z_1, Z_2) = \frac{1}{3m}\sum_{u \in E}\sum_{k_1=1}^{S_{u1}}\sum_{k_2=1}^{S_{u2}} p_{u1k_1} p_{u2k_2} G_1 G_2 [Q_1 Q_2]^{1/2}$$

Where, for $j = 1, 2$, $Q_j = (a_{ujk_j} - \bar{Z}_j)^2 + (a_{ujk_j} - \bar{Z}_j)(b_{ujk_j} - \bar{Z}_j) + (b_{ujk_j} - \bar{Z}_j)^2$, $G_j = \begin{cases} 1, & \text{if } \bar{Z}_{uj} \leq \bar{Z}_j \\ -1, & \text{if } \bar{Z}_{uj} > \bar{Z}_j \end{cases}$

Correlation coefficient $\quad r(Z_1, Z_2) = Cov(Z_1, Z_2)/S_{Z_1} S_{Z_2}$

Where

$\bar{Z}_{uj} = \frac{1}{2}\sum_{k_j=1}^{S_{uj}} p_{ujk_j}(b_{uj} + a_{uj})$, $\bar{Z}_j = \frac{1}{2m}\sum_{u \in E}\left[\sum_{k_j=1}^{S_{uj}}(b_{ujk_j} + a_{ujk_j})p_{ujk_j}\right]$, $S_{Z_j} = \frac{1}{3m}\sum_{u \in E}\sum_{k_j=1}^{S_{uj}}(b_{ujk_j}^2 + b_{ujk_j}a_{ujk_j} + a_{ujk_j}^2)p_{ujk_j} - \frac{1}{4m^2}\left[\sum_{u \in E}\sum_{k_j=1}^{S_{uj}}(b_{ujk_j} + a_{ujk_j})\ p_{ujk_j}\right]^2$

2. Computation of proximity matrix for symbolic units

Consider two symbolic units there are some proximity measures (Diday and Noirhomme 2008).

Dissimilarity measures for Boolean symbolic descriptions
Gowda and Diday's dissimilarity measure (1991)

Ichino and Yaguchi's first formulation of a dissimilarity measure (1994)
Ichino and Yaguchi's normalized dissimilarity measure (1994)
Ichino and Yaguchi's normalized and weighted dissimilarity measure (1994)

de Carvalho's normalized dissimilarity measure for constrained Boolean descriptions (1998)
de Carvalho's dissimilarity measure (1994)
de Carvalho's extension of Ichino and Yaguchi's dissimilarity (1994)
de Carvalho's first dissimilarity measure based on description potential (1998)
de Carvalho's second dissimilarity measure based on description potential (1998)
de Carvalho's normalized dissimilarity measure based on description potential (1998)

The Hausdorff distance, The L_1 distance, The L_2 distance.

Dissimilarity measures for probabilistic symbolic descriptions
The *Kullback–Leibler* (KL) *divergence*, The χ^2 *divergence*, The Hellinger coefficient, *Renyi's divergence*, The *variation distance*, The *Kullback divergence*
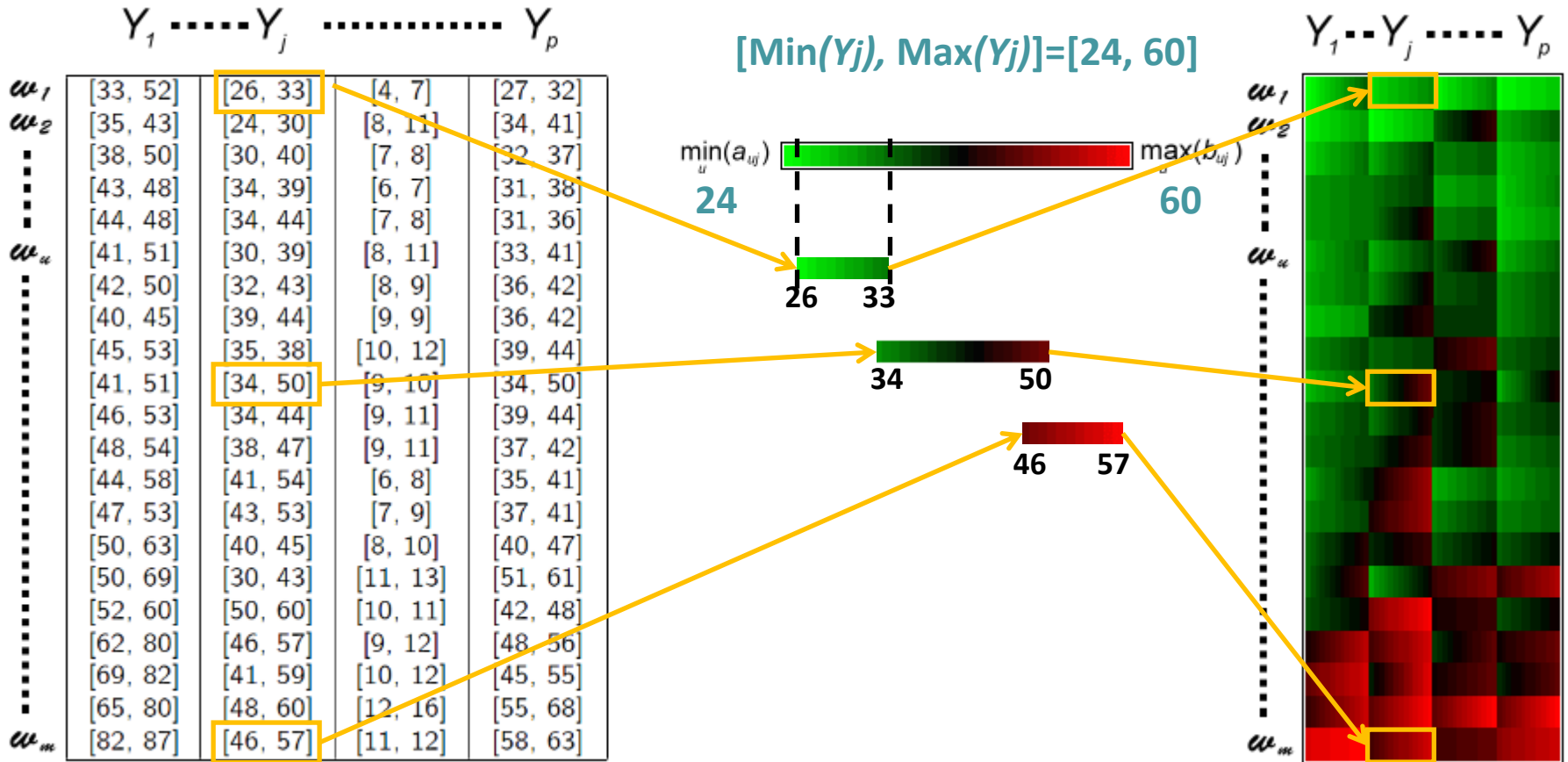
Interval data

Continuous multi-valued
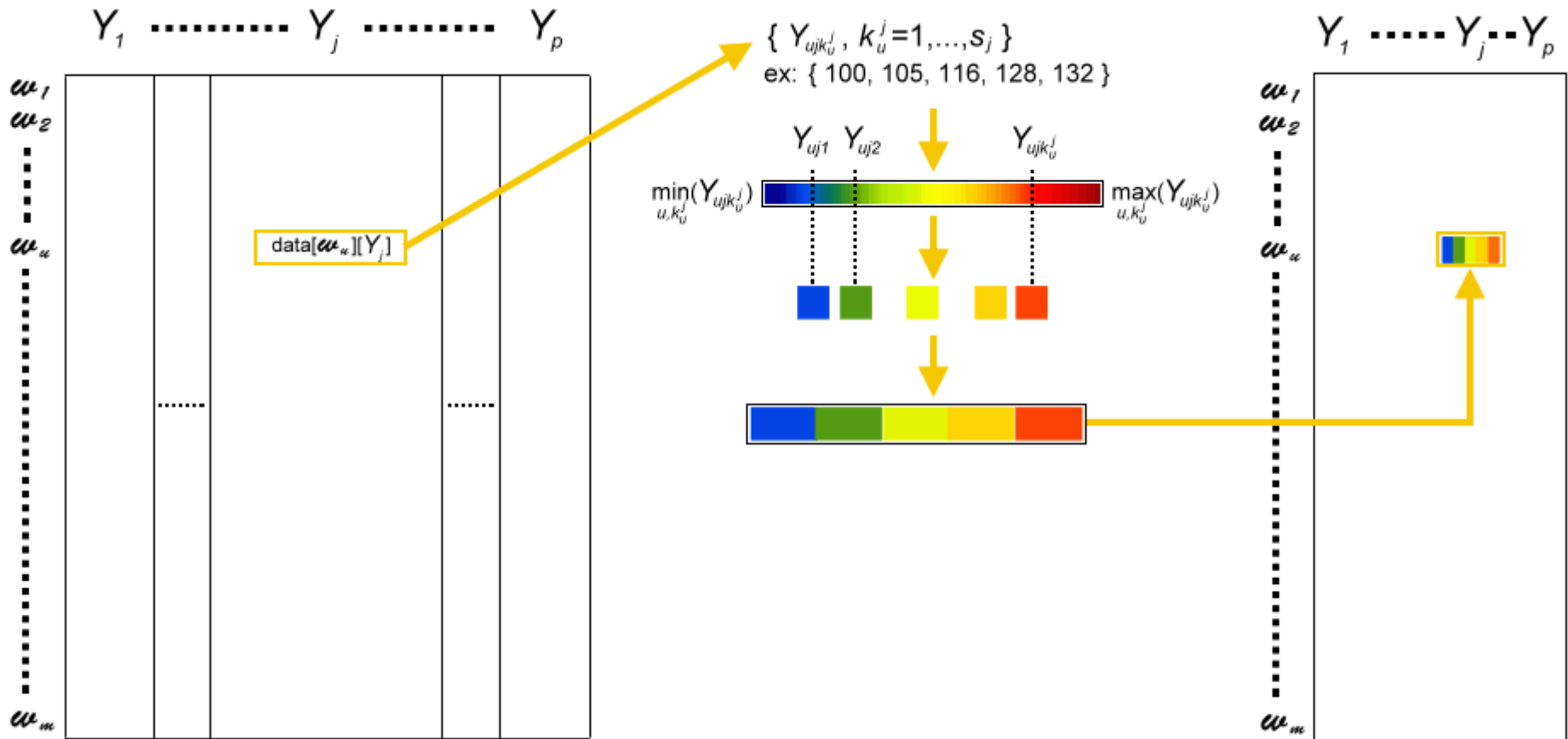
Y_1 .... Y_j .... Y_p

w_1
w_2
⋮
w_u
⋮
w_m

data[w_u][Y_j]

$\{ Y_{ujk_u^j}, k_u^j = 1,\dots,s_j \}$
ex: { 100, 105, 116, 128, 132 }

Y_{uj1} Y_{uj2} $Y_{ujk_u^j}$

$\min\limits_{u,k_u^j}(Y_{ujk_u^j})$ $\max\limits_{u,k_u^j}(Y_{ujk_u^j})$

Y_1 ...... Y_j -- Y_p

w_1
w_2
⋮
w_u
⋮
w_m

Ordinal multi-valued
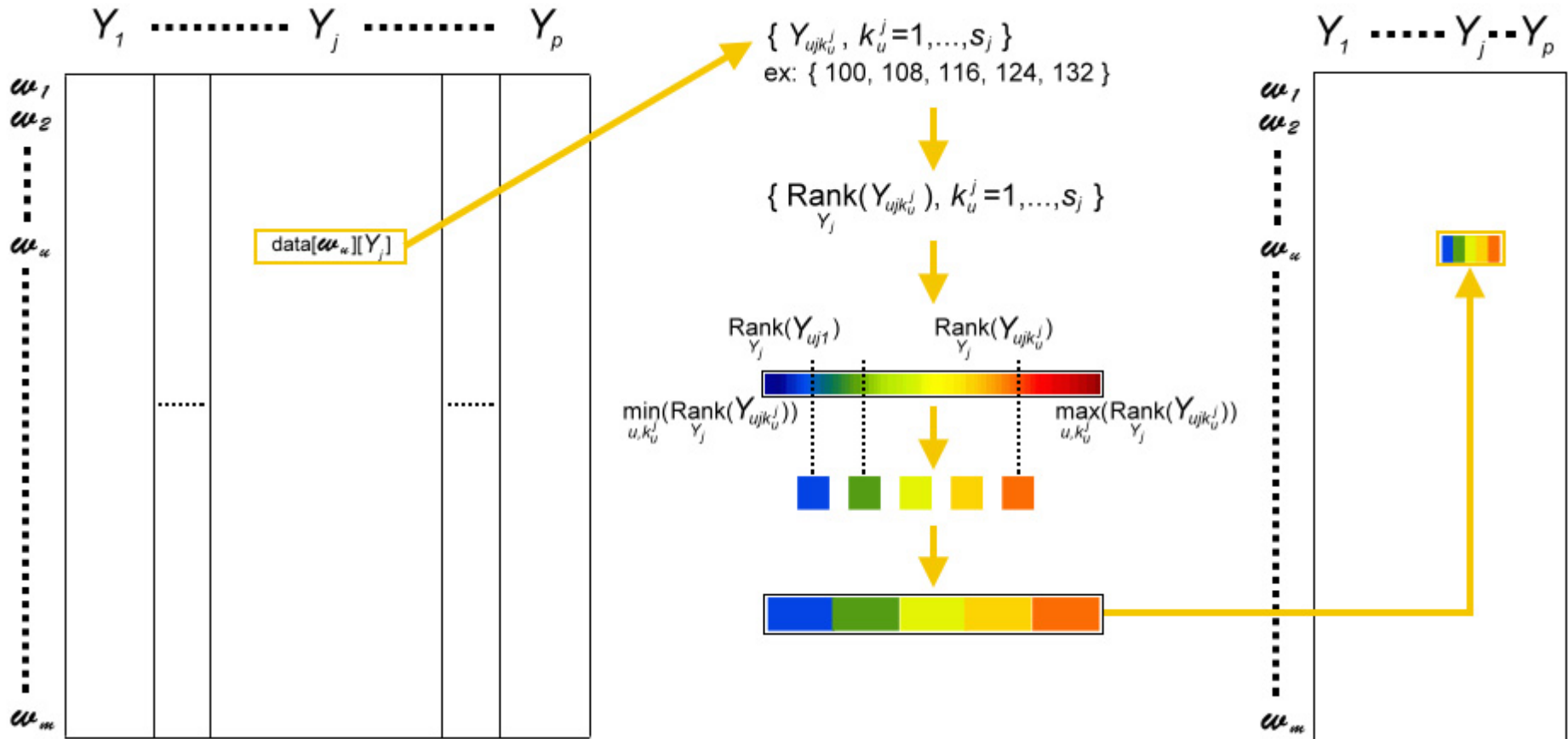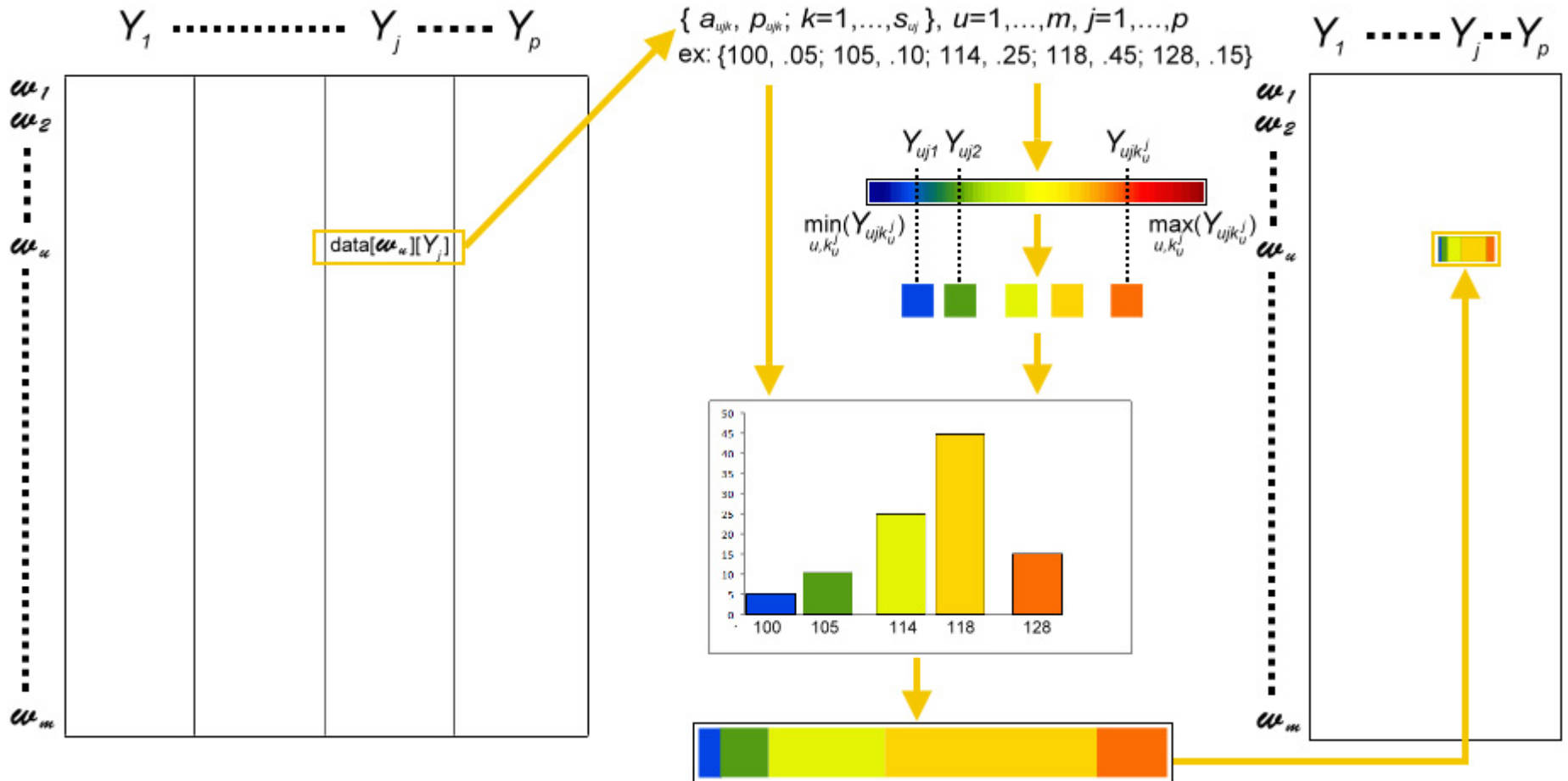
$\{ Y_{ujk_u^j}, k_u^j = 1, \ldots, s_j \}$

ex: $\{ 100, 108, 116, 124, 132 \}$

$\{ \underset{Y_j}{\mathrm{Rank}}(Y_{ujk_u^j}), k_u^j = 1, \ldots, s_j \}$

$\underset{Y_j}{\mathrm{Rank}}(Y_{uj1}) \qquad \underset{Y_j}{\mathrm{Rank}}(Y_{ujk_u^j})$

$\underset{u,k_u^j}{\min}(\underset{Y_j}{\mathrm{Rank}}(Y_{ujk_u^j})) \qquad \underset{u,k_u^j}{\max}(\underset{Y_j}{\mathrm{Rank}}(Y_{ujk_u^j}))$

Modal multi-valued

Modal interval-valued (histogram)

$\{[a_{ujk}, b_{ujk}), p_{ujk}; k=1,\ldots,s_{uj}\}, u=1,\ldots,m, j=1,\ldots,p$

ex: $\{[100,108), .05; [111,115), .10; [120,130), .25;$
$[132,138), .45; [142,154), .15\}$
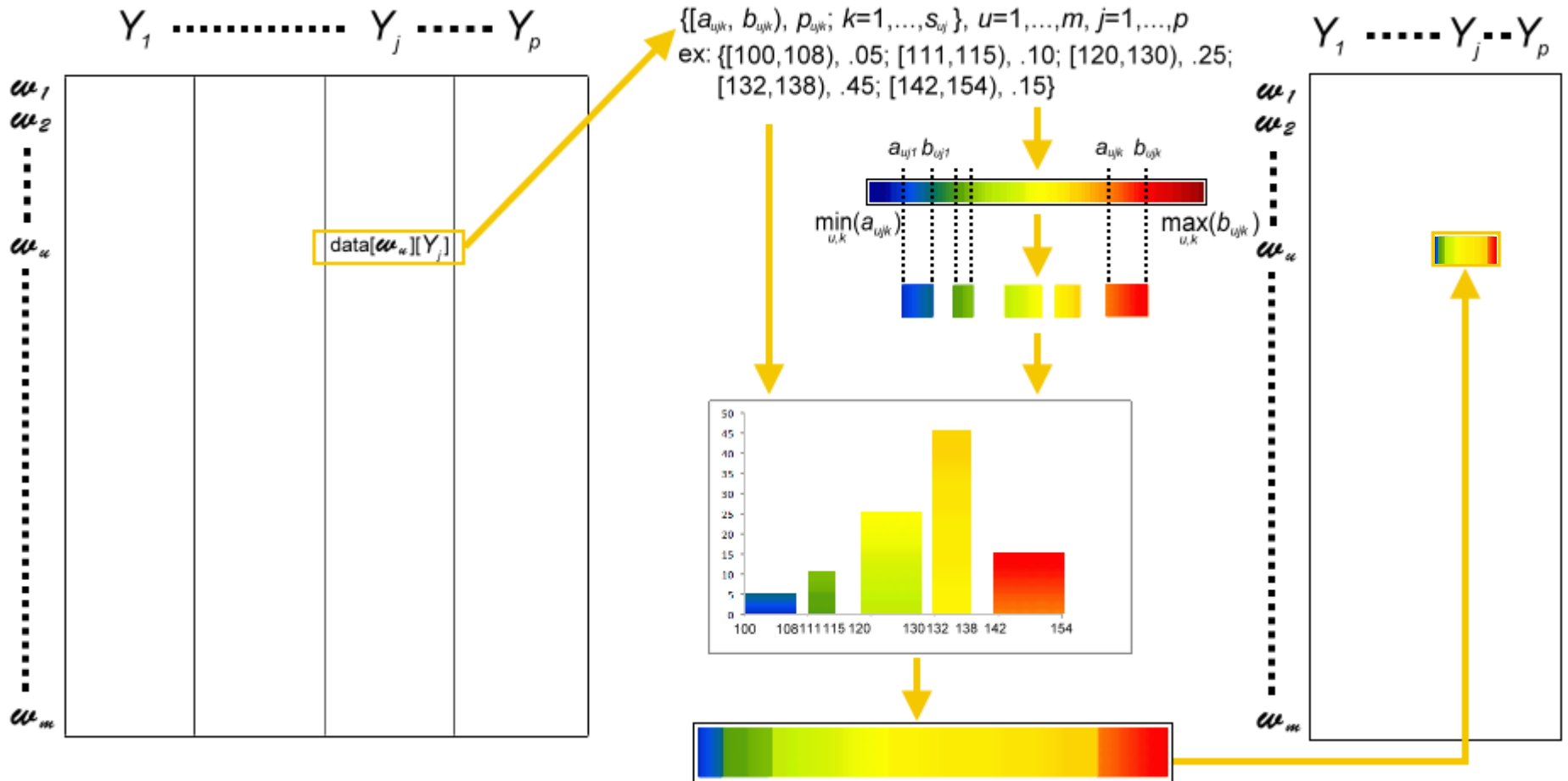
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Interval

Bats data:
(21 Species, 4 variables)

Empirical Correlation

Species	Head	Tail	Height	Forearm
PIPC	[33,52]	[26,33]	[4,7]	[27,32]
PRH	[35,43]	[24,30]	[8,11]	[34,41]
MOUS	[38,50]	[30,40]	[7,8]	[32,37]
PIPS	[43,48]	[34,39]	[6,7]	[31,38]
PIPN	[44,48]	[34,44]	[7,8]	[31,36]
MDAUB	[41,51]	[30,39]	[8,11]	[33,41]
MNAT	[42,50]	[32,43]	[8,9]	[36,42]
MDEC	[40,45]	[39,44]	[9,9]	[36,42]
MGP	[45,53]	[35,38]	[10,12]	[39,44]
OCOM	[41,51]	[34,50]	[9,10]	[34,50]
MBEC	[46,53]	[34,44]	[9,11]	[39,44]
SBOR	[48,54]	[38,47]	[9,11]	[37,42]
BARB	[44,58]	[41,54]	[6,8]	[35,41]
OGRIS	[47,53]	[43,53]	[7,9]	[37,41]
SBIC	[50,63]	[40,45]	[8,10]	[40,47]
FCHEV	[50,69]	[30,43]	[11,13]	[51,61]
MSCH	[52,60]	[50,60]	[10,11]	[42,48]
SCOM	[62,80]	[46,57]	[9,12]	[48,56]
NOCT	[69,82]	[41,59]	[10,12]	[45,55]
GMUR	[65,80]	[48,60]	[12,16]	[55,68]
MGES	[82,87]	[46,57]	[11,12]	[58,63]

Head
Tail
Height
Forearm

PIPC
PRH
MOUS
PIPS
PIPN
MDAUB
MNAT
MDEC
MGP
OCOM
MBEC
SBOR
BARB
OGRIS
SBIC
FCHEV
MSCH
SCOM
NOCT
GMUR
MGES

Euclidean Housdorff
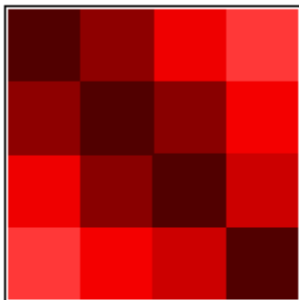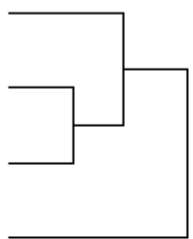
SymbolicGAP
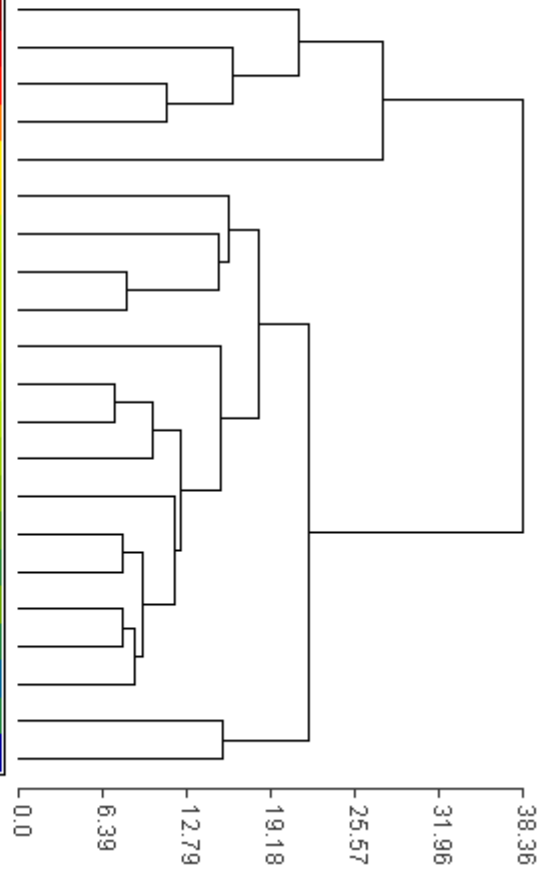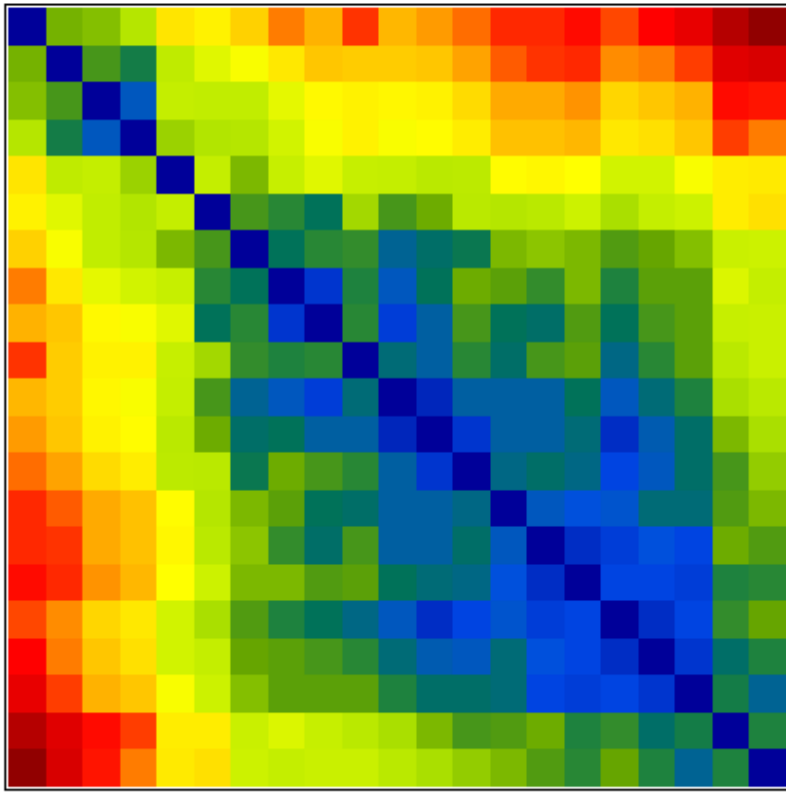
2 real examples of MV for SDA:

A.民力**2010 Database (interval)**
(with Junji Nakano, ISM)
(DVD national manpower-ROM"published by the Asahi Shimbun)
A collection of regional data.

B. Cross Cultural Comparison of Rural Education Practice in China, Taiwan, and the US (modal multi-valued)

Example: 民力 2010 Database (Collabor. with Junji Nakano, ISM)

民力　マーケティング必携の地域データベース

トップページ　ヘルプ　お問い合わせ
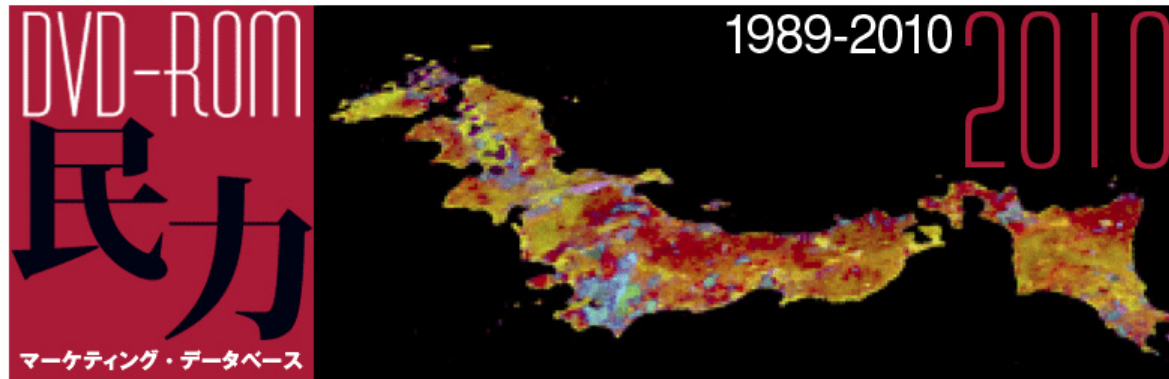
調べる　エリア・都市圏・市区町村別 | 都道府県別 | 都道府県別民力指数　解説を読む

エリア・都市圏・市区町村別に調べる

Step.1 ブロックを選択

見たいエリアが含まれるブロック名を地図上（文字の上）でクリックするか、右側のブロック名一覧の該当ボタンをクリックしてください。

エリア選択

- 北海道
- 東北
- 関東
- 甲信越・北陸・東海
- 近畿
- 中国・四国
- 九州・沖縄
- 東京狭域エリア
- 名古屋狭域エリア
- 大阪狭域エリア

前のページへ戻る

千代田都市圏	千代田区
中央都市圏	中央区
港都市圏	港区
新宿都市圏	新宿区
文京都市圏	文京区
台東都市圏	台東区
渋谷都市圏	渋谷区
豊島都市圏	豊島区

都心拠点地域

東京狭域エリア

Hierarchy for Regions of 民力 Data

Level 1	Level 2	Level 3	Level 4	Level 0
Major Region (10)	Region (151)	Major Area (821)	Area (1962)	都道府縣 (45)
東京狭域エリア	立川地域	あきる野都市圏	あきる野市	東京都
東京狭域エリア	立川地域	あきる野都市圏	日の出町	東京都
東京狭域エリア	立川地域	あきる野都市圏	檜原村	東京都
東京狭域エリア	立川地域	立川都市圏	立川市	東京都
東京狭域エリア	立川地域	羽村都市圏	羽村市	東京都
東京狭域エリア	立川地域	羽村都市圏	瑞穂町	東京都
東京狭域エリア	立川地域	国分寺都市圏	国分寺市	東京都
東京狭域エリア	立川地域	国立都市圏	国立市	東京都
東京狭域エリア	立川地域	東大和都市圏	東大和市	東京都
東京狭域エリア	立川地域	武蔵村山都市圏	武蔵村山市	東京都
東京狭域エリア	立川地域	青梅都市圏	青梅市	東京都
東京狭域エリア	立川地域	青梅都市圏	奥多摩町	東京都
東京狭域エリア	立川地域	青梅都市圏	小菅村	山梨縣
東京狭域エリア	立川地域	青梅都市圏	丹波山村	山梨縣
東京狭域エリア	立川地域	昭島都市圏	昭島市	東京都
東京狭域エリア	立川地域	福生都市圏	福生市	東京都
東京狭域エリア	都心拠点地域	千代田都市圏	千代田區	東京都
東京狭域エリア	都心拠点地域	中央都市圏	中央區	東京都
東京狭域エリア	都心拠点地域	中央都市圏	中央市	山梨縣
東京狭域エリア	都心拠点地域	中央都市圏	市川三郷町	山梨縣
東京狭域エリア	都心拠点地域	中央都市圏	身延町	山梨縣
東京狭域エリア	都心拠点地域	文京都市圏	文京區	東京都
東京狭域エリア	都心拠点地域	台東都市圏	台東區	東京都
東京狭域エリア	都心拠点地域	渋谷都市圏	渋谷區	東京都
東京狭域エリア	都心拠点地域	港都市圏	港區	東京都
東京狭域エリア	都心拠点地域	新宿都市圏	新宿區	東京都
東京狭域エリア	都心拠点地域	豊島都市圏	豊島區	東京都
近畿	熊野灘エリア	尾鷲都市圏	紀北町	三重縣
近畿	熊野灘エリア	尾鷲都市圏	尾鷲市	三重縣
近畿	熊野灘エリア	熊野都市圏	熊野市	三重縣
近畿	熊野灘エリア	熊野都市圏	北山村	和歌山縣
近畿	熊野灘エリア	熊野都市圏	御浜町	三重縣
近畿	熊野灘エリア	新宮都市圏	紀宝町	三重縣
近畿	熊野灘エリア	新宮都市圏	新宮市	和歌山縣
近畿	熊野灘エリア	新宮都市圏	那智勝浦町	和歌山縣
近畿	熊野灘エリア	新宮都市圏	太地町	和歌山縣
近畿	熊野灘エリア	新宮都市圏	古座川町	和歌山縣
近畿	熊野灘エリア	新宮都市圏	串本町	和歌山縣

Population_Basic_Resident_Registers
Household Basic Resident Registers
Population moved in
Population moved out
Population by year 0-4
Population by year 5-9
Population by year 10-14
Population by year 15-19
Population by year 20-24
Population by year 25-29
Population by year 30-34
Population by year 35-39
Population by year 40-44
Population by year 45-49
Population by year 50-54
Population by year 55-59
Population by year 60-64
Population by year > 65
Municipal workers
New construction housing stock
Total number of establishments
Total number of employees, business
Number of private establishments
The number of employees at private businesses
Number of establishments Services
Number of private establishments Services
Total Number of Retail Stores
Annual Sales Stores
Annual Sales Retail Stores
Number of restaurants
Annual Shipments of industrial products
Agricultural output value
Taxable income
Local tax revenues
Total expenditures

Number of private establishments Services
Total Number of Retail Stores
Annual Sales Stores
Annual Sales Retail Stores
Number of restaurants
Annual Shipments of industrial products
Agricultural output value
Taxable income
Local tax revenues
Total expenditures
Number of ownership car
Number of educational facilities
Number of Establishments Books Stationery Retail
Number of libraries
Number of nursery
Number of community centers
Number of hospitals
National manpower Composite Index
Population index
Per capita level of national manpower
Population ratio populated area (Area)
Daytime and nighttime population ratio
Basic Resident Registers population growth
Population density (area)
Census households (compared to single-person hous
Percentage of population < 15
Percentage of population 15-29
Percentage of population 30-44
Percentage of population 45-64
Percentage of population > 65
3 Industrial sector work force composition_1
3 Industrial sector work force composition_2
3 Industrial sector work force composition_3
Annual sales growth rate of retail shops
Income gap
Increase local tax revenues

Data :
63 (continuous) variables for 1962 Local area (Level 4)
were merged into
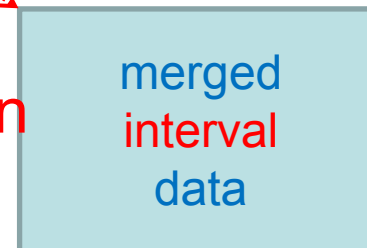63 (interval) variables for 151 Region (Level 2)

63 variables

1962
Local area
(Level 4)

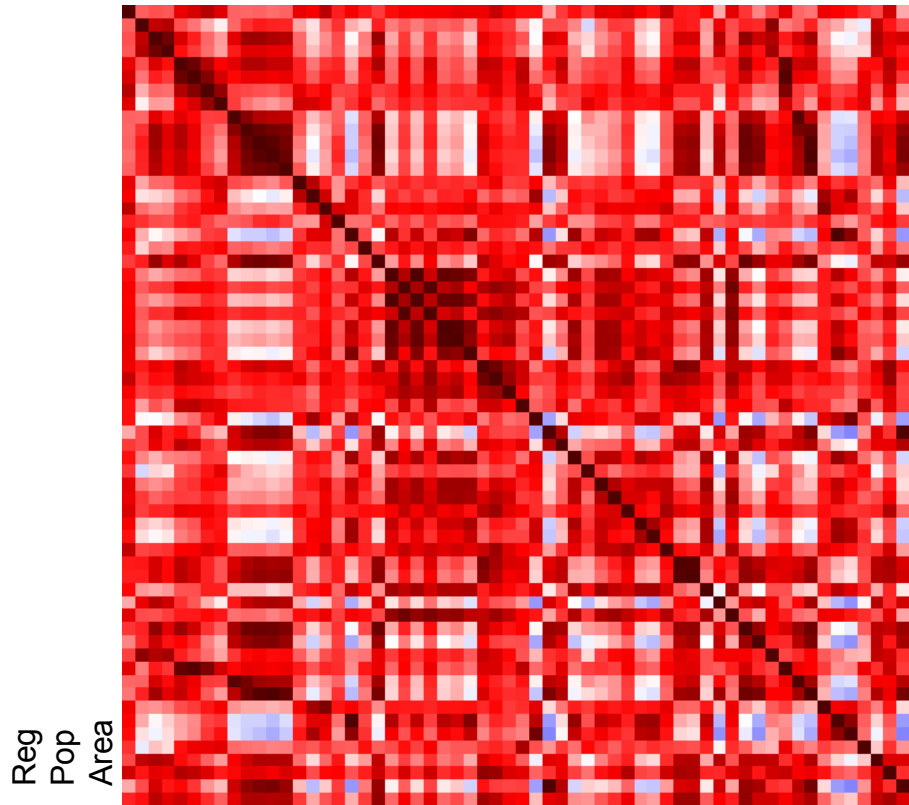original
continuous
data
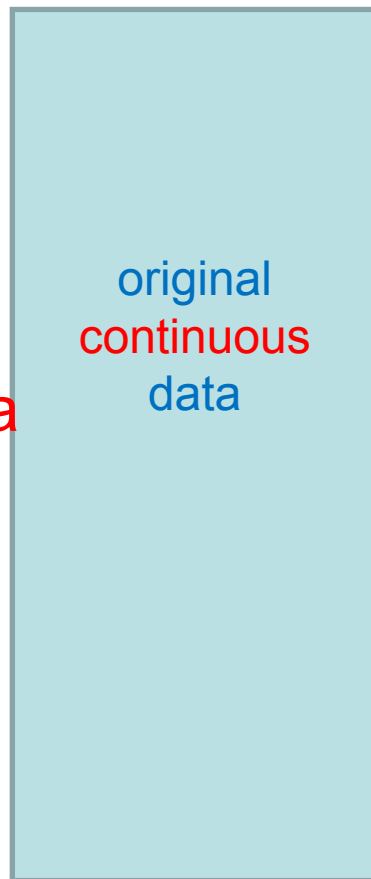
151 Region
(Level 2)

63 variables
(interval)

merged
interval
data

Level 1
Major Region (10)

0	北海道
1	東北
2	關東
3	甲信越・北陸・東海
4	近畿
5	中國・四國
6	九州・沖繩
7	東京狹域エリア
8	名古屋狹域エリア
9	大阪狹域エリア

Symbolic GAP for 民力2010 Data (Original Orders)

Variable Proximity:
Empirical Correlation
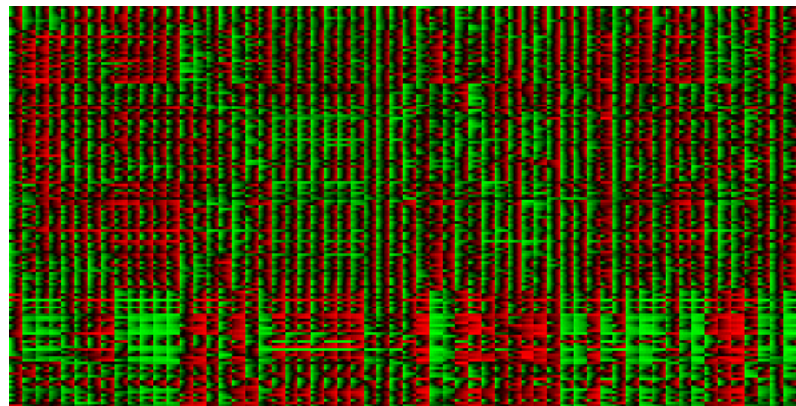
Unit Proximity:
Euclidean Hausdorff

Reg Pop Area

area_id	area_name
0	北海道
1	東北
2	關東
3	甲信越・北陸・東海
4	近畿
5	中國・四國
6	九州・沖繩
7	東京狹域エリア
8	名古屋狹域エリア
9	大阪狹域エリア
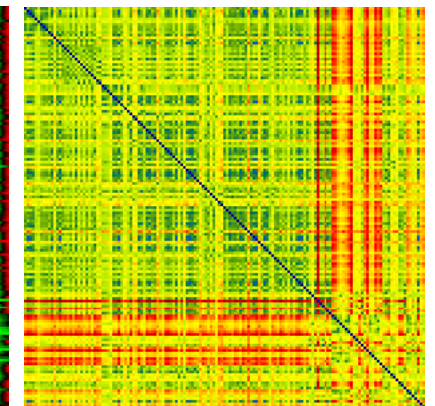
Symbolic GAP for 民力2010 Data (HCT_R2E Orders)

Reg:Pop:Area
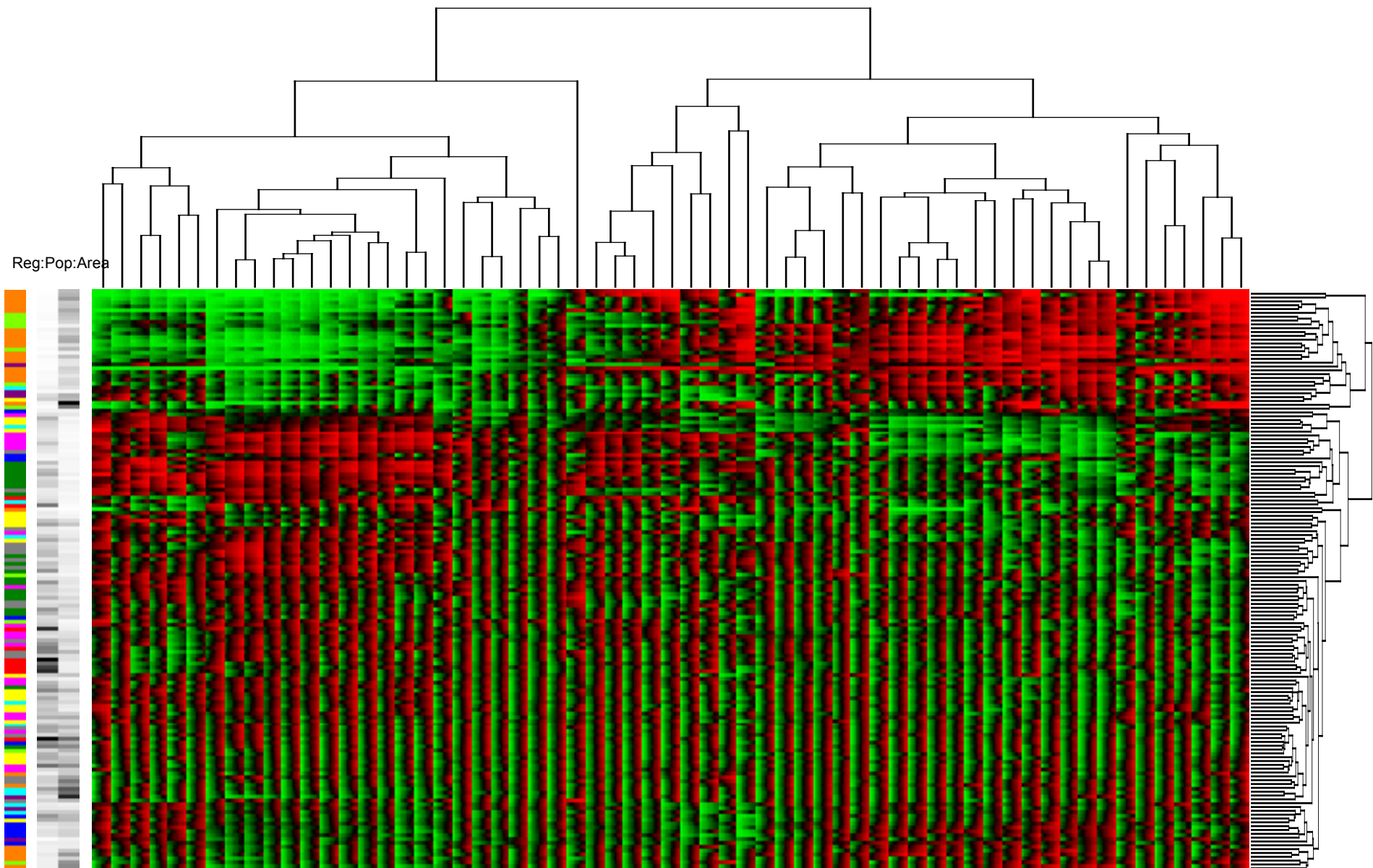
Cross Cultural Comparison of Rural Education Practice in China, Taiwan, and the US

1. MATHEMATICAL KNOWLEDGE TEST
   Part A: Computation
   Part B: Number Concepts and Equations
   Part C: Geometry
   Part D: Word Problems
2. AFTER SCHOOL LEARNING ACTIVITIES
3. ATTITUDES TOWARD LEARNING
4. SCHOOL CLASSMATES AND FRIENDS
5. HOME ENVIRONMENT
6. CREATIVITY—How creative are students

7. On the back side of this page,
   please use your pen or pencil to draw a picture of
   what an ALIEN--Creature from outer space--
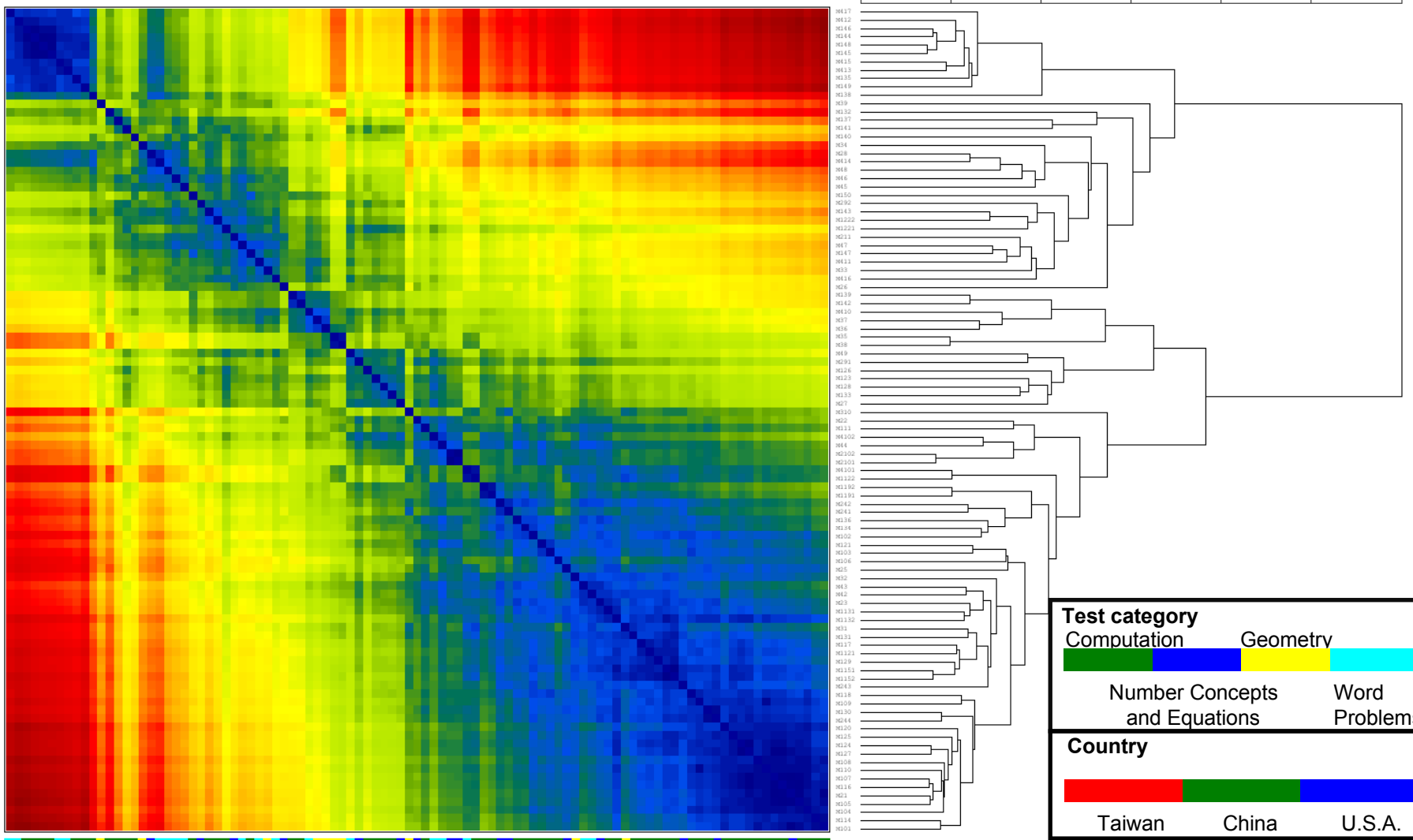   looks like

Benjamin, J. (2006) "Cross Cultural Comparison of Rural Education Practice in China, Taiwan, and the United States," American Educational Research Association Annual Conference.

Madigan, T., Benjamin, J., and Shieh, S. H. (2006) "Rural Education Practices and Outcomes in China and the United States," 101 Annual Meeting of the American Sociological Association, Montreal, Quebec.
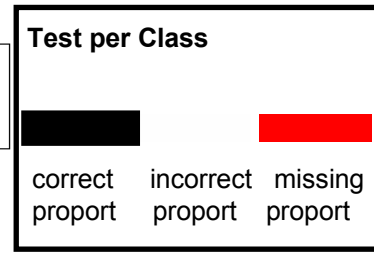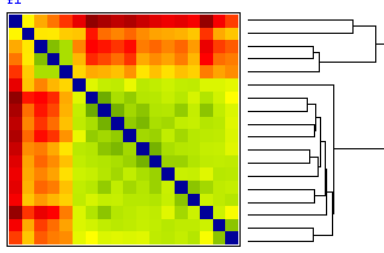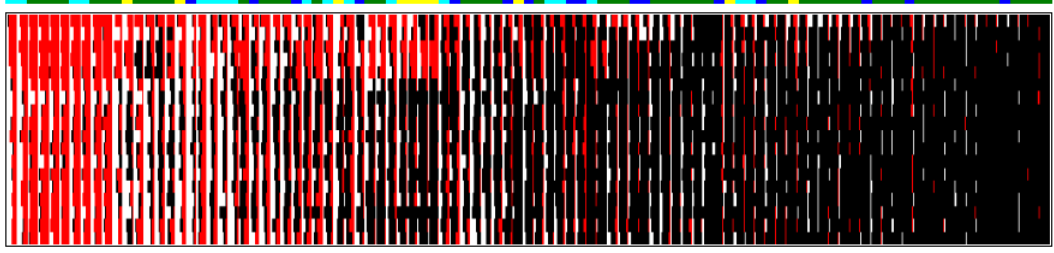
	China	Taiwan	USA
School	3	5	2
Class	3	13	2
students	272	361	95

	category	number of testing
Mathematical Knowledge Test	Computation	50
	Number Concepts and Equations	11
	Geometry	10
	Word Problems	17

	number of testing
After School Learning Activities	3
Attitudes Toward Learning	5
School Classmates And Friends	6
Home Environment	12
Creativity	8

Test category

Computation — Geometry — Number Concepts and Equations — Word Problems

Country

Taiwan — China — U.S.A.

Test per Class

correct proport — incorrect proport — missing proport

Test category

Computation   Geometry

Number Concepts   Word
and Equations   Problems

Country

Taiwan   China   U.S.A.

Test per Class

correct proportion   incorrect proportion   missing proportion
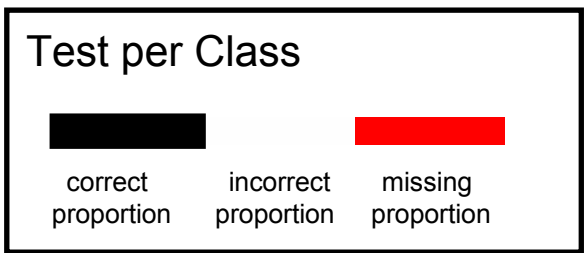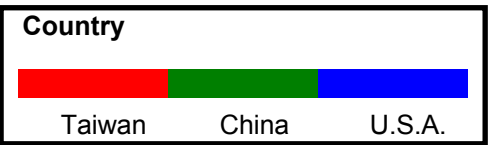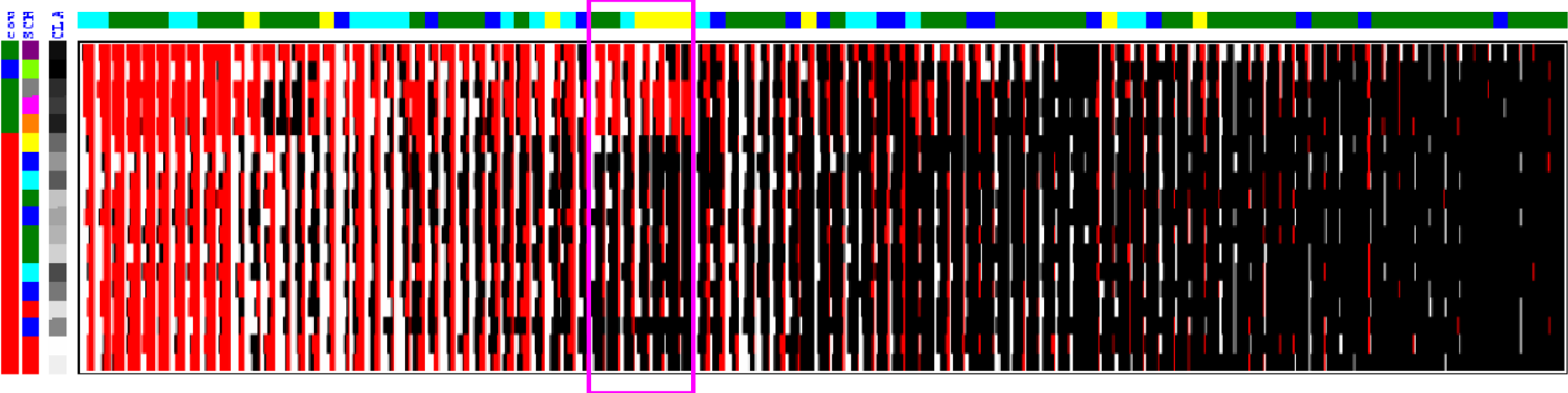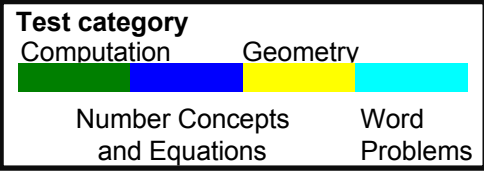
Summary

- We have extended our matrix visualization methods on symbolic data with continuous data types.

- We will also try to extend our matrix visualization methods to other symbolic data types (categorical).

Thank you for your attention !