The Representation Race
Handling Time Phenomena

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- MiningMart -- an approach to the representation race
- Time related learning tasks
- Case studies
  – shop
  – intensive care

The Problem: Method Selection

- Criteria for selecting a learning method for an application are missing -- no expert knowledge available! (MLT Consultant)
- Empirical studies do neither result in clear guidelines. (StatLog)
- Learning the rules that recommend a method for an application requires well-chosen descriptions of methods and tasks. (MetaL, CORA)

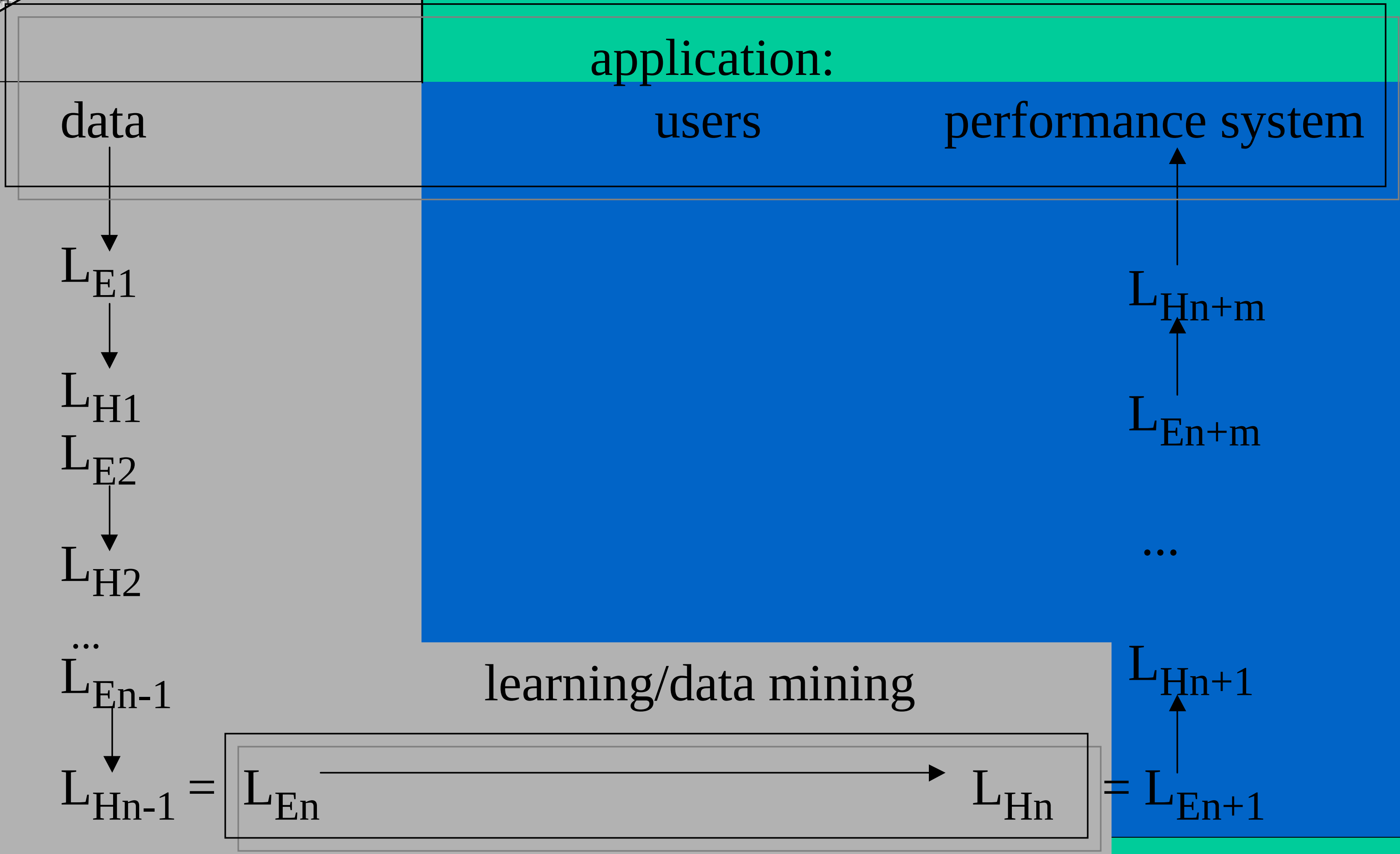
Observation

Experienced users can apply any learning system successfully to any application, since they prepare the data well...

- The representation L_E of examples determines the applicability of learning methods.
- A chain of data transformations (learning steps) leads to L_E of the method that delivers the desired result.

Experienced users remember prototypical successful transformation/learning chains

The Representation Race



The Consortium

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- Lorenza Saitta Univ. Piemonte del Avogadro, I
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- Fabio Malabocchia CSELT, I

The MiningMart Approach

Best practice cases of transformation/learning chains exist

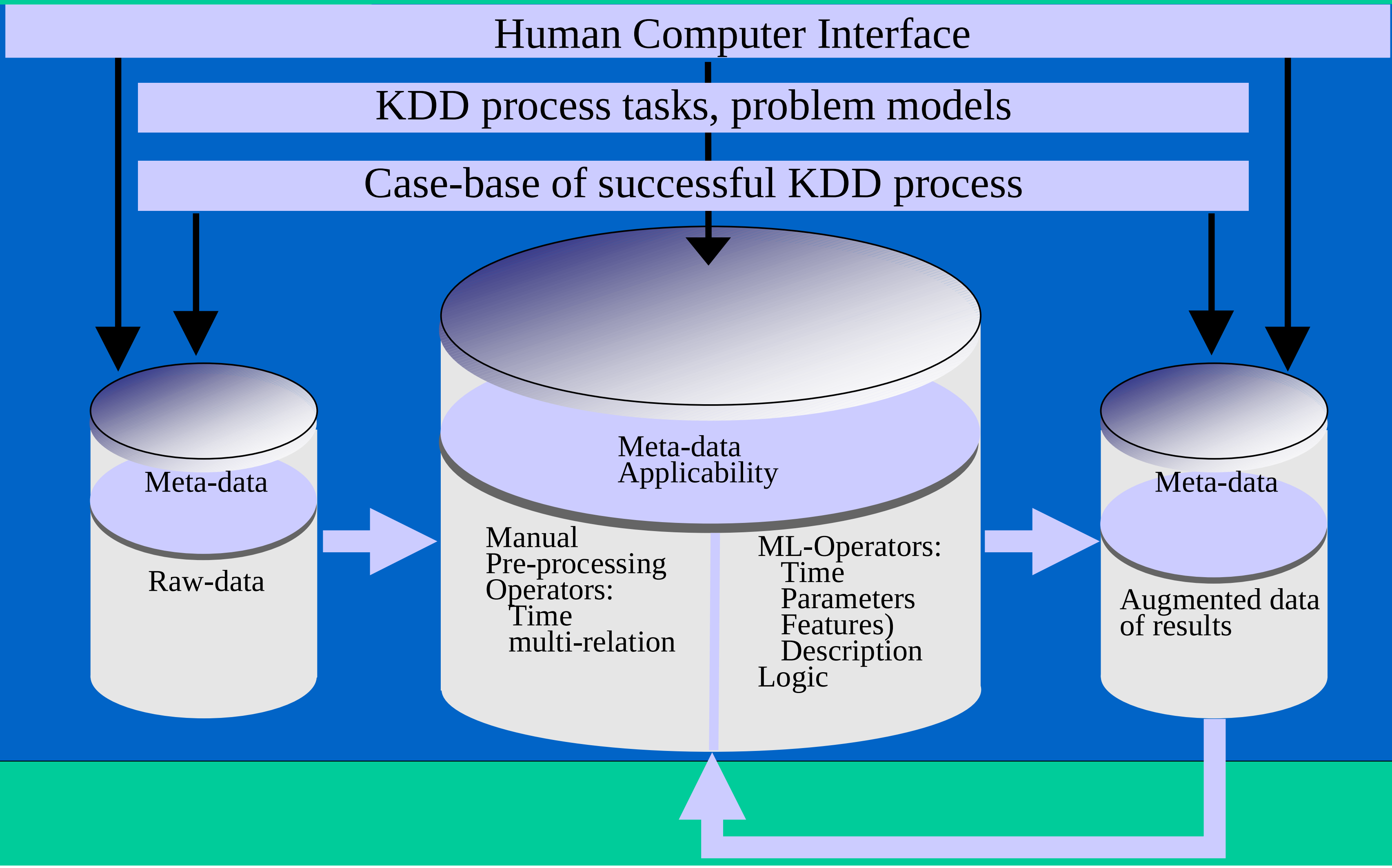
- Data, L_E and L_H are described on the meta level.
- The meta-level description is presented in application terms.
- MiningMart users choose a case and apply the corresponding transformation and learning chain to their application.

... and **more can be obtained!**

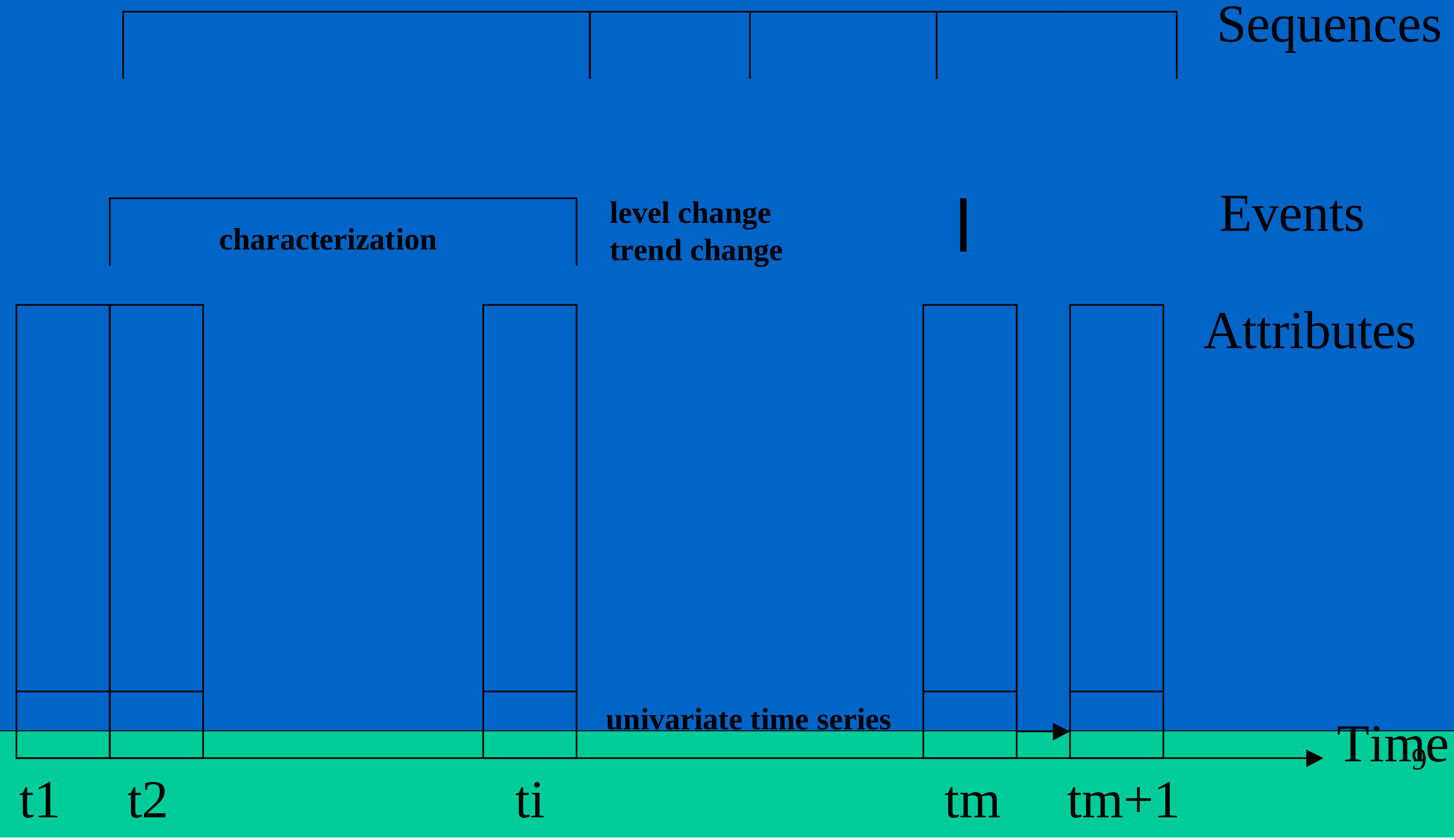
Call for Participation

- MiningMart is about to develop an operational meta-language for describing data and operators.
- MiningMart prepares the first cases of KDD.
- MiningMart will present the case-base in the WWW.
- You may contribute to the representation race!
  - Apply the meta-language to your application and deliver it as a positive example to the case-base; or
  - apply a case of MiningMart to your data.

The MiningMart System



Time Phenomena



Typical Time-Related Data

On-line measurements

- univariate time series
- multivariate time series

Database relations

- sales/contract data
- age/life situation

Granularity

- continuous measurements in day, hours, minutes, seconds
- time stamped events in years, half/quarter years, months, days

Learning Tasks -- Precedence

From a time series until t_m

univariate

- predict value at t_{m+n}
- find a common trend
- find cycles, seasons
- find level changes

Given sequences

- find clusters of similar subsequences

multivariate

- find co-occurrences
- find subsets of co-occurring attribute values (events)
- find time regions

Learning Tasks -- Dominance

Define sequences as

Frequent sequences:

precedence relation between sets of events (episodes)

Legal sequences:

proportions of time intervals (predicting actual time point)

Relations between time intervals:

overlap, inclusion, (direct) precedence

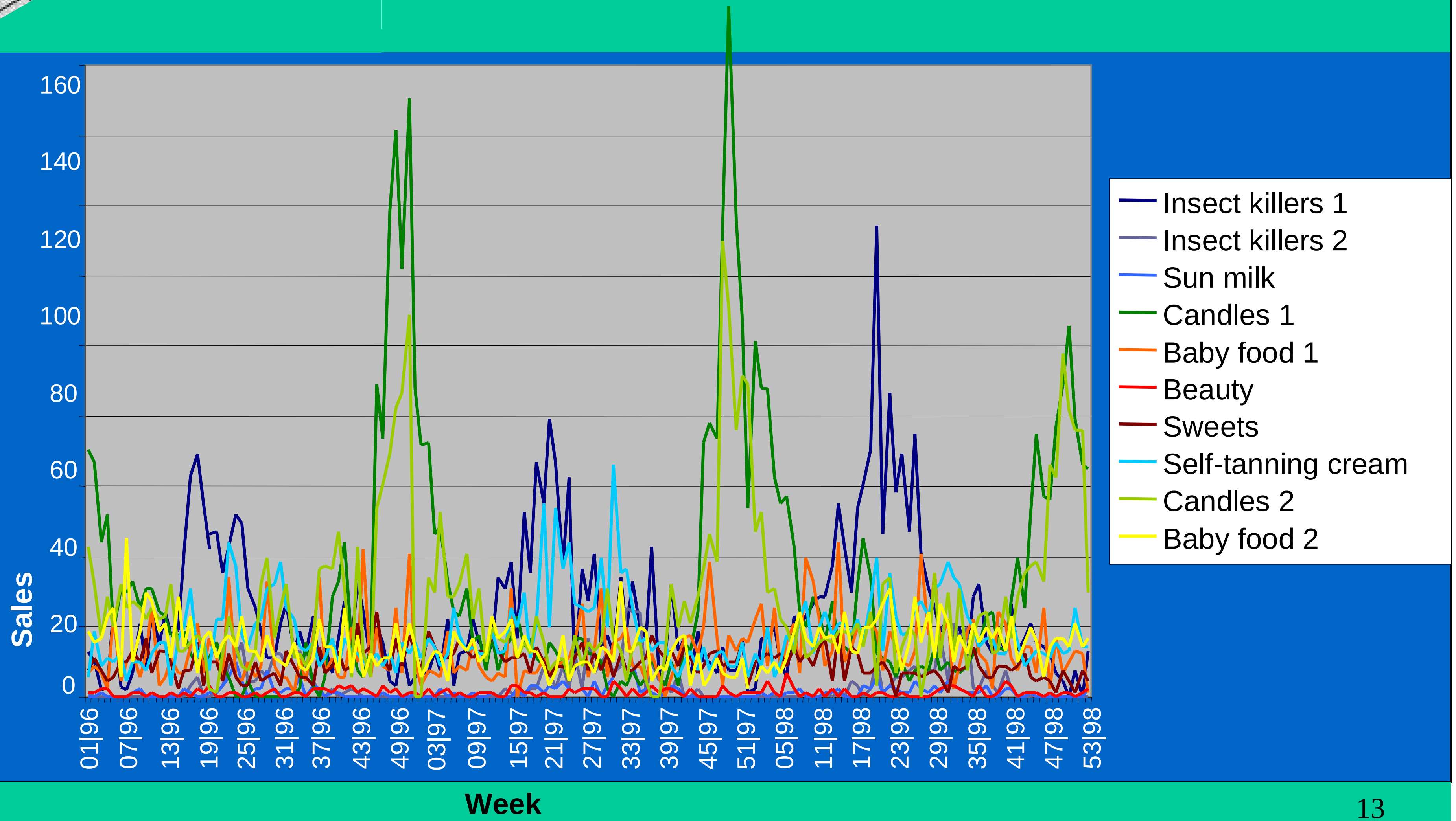
Higher-level categories:

a sequence of actions constitutes a category at the higher level

in terms of

- association rules
- first order logic
- prefix trees
- automata
- Hidden Markov Models

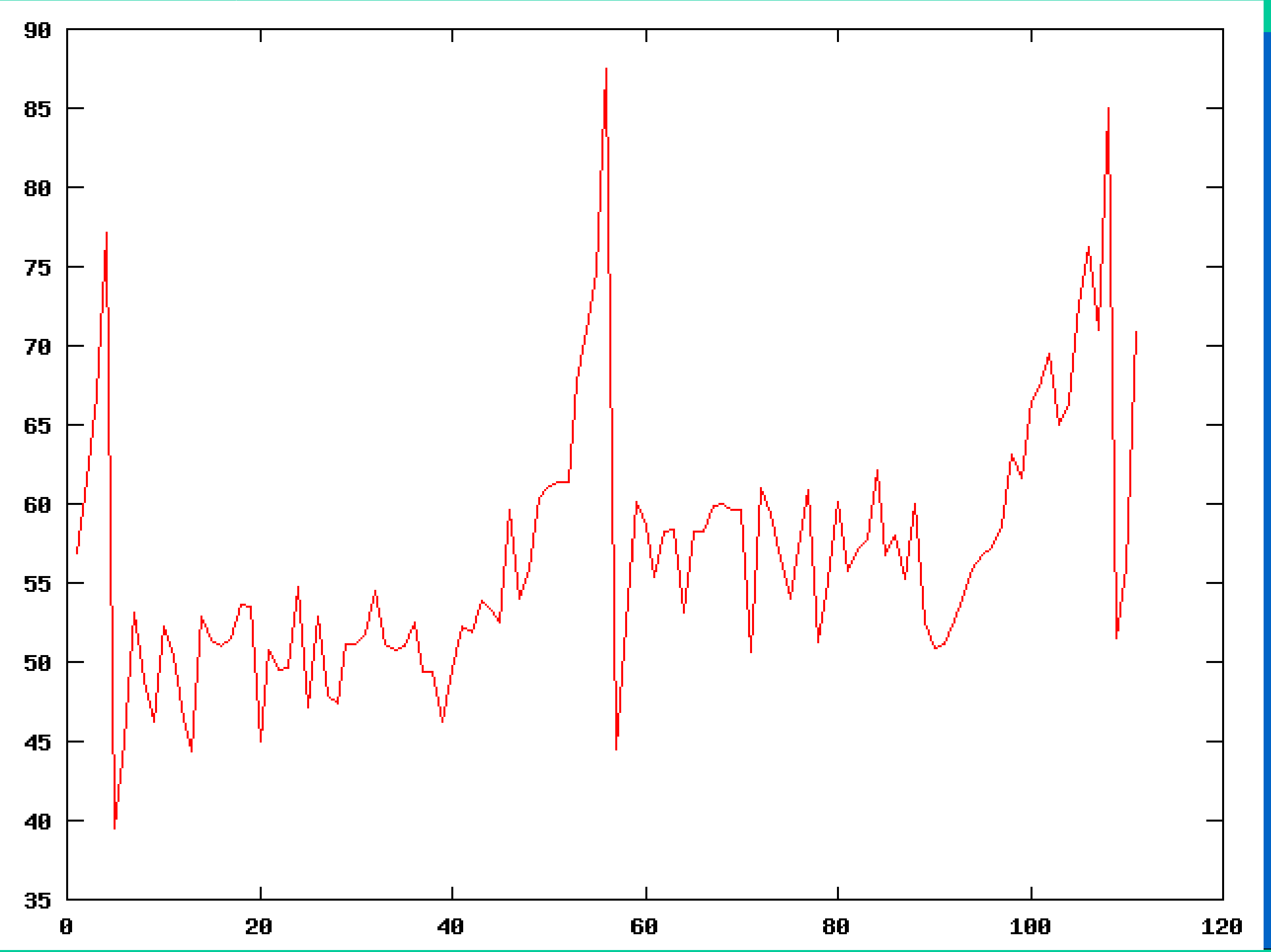
Sales of Items of a Drugstore



Learn About All Sales

- Find seasons, cycles, trends in general
- Aggregate all items, all shops
- Define a standard function of sales in a year
- Inspect deviations of particular shops from the standard

Aggregation of All Items Over Time



Predict Sales of an Item

Given drug store sales data of 50 items in 20 shops over 104 weeks

predict the sales of an item such that

- the prediction never underestimates the sale,
- the prediction overestimates less than the rule of thumb.

Observation: 90% of the items are sold less than 10 times a week.

Requirement: prediction horizon is more than 4 weeks ahead.

Shop Application -- Data

Shop	Week	Item 1	...	Item 50
Dm1	1	4	...	12
Dm1	...	...	...	...
Dm1	104	9	...	16
Dm2	1	3	...	19
...	...	...	...	...
Dm20	104	12	...	16

LE_{DB1}: I: T_1 A_1 ... A_{50}; set of multivariate time series

Transformations

- From shops to items: multivariate to univariate

$L_{E1'}$: $i{:}t_1\ a_1\ \ldots\ t_k\ a_k$

For all shops for all items:
Create view Univariate as
Select shop, week, $item_i$
Where shop="dm_j"
From Source;

Dm1 _teIn 1	1	4 ...	104	9
...				
Dm1 _teIn 5 0	1	12...	104	16

....

Dm2 0 temI 5 0	1	14...	104	16

- Multiple learning

Exponential Smoothing

- Univariate time series as input ($LE_{1‘}$),
- incremental method:
  current hypothesis h and new observation o yield next hypothesis by $h := h + \lambda\ o$,
  where λ is given by the user,
- predicts sales of n-next week by last h.

Transformations

- Obtaining many vectors from one series by sliding windows

L_{H5} i:t_1 a_1 ... t_w a_w
move window of size w by m steps

Dm1_Item1_1	1	4...	5	7
Dm1_Item1_2	2	4...	6	8
...				
Dm1_Item1_1	100	6...	104	9

...

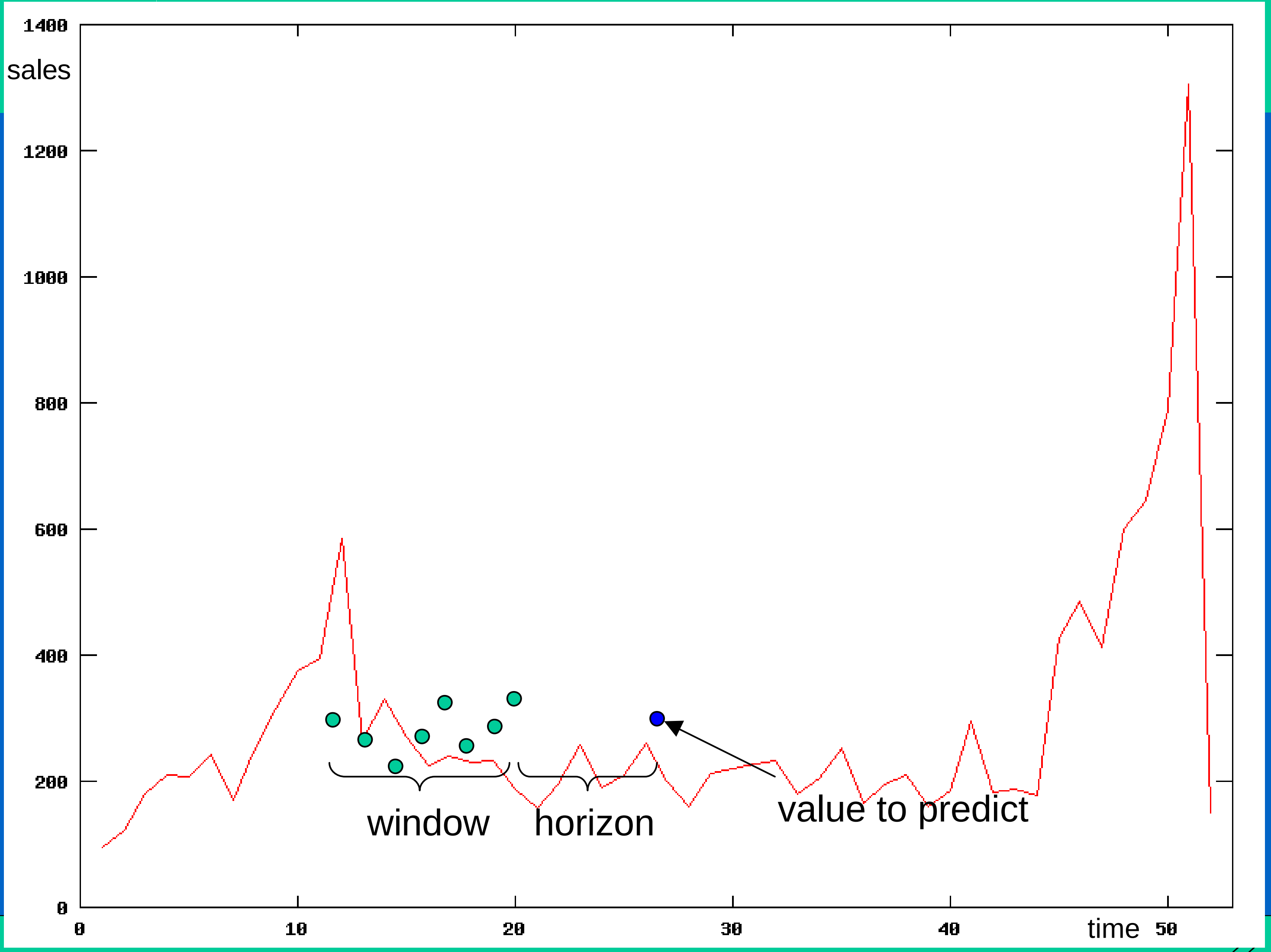
...				
Dm20_Item50_100	100	12...	104	16

SVM in the Regression Mode

- Multiple learning:
  for each shop and each item, the support vector machine learned a function which is then used for prediction.
- Asymmetric loss:
  – underestimation was multiplied by 20,
    i.e. 3 sales too few predicted -- 60 loss
  – overestimation was counted as it is,
    i.e. 3 sales too much predicted -- 3 loss

(Stefan Rüping 1999)

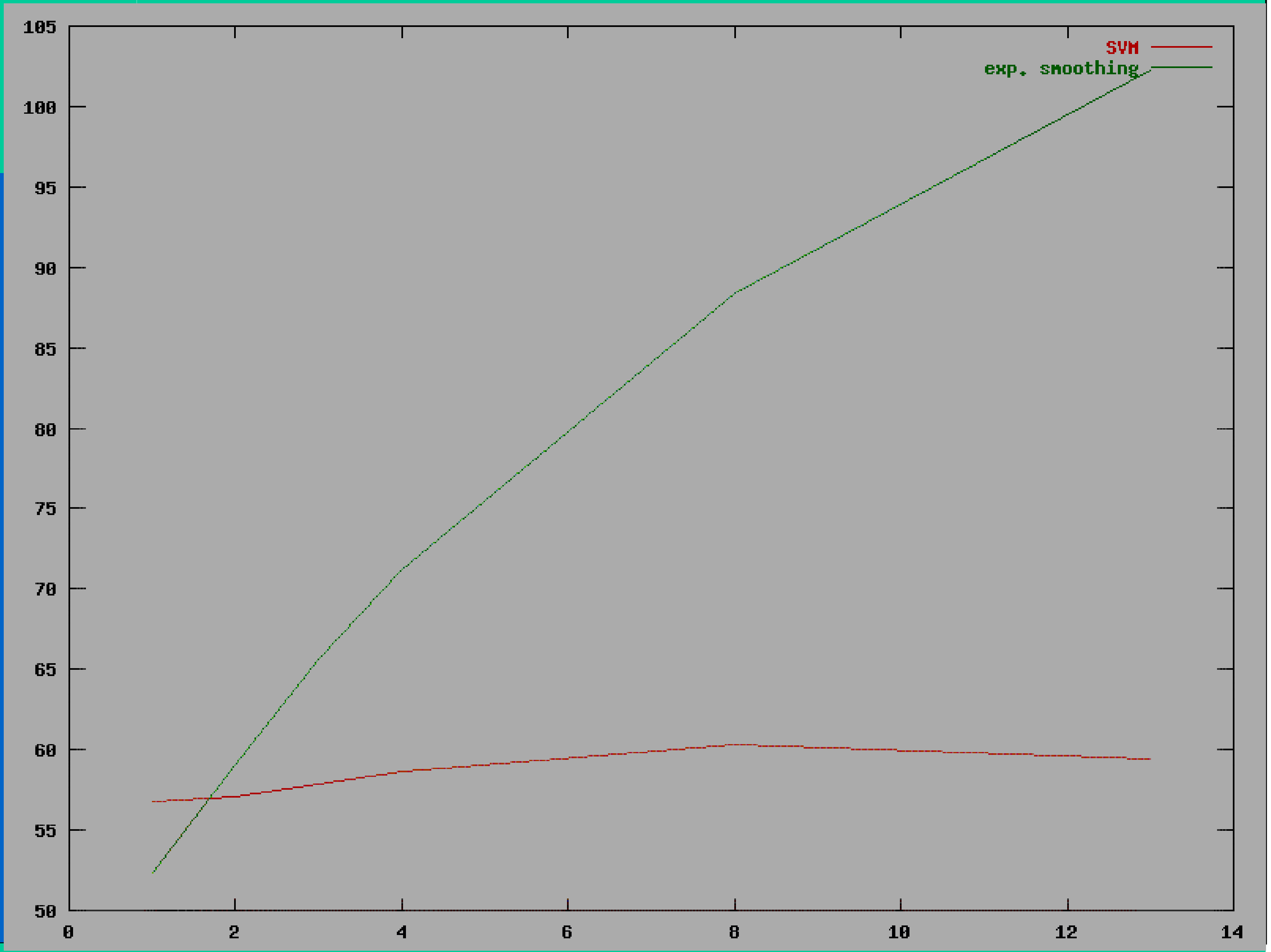
Article 766933 (bag?)



Comparison with Exponential Smoothing

horizon	SVM	exp. smoothing
1	56.764	52.40
2	57.044	59.04
3	57.855	65.62
4	58.670	71.21
8	60.286	88.44
13	59.475	102.24

loss

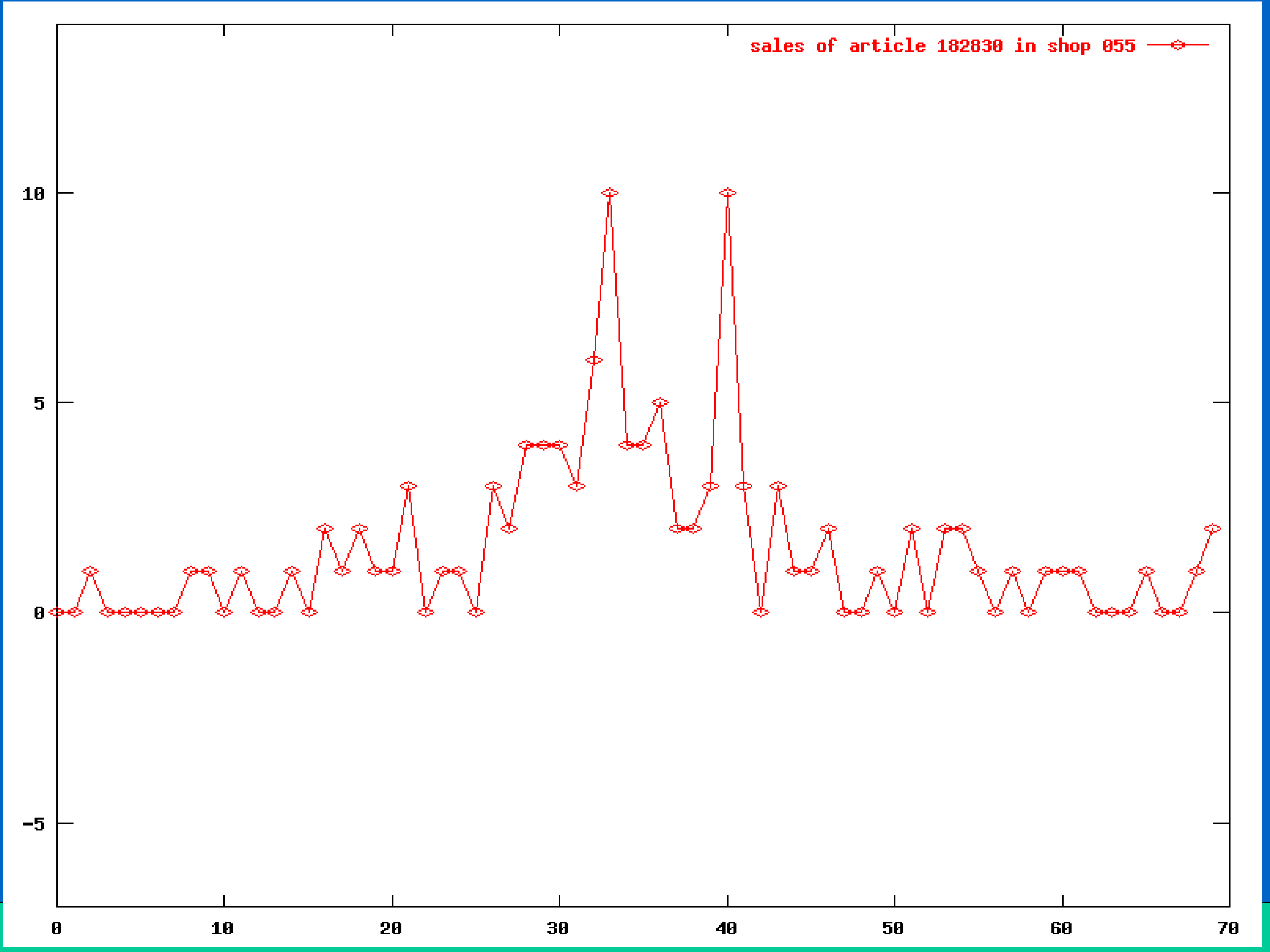


horizon

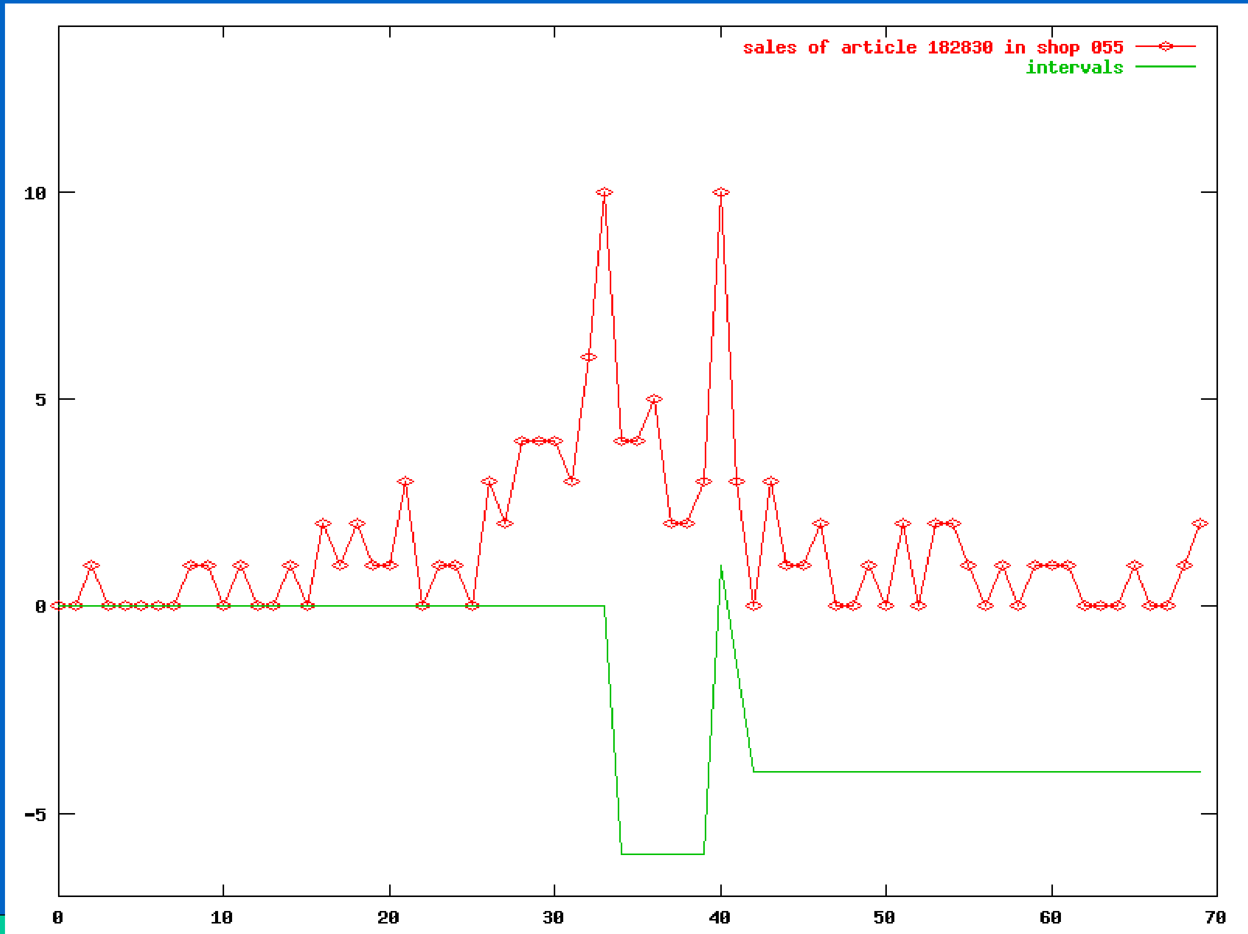
Learning Relations

- Are there typical sequences that are valid for <u>all</u> items? Prepocessing for rule learning about abstract episodes:
- Summarizing values within time intervals
  $L_{E1'}$: $i{:}t_1\ a_1 \ldots t_k\ a_k \Rightarrow$
  L_{H6}: $i{:}\ [t_1, t_w] f(a_1,\ldots,a_w),\ldots, [t_m, t_{m+w}]\ g(a_1,\ldots,a_w)$
- Abstraction into classes of gradients valid for a time interval $\Rightarrow$
  L_{H2}: $\mathit{Label}_j\ [t_1, t_w],\ldots,\mathit{Label}_l\ [t_m, t_{m+w}]$

Sales of Item 182830 in Shop 55



Summarizing Sales



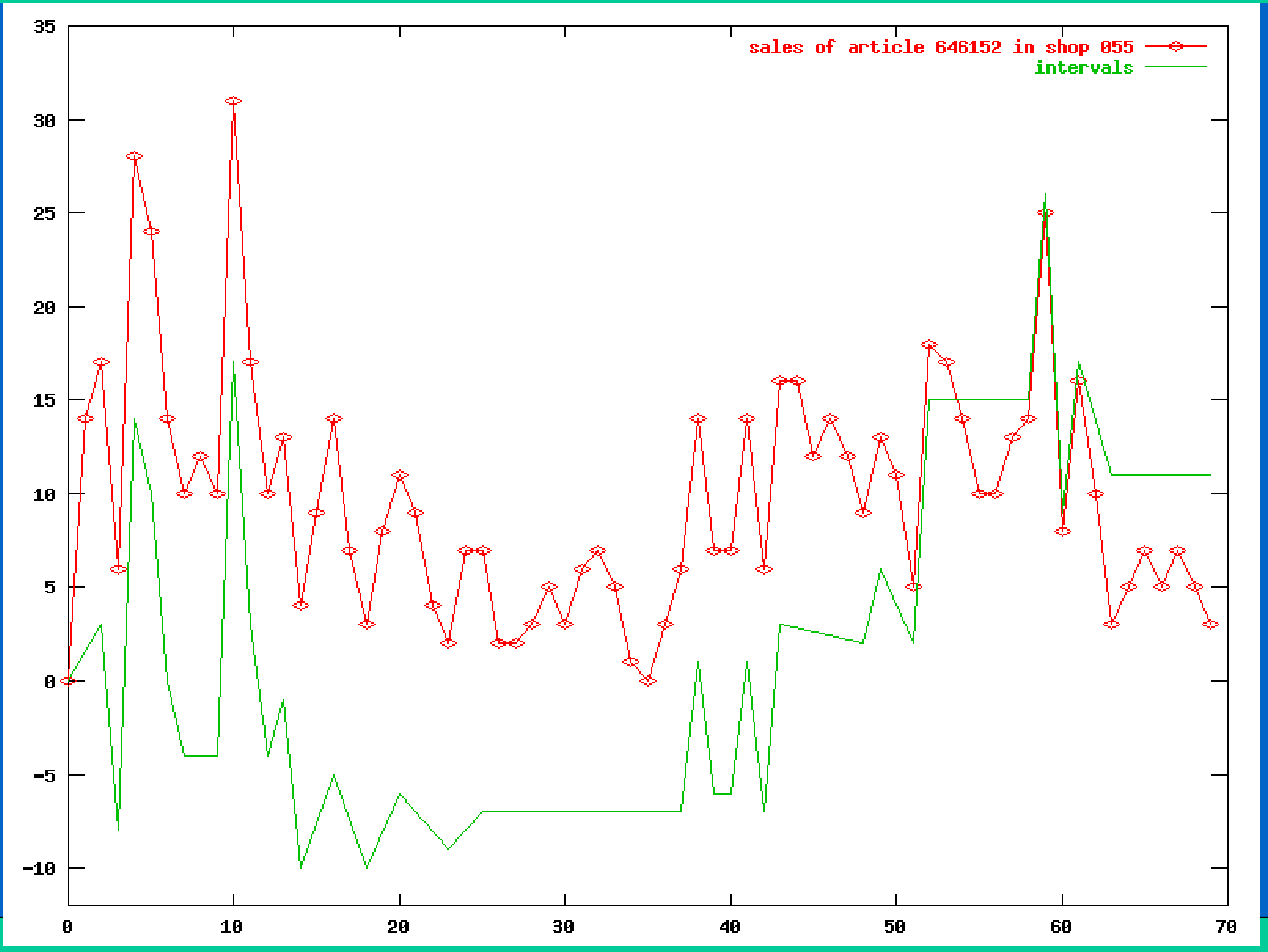
(Wessel, Morik 1999)

Transformation into Facts

L_{E4}:

stable(182830,1,33,0).
decreasing(182830, 33,34,-6).
stable(182830, 34, 39,0).
increasing(182830, 39, 40,7).
decreasing(182830, 40, 42,-5).
stable(182830, 42,108,0).

Summarizing Item 646152 in Shop 55



Corresponding Facts

increasing(646152,1,2,3).
decreasing(646152,2,3,-11).
increasingPeak(646152,3,4,22).
...
stable(646152, 25,37,0).
increasing(646152, 37, 38, 8).
decreasing(646152, 38, 39, -7).
stable(646152, 39,40, 0).
increasing(646152, 40, 41,7).
decreasing(646152, 41, 42,-8).
increasing(646152, 42, 43,10).
stable(646152, 43, 48,-1).

small time intervals

Rule Learning

- Transformations into facts:
  $L_{E\,4}$: $p(I, T_b, T_e, A_r, \ldots, A_s)$
- Rules about sequences:
  $p_1(I, T_b, T_e, A_r), p_2(I, T_e, T_{e2}, A_s) \rightarrow$
  $p_3(I, T_{e2}, T_{e3}, A_t)$
- results for sequences of sales trends:
  increasing (Item, T_b, T_e) $\rightarrow$ decreasing(Item, T_e, T_{e2})
  increasing (Item, T_b, T_e), decreasing(Item, T_e, T_{e2})
  $\rightarrow$ stable(Item, T_{e2}, T_{e3})

Same Data -- Several Cases

- Find seasons or cycles in all sales

  aggregation of items and shops, description of the curve as a function

- Predict sales of a particular item in a particular shop

  multivariate to univariate, multiple exponential smoothing OR
  multivariate to univariate, sliding windows, multiple learning with SVM

- Find relations between trends that are valid for all sales in all shops

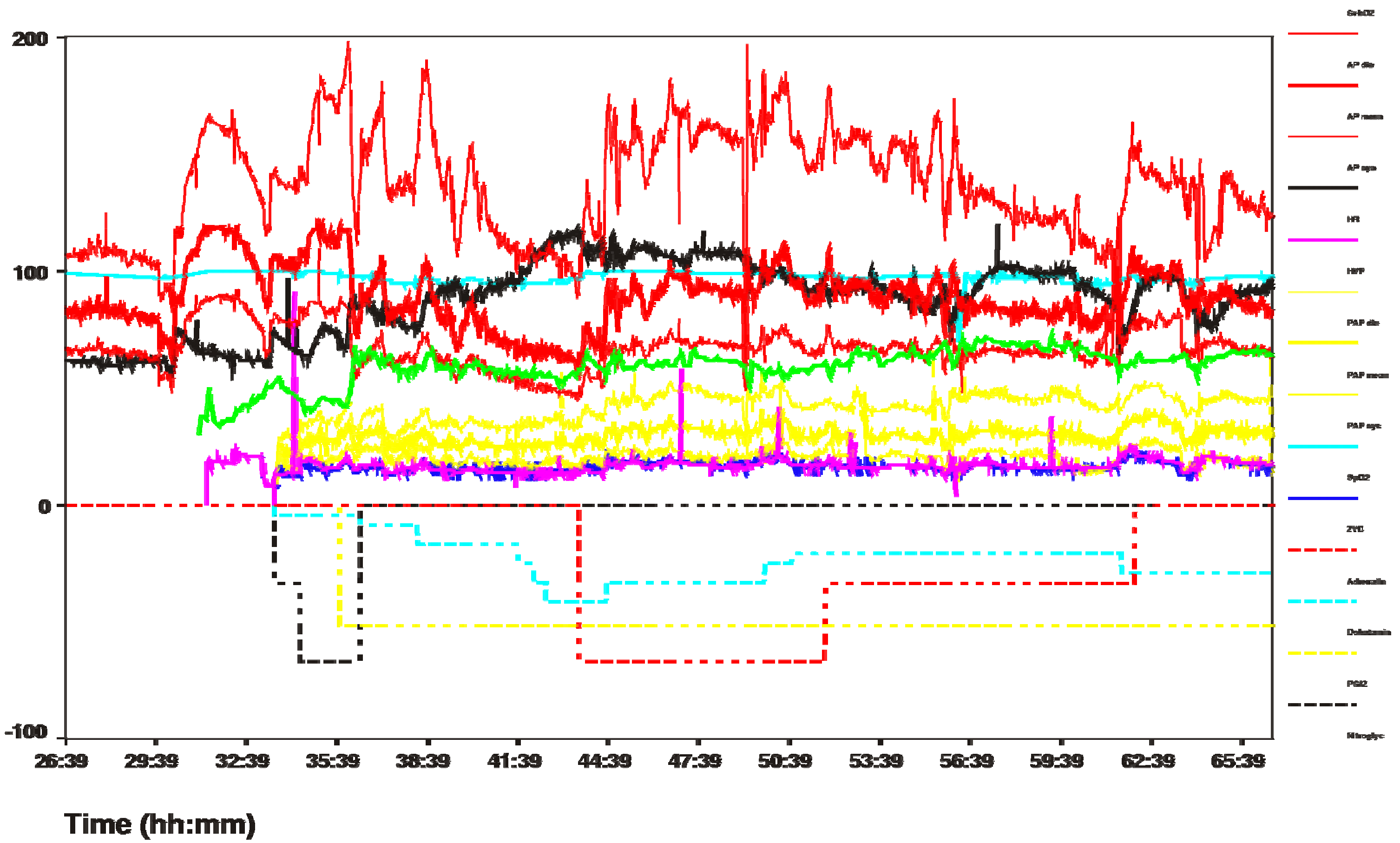
  summarizing, transformation into facts, rule learning

Applications in Intensive Care

- On-line monitoring of intensive care patients
- high-dimensional data about patient and medication
- measured every minute
- stored in the Emtec database of patient records ---
- learning when to intervene in which way.

Patient G.C., male, 60 years old

Hemihepatektomie right



MINING MART

The Data

LE_{DB2}

i_1: t_1 $a_{1\,1}$ ... $a_{1\,k}$
i_1: t_2 $a_{2\,1}$ ... $a_{2\,k}$
...

i_2: t_1 $a_{1\,1}$ ... $a_{1\,k}$
...

set of rows for each patient:
1 row for each minute

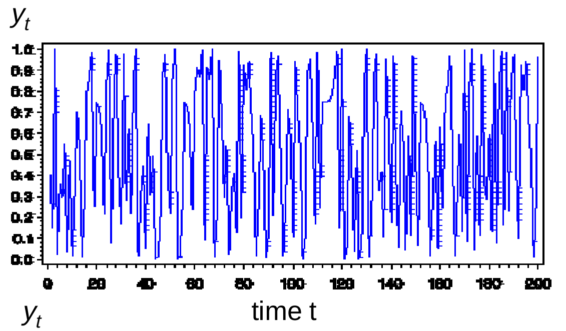
Transformations

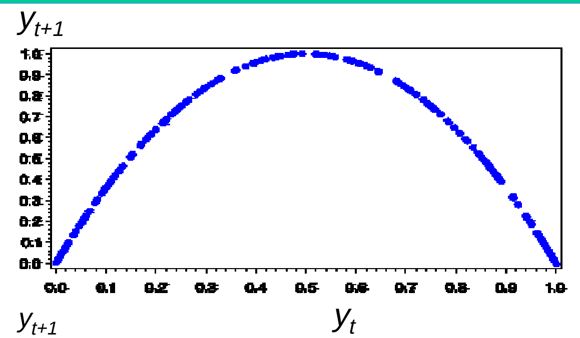
- Chaining database rows
  $i_1: t_1\ a_{1\,1} \ldots a_{1\,k}, t_2\ a_{2\,1} \ldots a_{2\,k}, \ldots$
- Multivariate to univariate
  $i_1: t_1\ a_1, t_2\ a_1 \ldots t_m\ a_1$
  $i_1: t_1\ a_2, t_2\ a_2 \ldots t_m\ a_2$
  ...
- Detecting level changes

Phase State Analysis

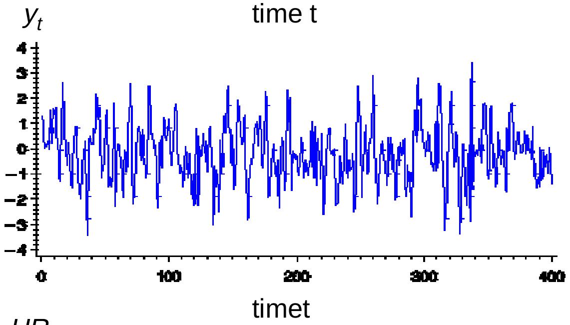
Time series $y_1,\ldots,y_N$ **Phase state** $\vec{y}_t=(y_t,y_{t+1})$

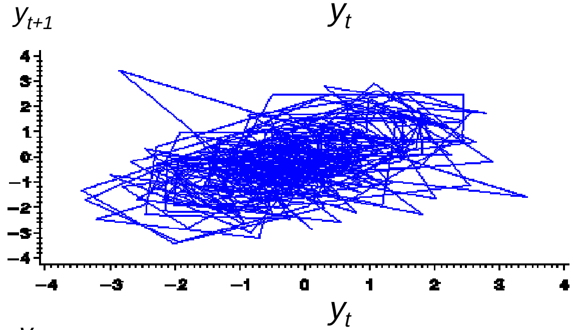
Deter-ministic Process



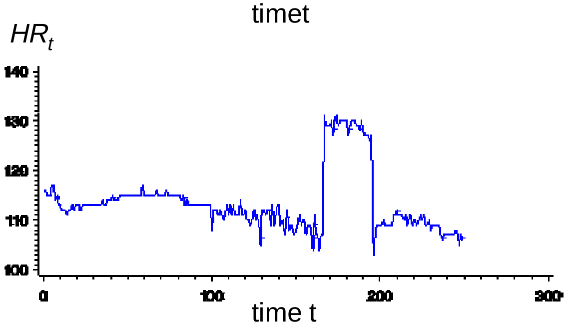


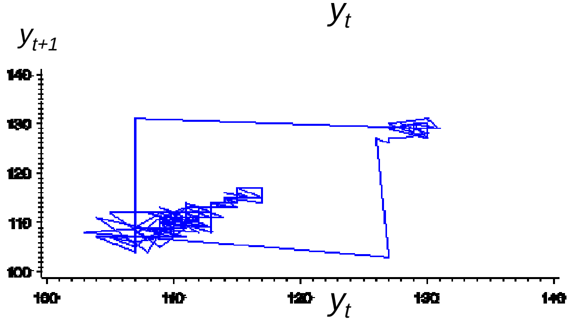
AR(1)-process with outlier (AO)





Heart rate





Level Change Detection

level_change(pat4999, 50, 112, hr, up)

level_change(pat4999, 112, 164, hr, down)

level_change(pat4999, 10, 74, art, constant)

level_change(pat4999, 74, 110, art, down)

Computed Feature

Comparing norm values for a vital sign and its mean in a time interval (± standard deviation):

deviation(pat4999, 10, 74, art, up)

Learning Task

Are there valid rules

for all multivariate time series,

such that therapeutical interventions follow from a patient’s state?

Relational Learning

Given patient records in the form of facts:

- deviations -- time intervals
- therapeutical interventions -- time points
- types of vital signs (group1: hr, swi, co; group2: art, vr)

Learn rules about interventions:

group1(V), deviation(P, T1, T2, V, Dir)

→noradrenaline(P, T2, Dir)

The Chain of Preprocessing Steps

LE_{DB2} :
i_1: $t_1\ a_{11}\ \ldots\ a_{1k}$
i_1: $t_2\ a_{21}\ \ldots\ a_{2k}$
...
i_2: $t_1\ a_{11}\ \ldots\ a_{1k}$

chaining db rows
i_1: $t_1\ a_{11}\ \ldots\ a_{k1}\ t_2\ a_{12}\ \ldots\ a_{k2}\ \ldots$
i_2: $t_1\ a_{11}\ \ldots\ a_{k1}\ t_2\ a_{12}\ \ldots\ a_{k2}\ \ldots$

multi- to univariate
i_1: $t_1\ a_{11}\ t_2\ a_{12}$
i_1: $t_1\ a_{21}\ t_2\ a_{22}$
...

level changes
(i_1, t_i, t_j, A)
...

relational learning
$p_1(I,T_i,T_j,A,D)$, $p_2(I,T_j,T_k,A,D)$
$\rightarrow p_3(I,T_k, Dir)$

computed feature
(i_1, t_i, t_j, A, D)

Disregarding Time

<u>Given</u> a patient's state at time t_i,

<u>learn</u> whether and how to intervene at t_{i+1}

Transformations:

- Selection of time points where an intervention was done
- Multiple to binary class

  for each drug, form the concepts drug_up, drug_down
- Multiple learning for each binary class resulting in classifiers for each drug and direction of dose change (SVM_light)

The Chain of Preprocessing Steps

LE_{DB2} :
$i_1: t_1\ a_{11} \ldots a_{1k}$
$i_1: t_2\ a_{21} \ldots a_{2k}$
…
$i_2: t_1\ a_{11} \ldots a_{1k}$

Select time points with interventions
$i_1: t_i\ a_{1i} \ldots a_{ki}$
$i_2: t_j\ a_{1j} \ldots a_{kj}$
…

Form binary classes
$a_1\_up_+$: $a_2 \ldots a_k$
…
$a_1\_up_-$: $a_2 \ldots a_k$
….
$a_6\_down_+$: $a_2 \ldots a_k$..
$a_6\_down_-$: $a_2 \ldots a_k$….

Learning classifiers using SVM_light
$a_1\_up_+: w_2\ a_2 \ldots w_k\ a_k$
…
$a_6\_down_+: w_2\ a_2 \ldots w_k\ a_k$

Same Data -- Several Cases

- Find time relations that express therapy protocols

  chaining db rows, multivariate to univariate, level changes, deviations, RDT
- Predict intervention for a particular drug

  select time points, multiple to binary class, SVM_light

Behind the Boxes

Db schema indicating time attribute(s), granularity,...

Select statement in abstract form, instantiated by db schema

Creating views in abstract form, instantiated by db schema and learning task

Syntactic transformation for SVM

Multiple learning control

Calling SVM_light and writing results

Summary of Cases Involving Time

Db schema indicating time attribute(s),their granularity, uniformity, starting point	Syntactic transformations L_{E1} ... L_{E4}	Sliding windows Summarizing windows Level changes

Relational learning (RDT)
SVM_light for classification
SVM for regression
Exponential smoothing

MiningMart Approach to the Representation Race

- Manager -- end-user
  knows about the business case
- Database manager
  knows about the data
- Case designer -- power-user
  expert in KDD
- Developer
  supplies (learning) operators