Visual Data Analysis:
real users, real data, right methods

Michael Sedlmair

Junior Group Leader
University of Vienna, Austria

Oct 24, 2013

data

becomes ubiquitous

visualization & data analysis

real users/real data:

technique angle: characterize how proposed visualization and data analysis techniques perform under real circumstances

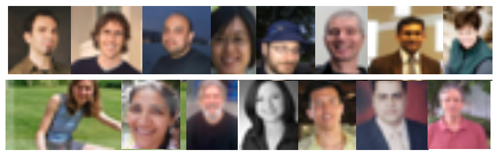
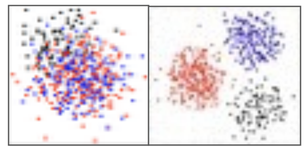
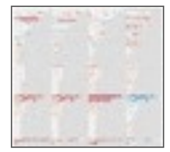
problem angle: understand real needs, problems and practices & provide visual and computational solutions

right methods:

innovate and refine research methods for visual data analysis

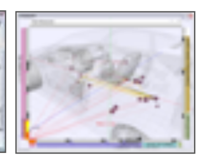
real users/real data:

Studies on high-dimensional data analysis techniques

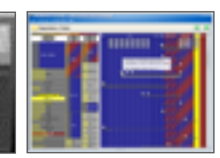
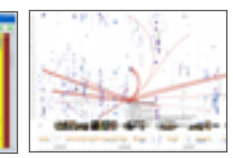




Applied visualization projects (9 BMW, 3 others)





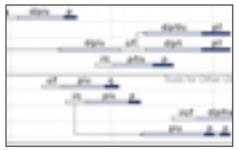
real users/real data:

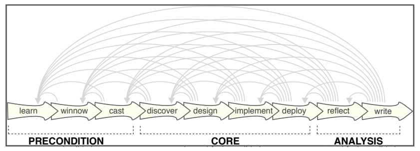
Studies on high-dimensional data analysis techniques

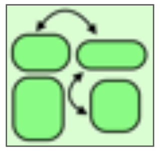
Applied visualization projects (9 BMW, 3 others)

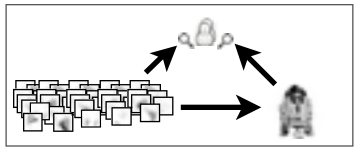
right methods:

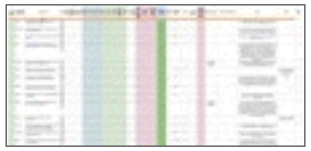
Novel and refined research methods/methodologies





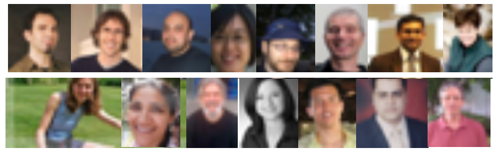
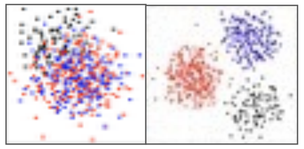
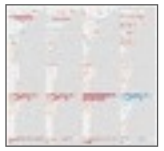






real users/real data:

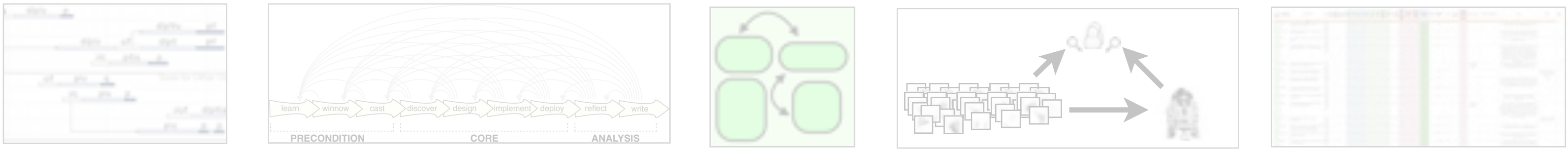
Studies on high-dimensional data analysis techniques

Applied visualization projects (9 BMW, 3 others)

right methods:

Novel and refined research methods/methodologies



studies on high-dimensional data analysis techniques

high-dimensional data

	length	weight	speed	hp	...
Car 1					
Car 2					
Car 3					
...					

highdim

dimension reduction (DR)

	length	weight	speed	hp	...
Car 1					
Car 2					
Car 3					
...					

highdim

DR

→

e.g., using PCA

	sporty	handling
Car 1		
Car 2		
Car 3		
...		

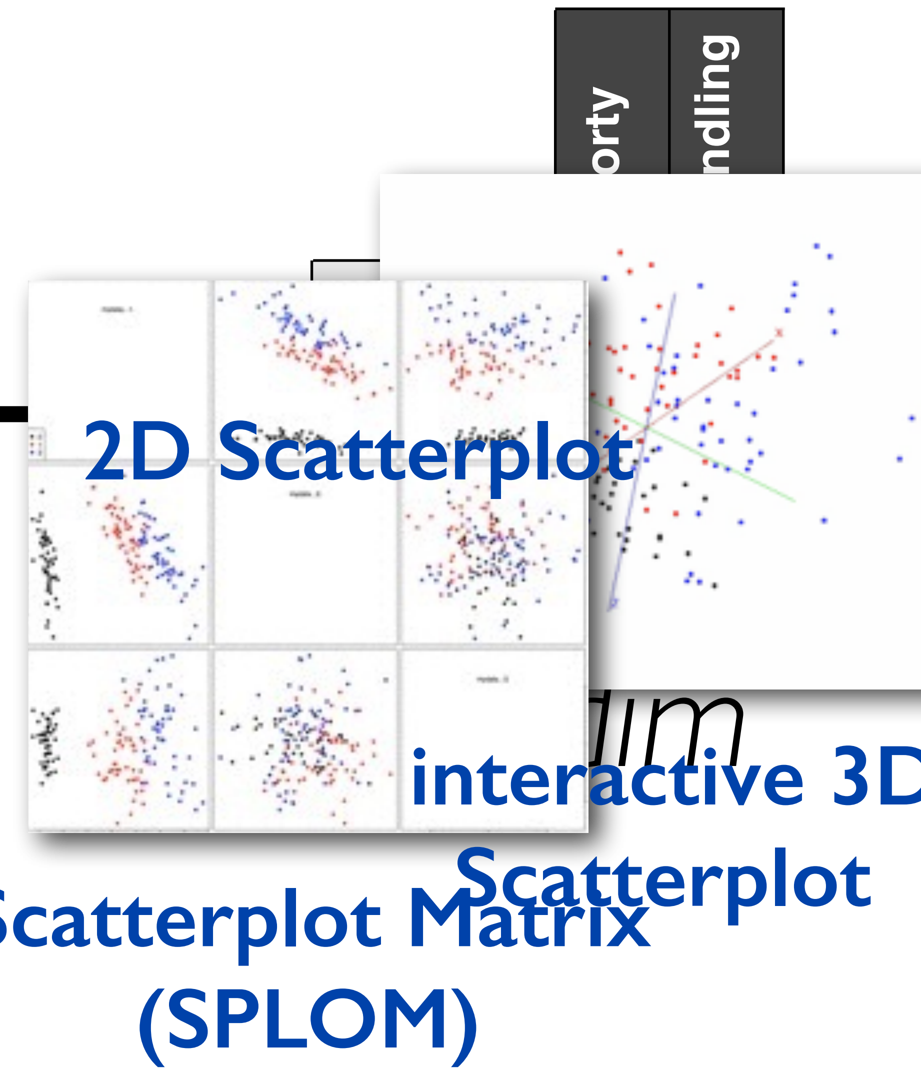
lowdim

visualizing DR data

	length	weight	speed	hp	...
Car 1					
Car 2					
Car 3					
...					

highdim

DR

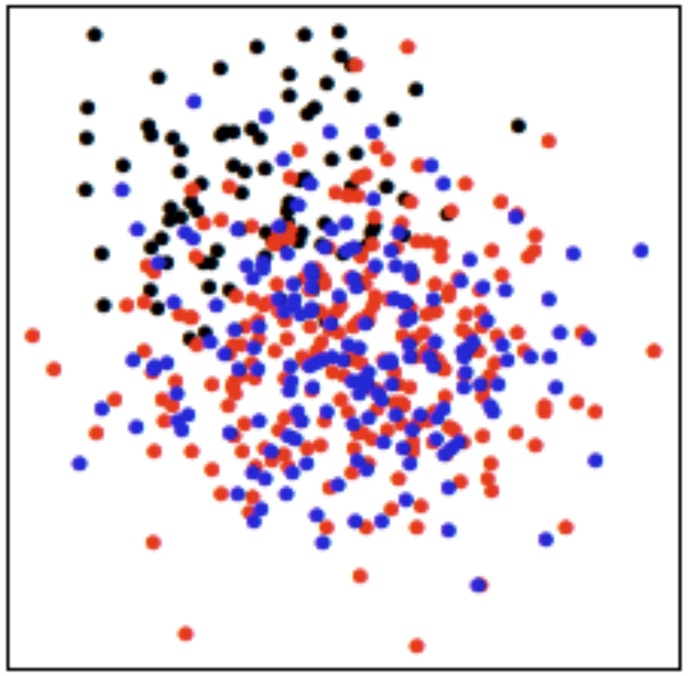


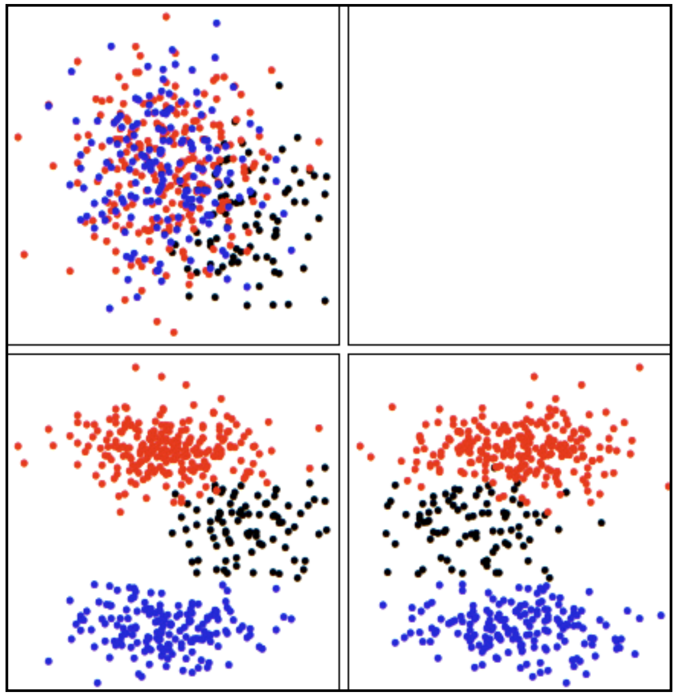
2D vs. 3D vs. SPLOM

Which visual encoding technique to use for visualizing DR data?

2D vs. 3D vs. SPLOM

The one that gives nicer cluster separability!

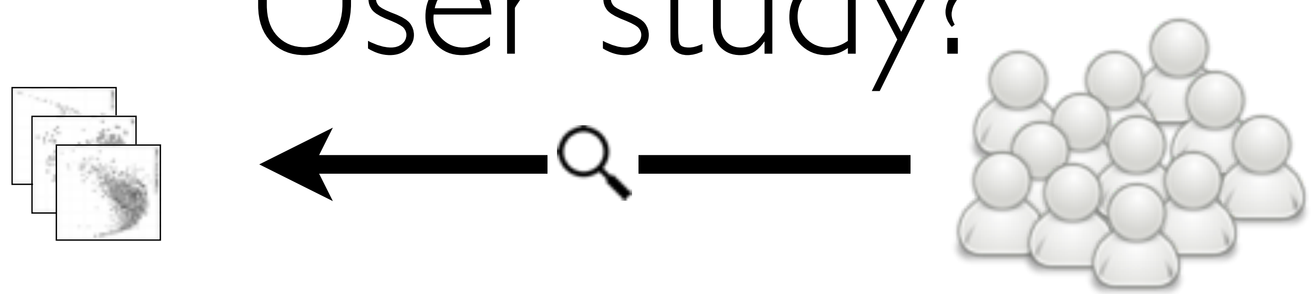




2D vs. 3D vs. SPLOM

How to study?

User study?



Pilot study - No!

Data characteristics outweigh subtle user differences!

2D vs. 3D vs. SPLOM

How to study?

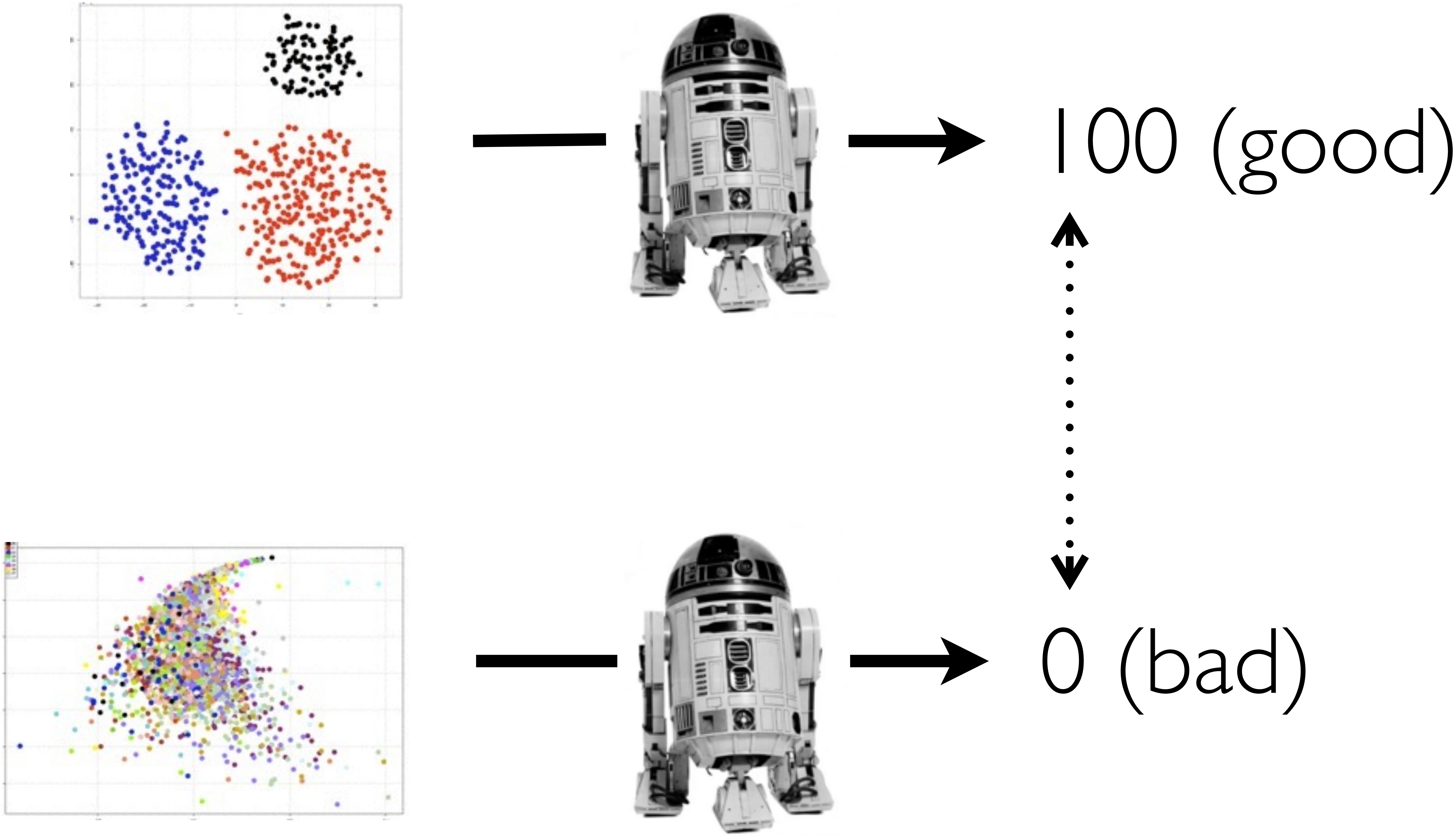
816 Plots

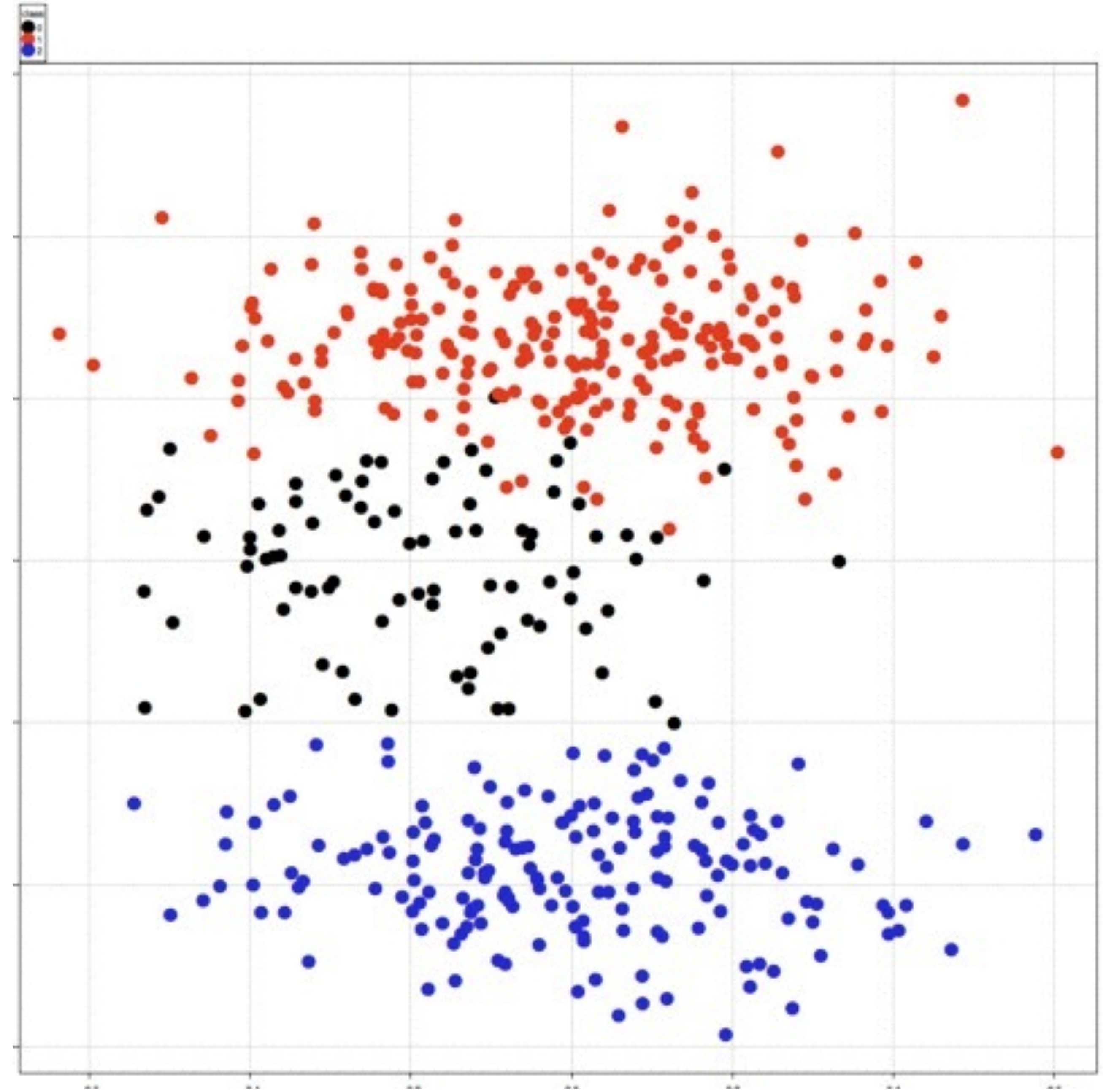
(75 x datasets,
4 x DR,
3 x visual encoding)

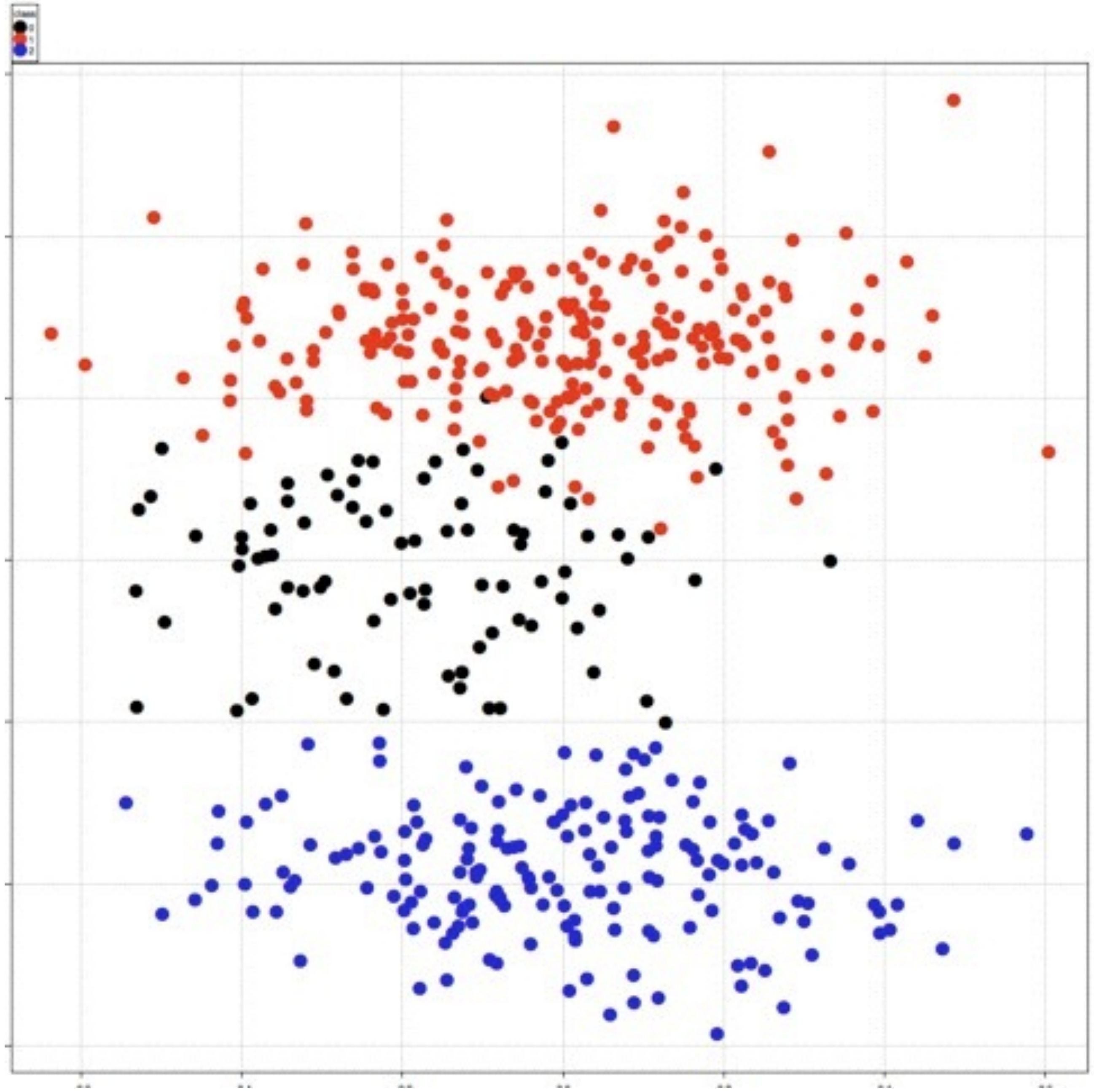
Data study!

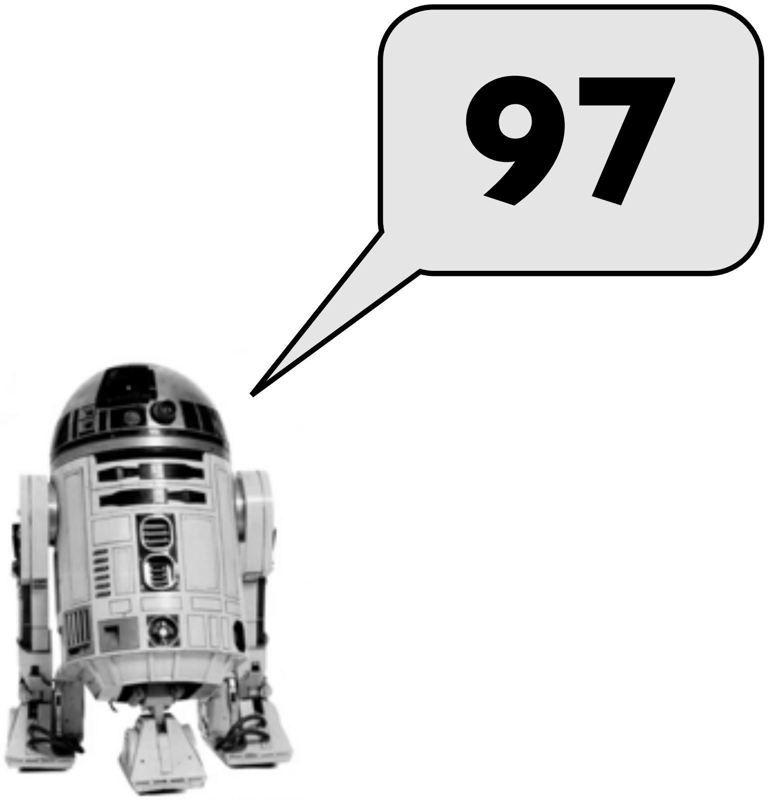
Automatic Judgements

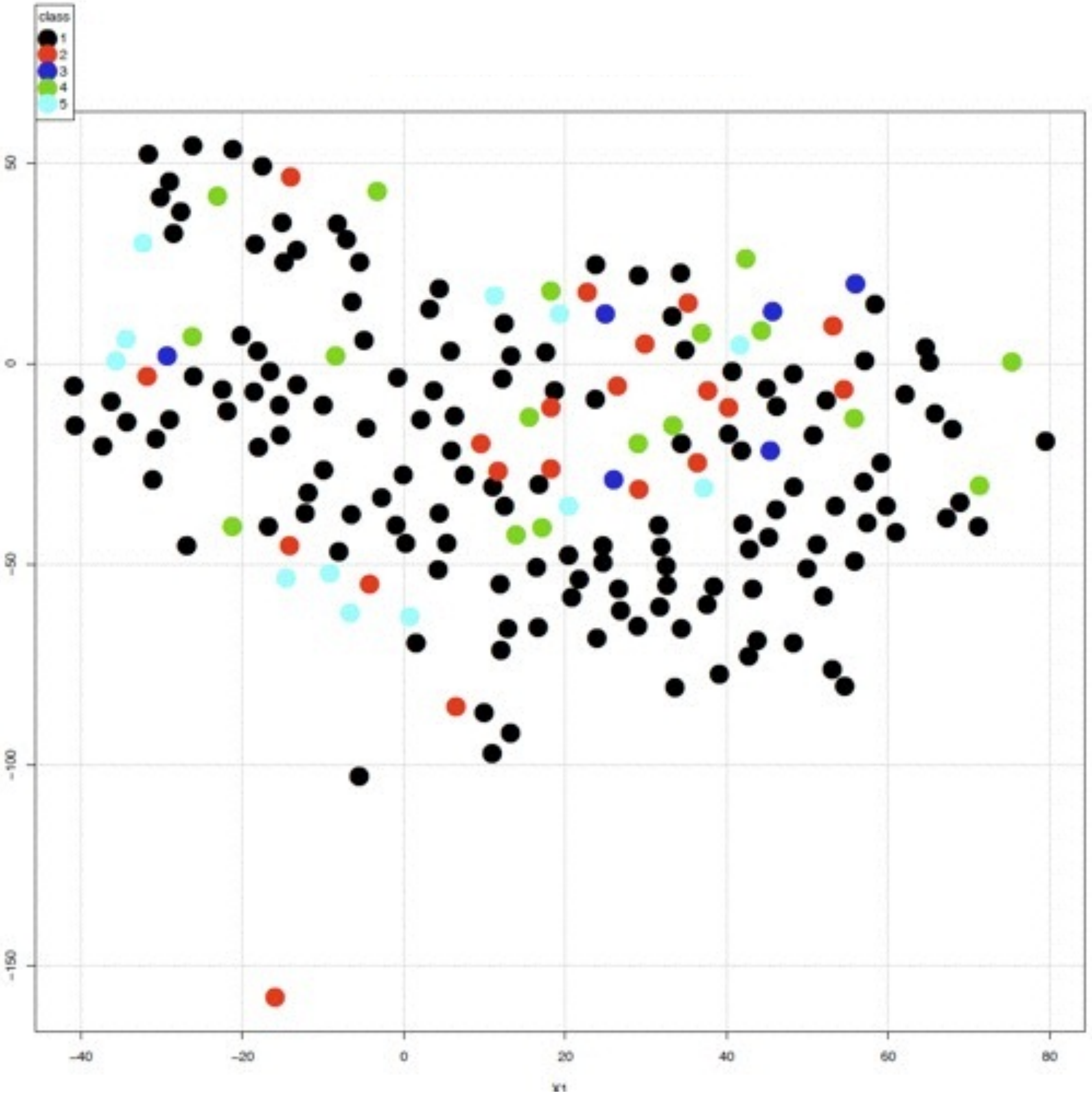
with state of the art separation measures

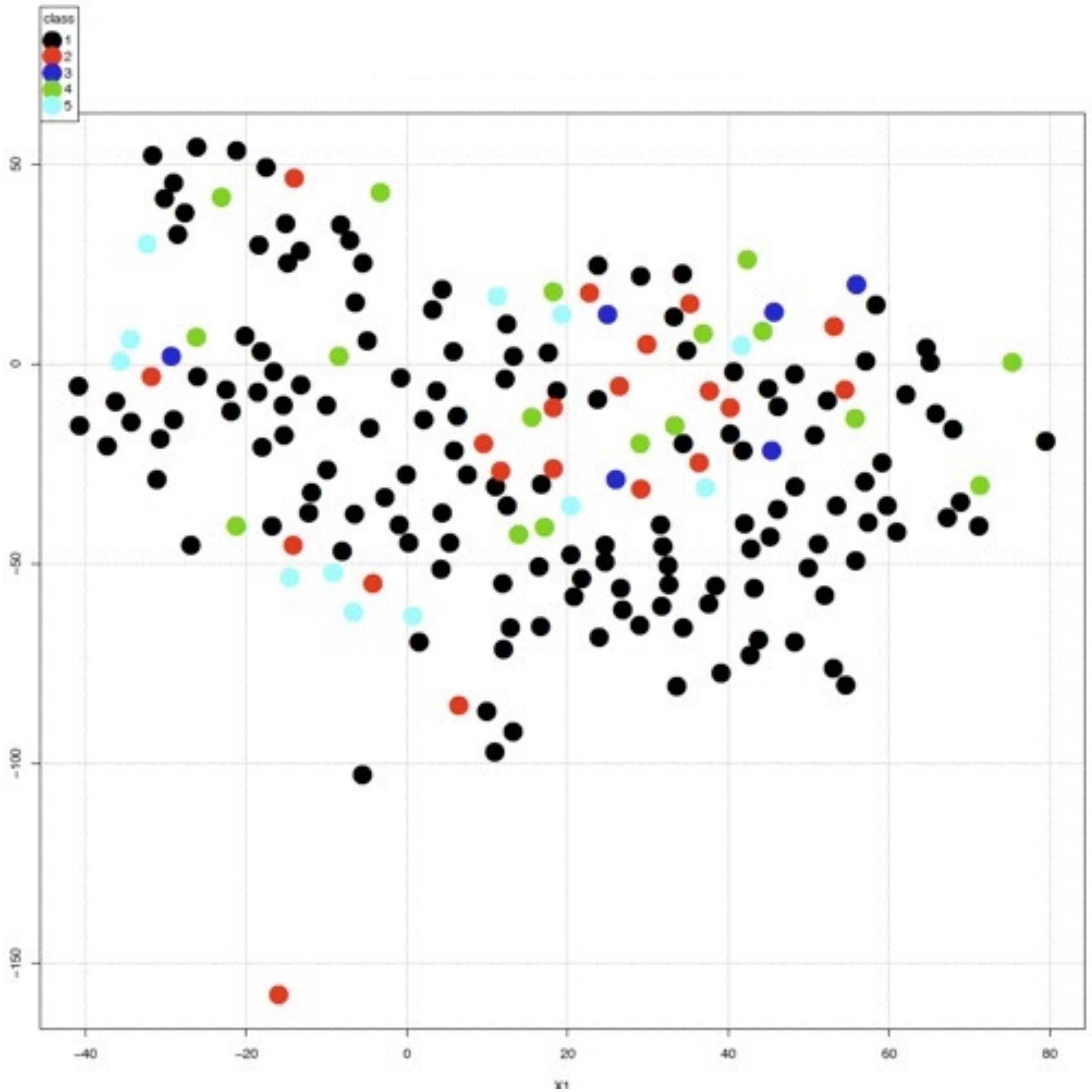

100 (good)
0 (bad)

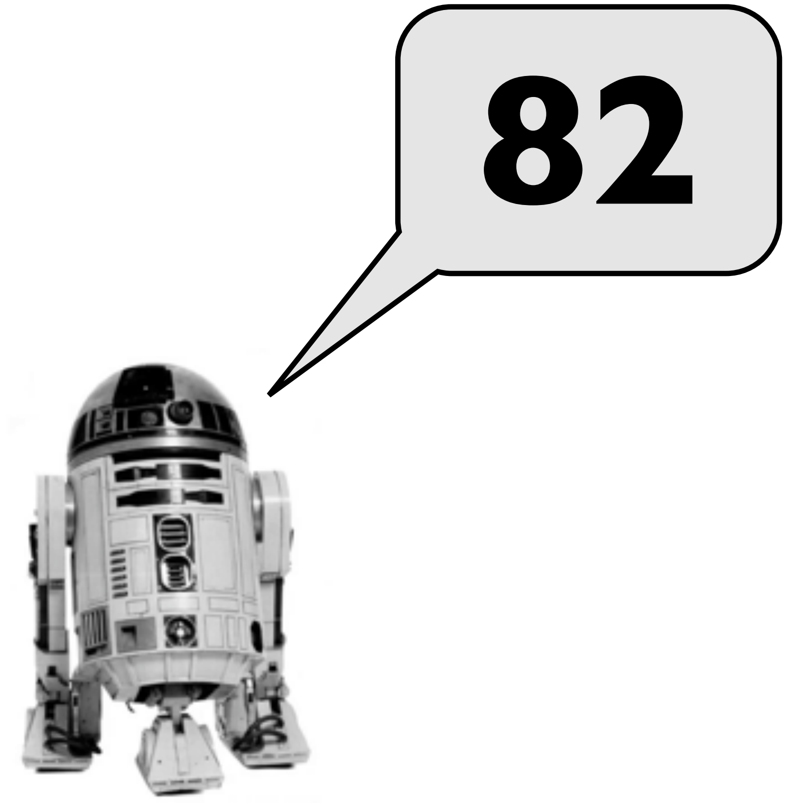


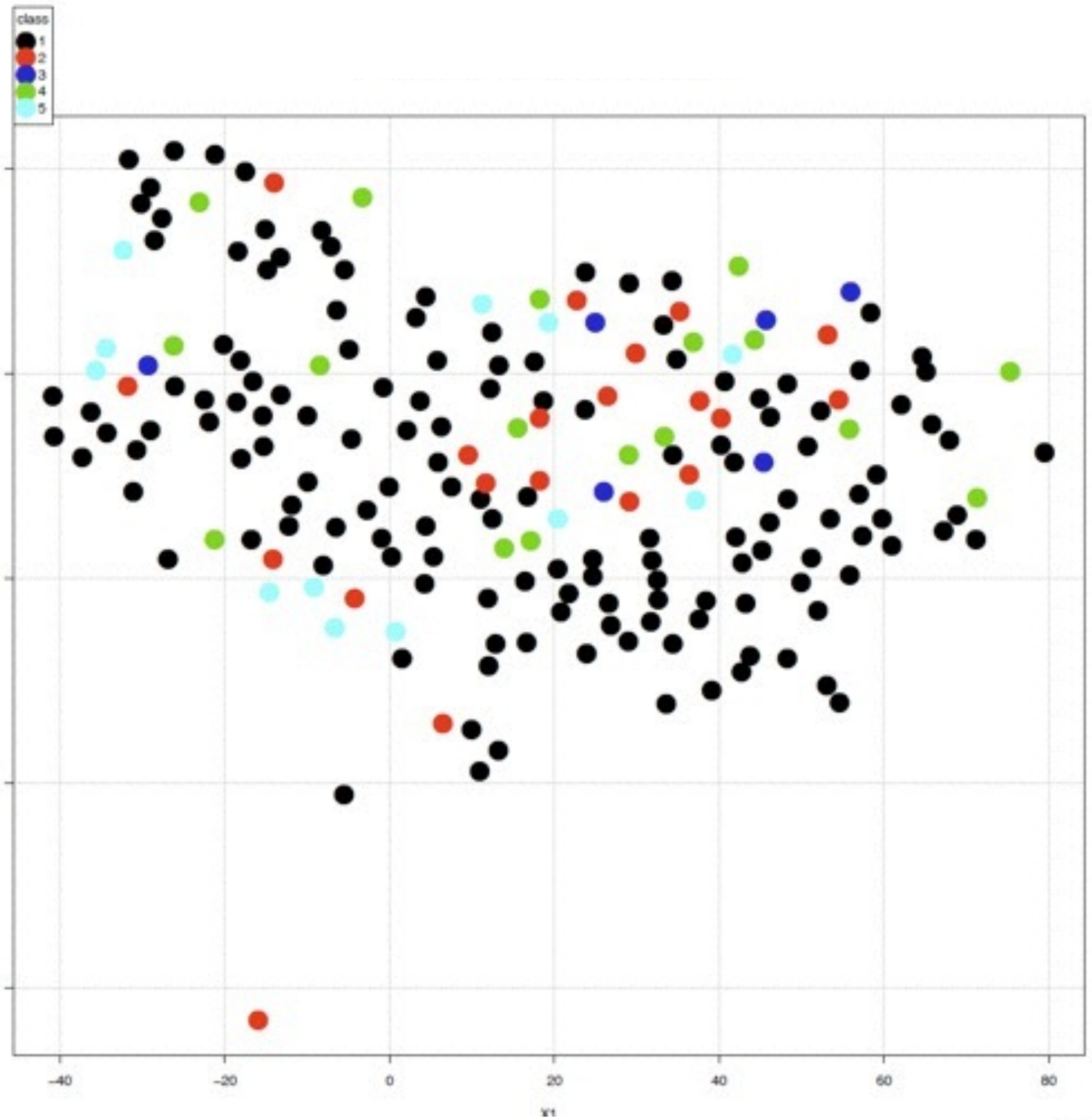


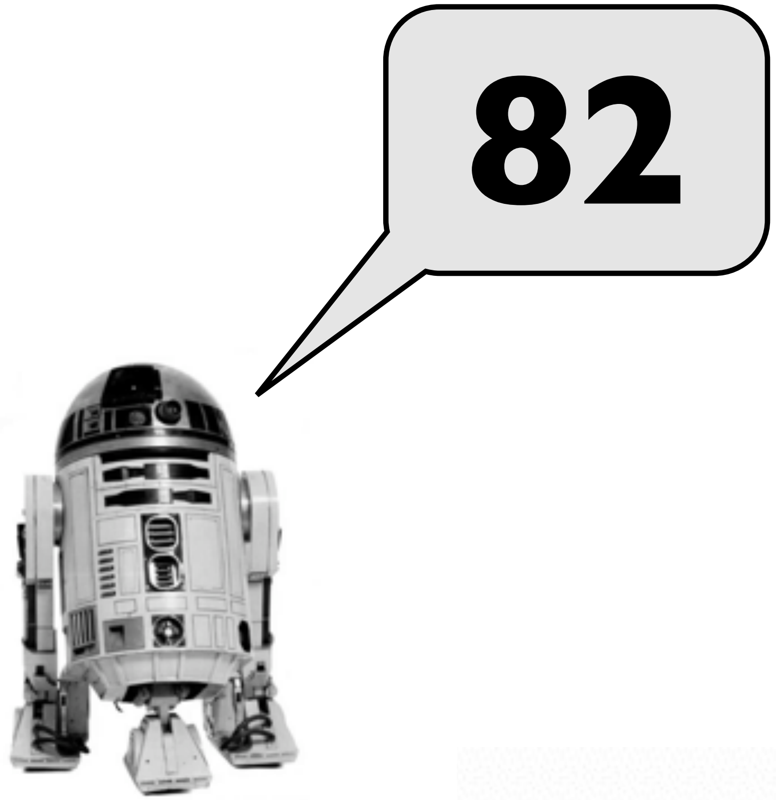

97


class
1
2
3
4
5
50
0
-50
-100
-150
-40
-20
0
20
40
60
80


class
1
2
3
4
5
50
0
-50
-100
-150
-40
-20
0
20
40
60
80


82





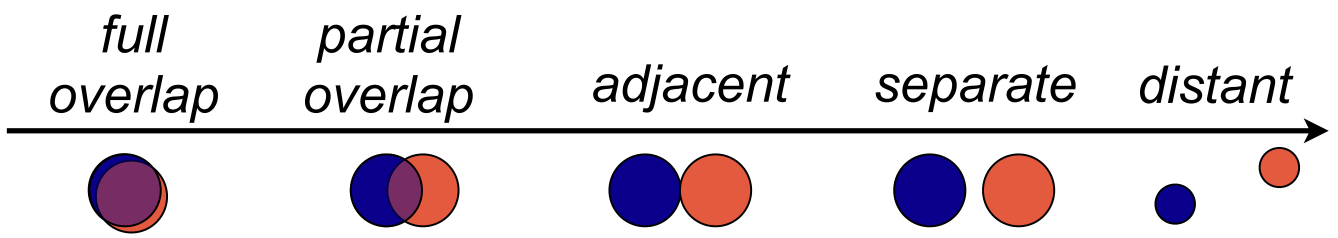
Many discrepancies

automatic vs. human

questions

How reliable are current separation measures on a diverse group of datasets?

What factors matter in human cluster perception?



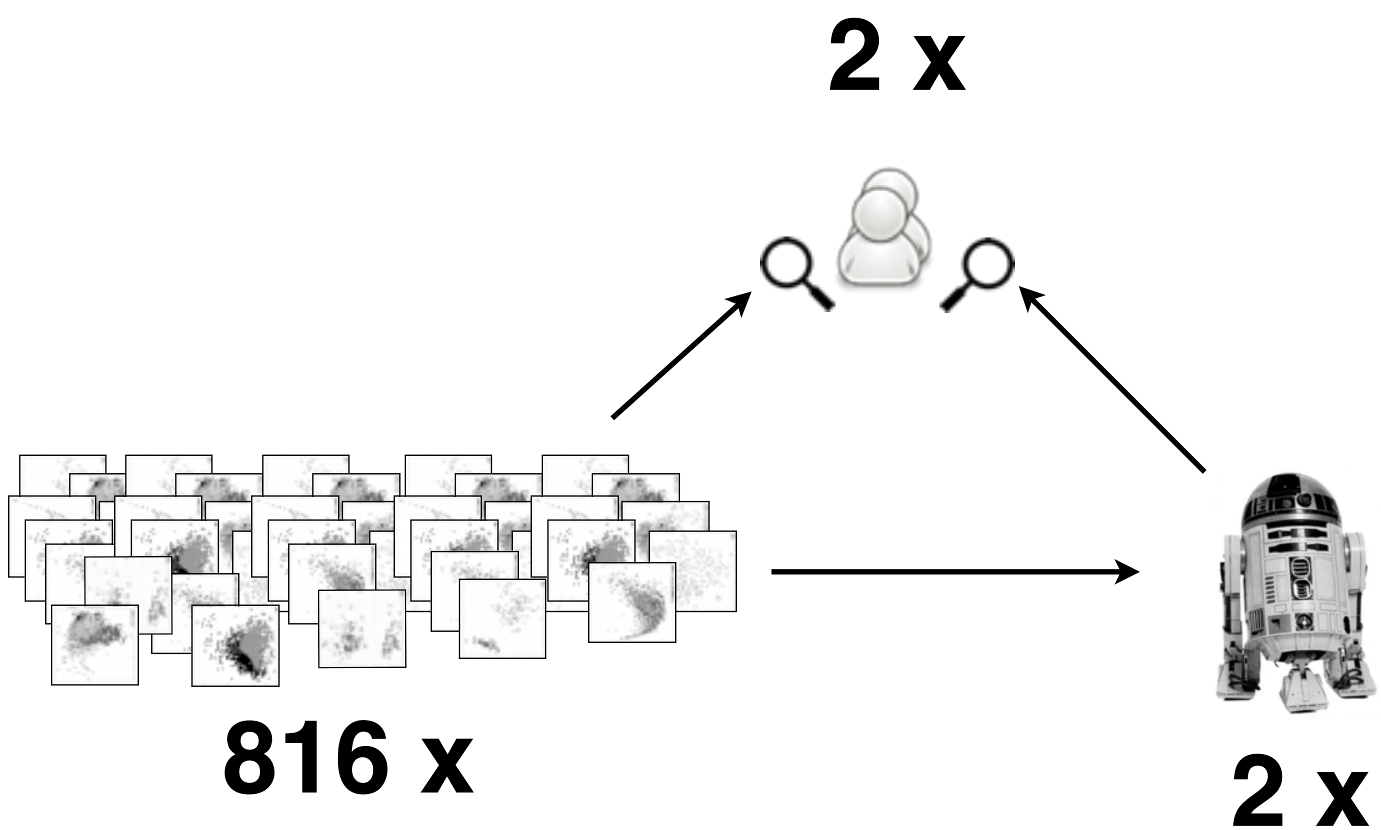
A Taxonomy of Visual Cluster Separation Factors

[EuroVis 2012]

M. Sedlmair, A. Tatu, T. Munzner, M. Tory

http://www.cs.ubc.ca/nest/imager/tr/2012/VisClusterSep/

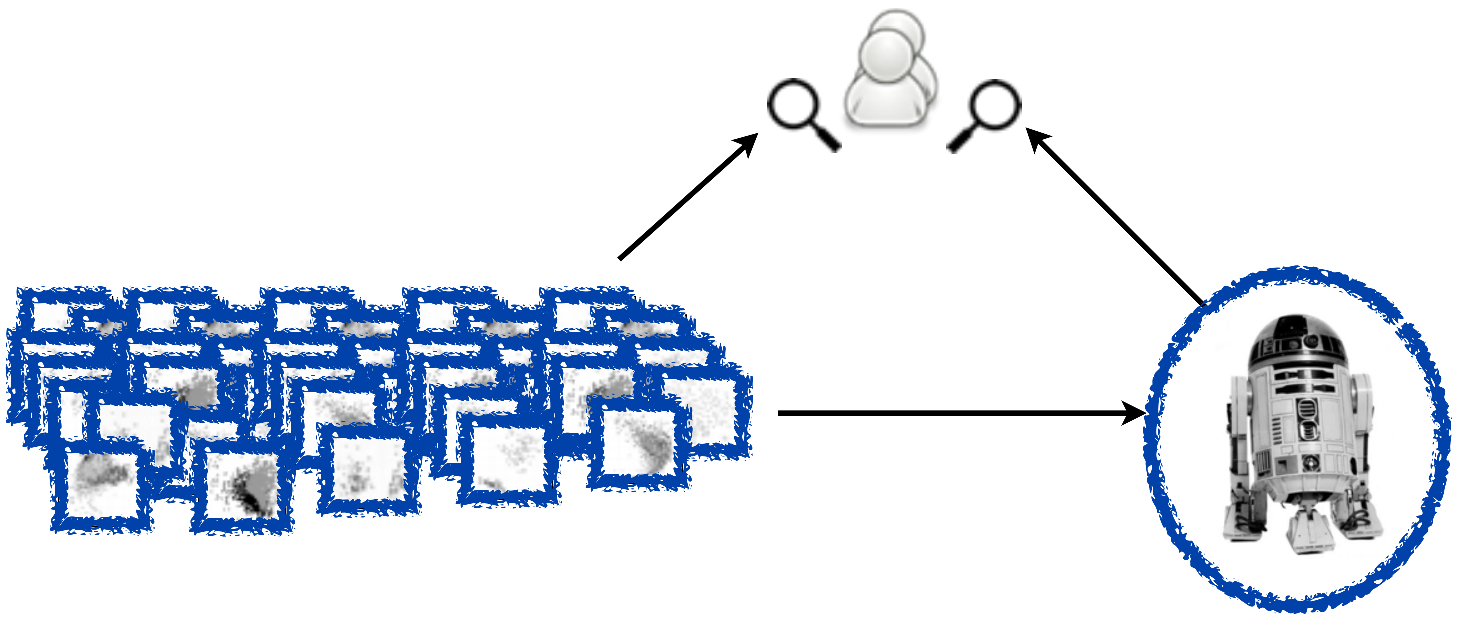
qualitative data study



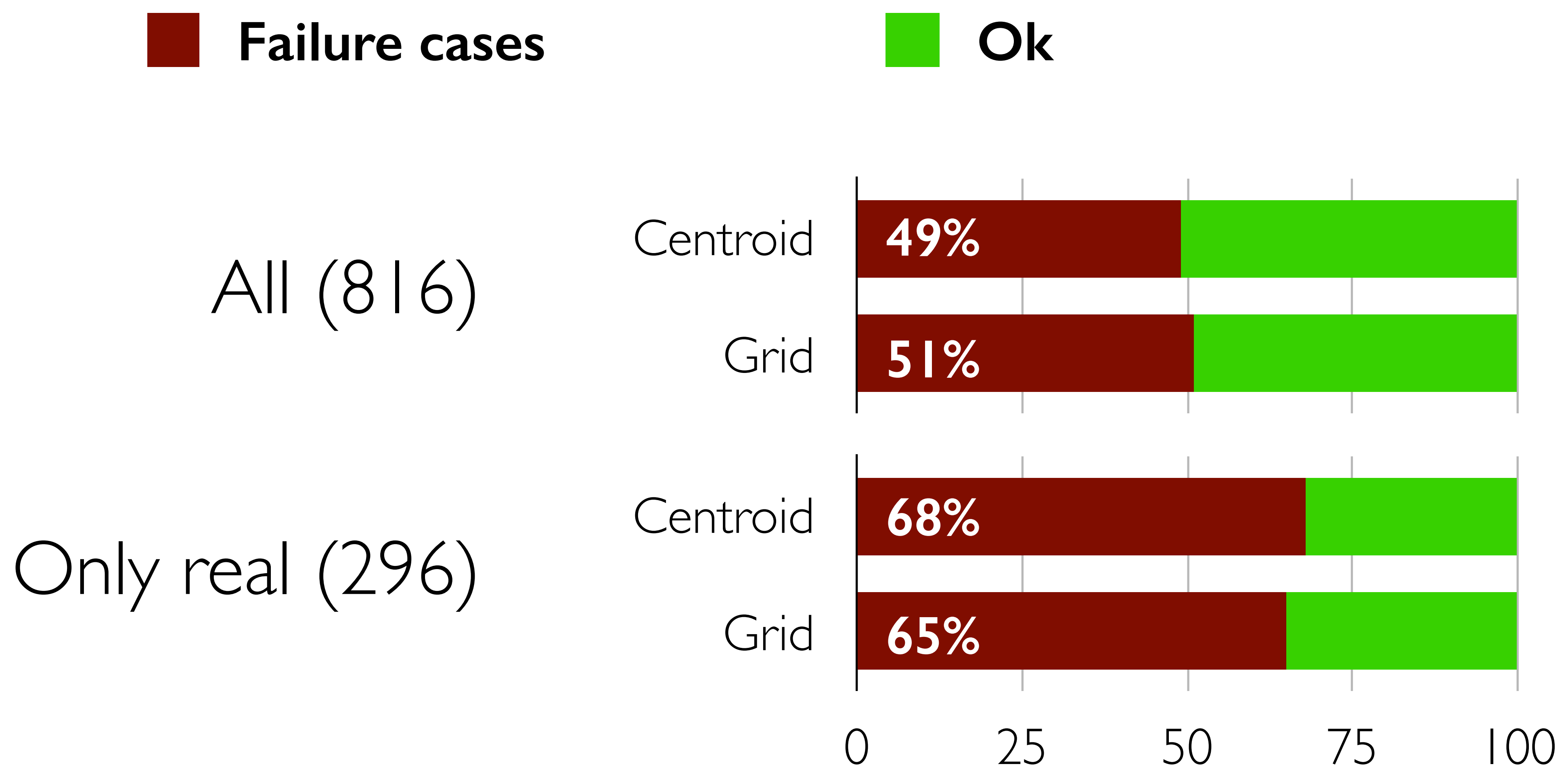
approach out of social science: open and axial coding*

* Charmaz, K. Constructing Grounded Theory: A Practical Guide through Qualitative Analysis. 2006.
* Furniss, D., Blandford, A., Curzon, P. and Mary, Q. (2011). Confessions from a grounded theory PhD: experiences and lessons learnt. Proc. ACM CHI 2011, p 113-122.

data analysis (part 1):
Evaluating the measures

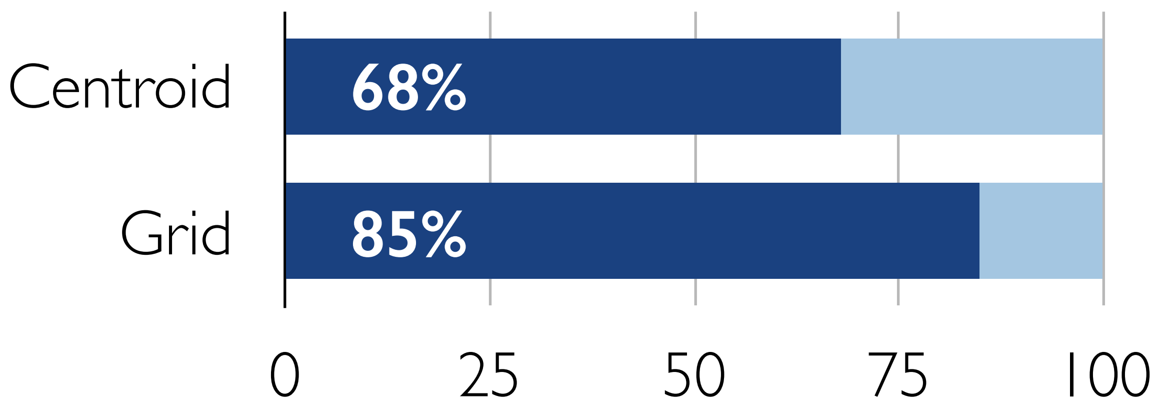


high-level results



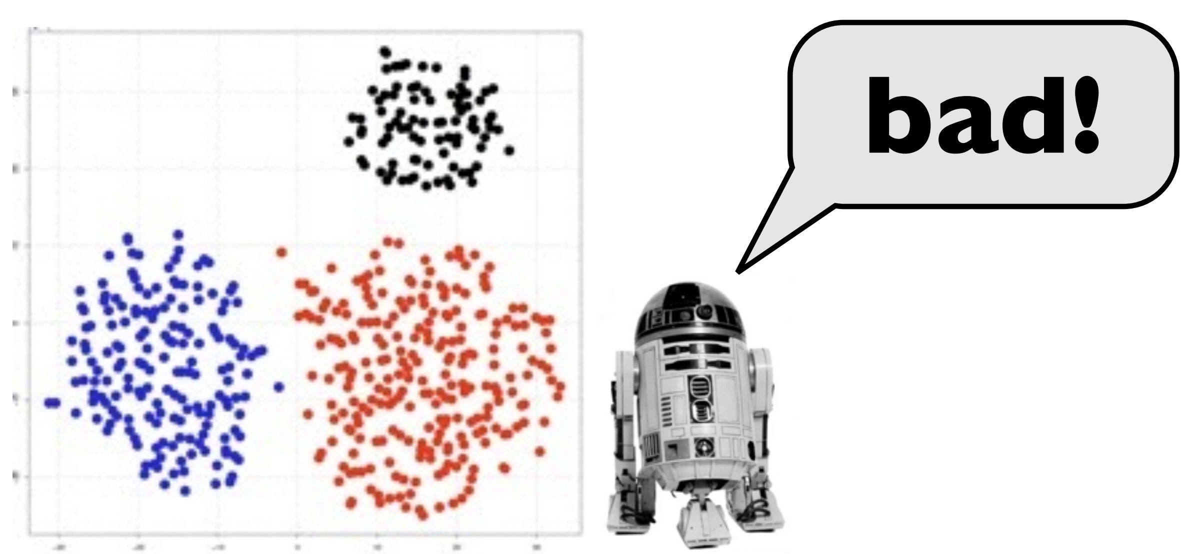
false positives / false negatives

All failure cases:

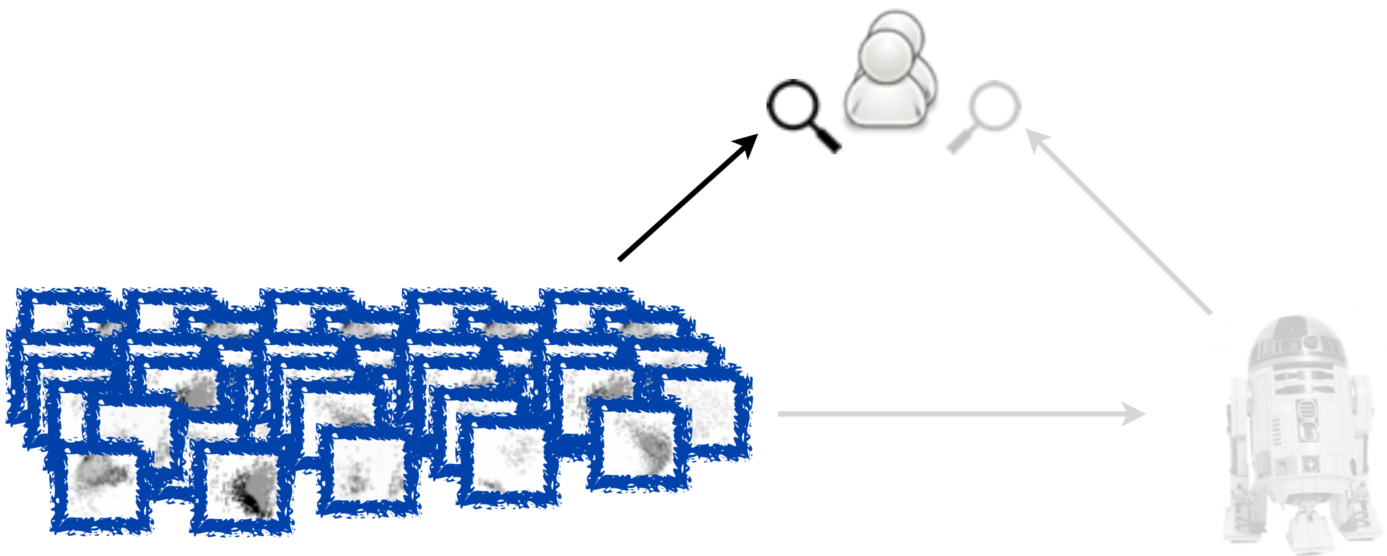


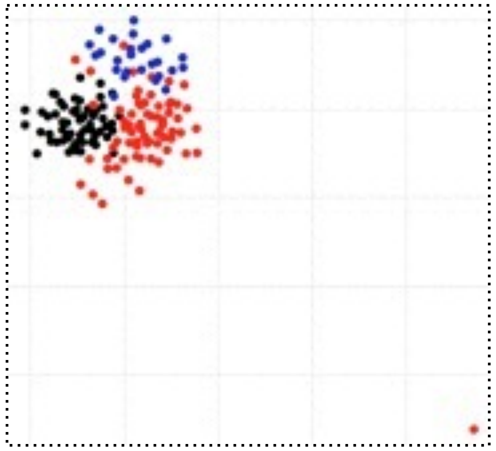
false positives

false negatives

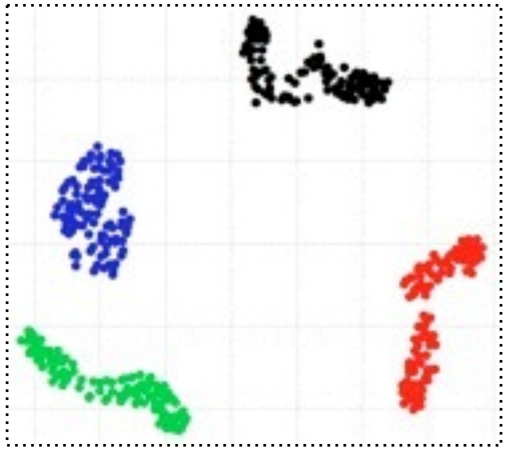


data analysis (part 2):
Qualitative analysis of cluster separation factors

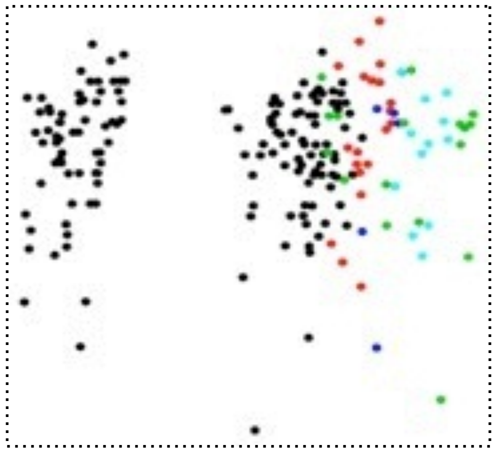




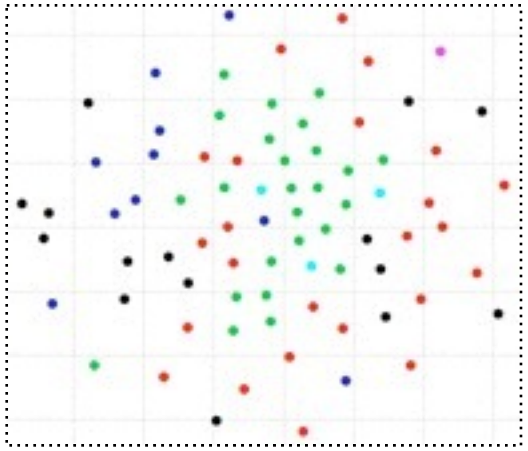
outlier



shape

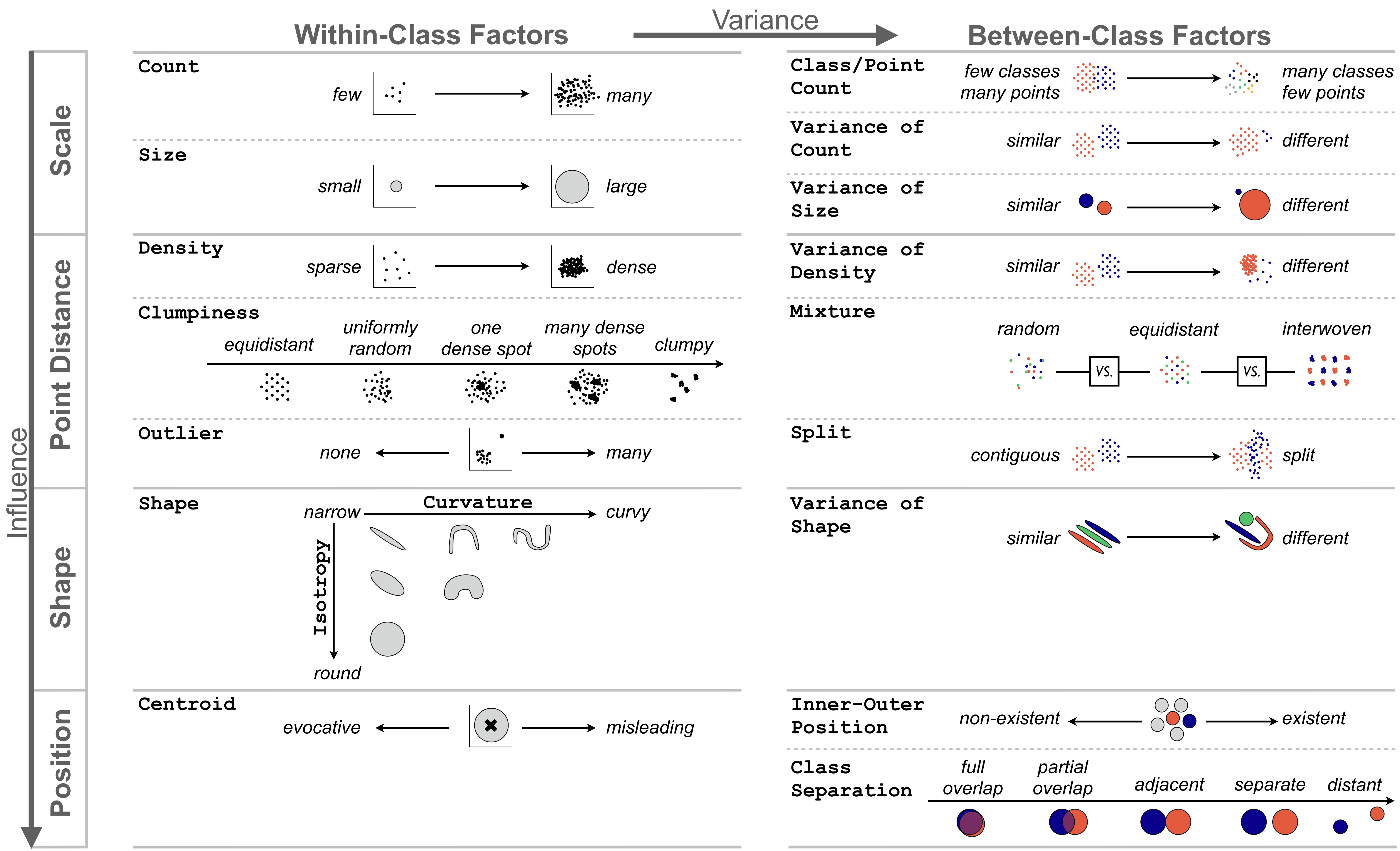


split

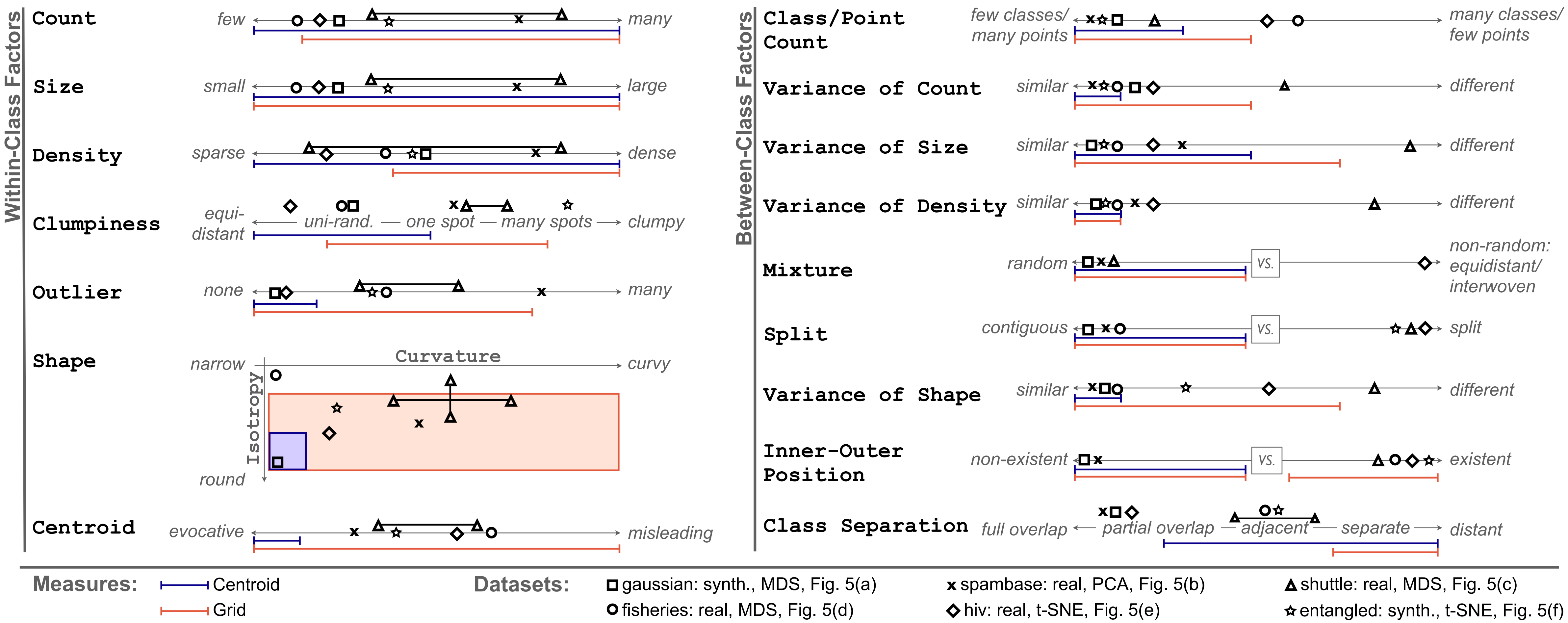


equidistant points

A **taxonomy** of visual cluster separation factors



Use taxonomy to analyze **why measures failed**



Empirical Guidance on Scatterplot and Dimension Reduction Technique Choices

[InfoVis 2013]

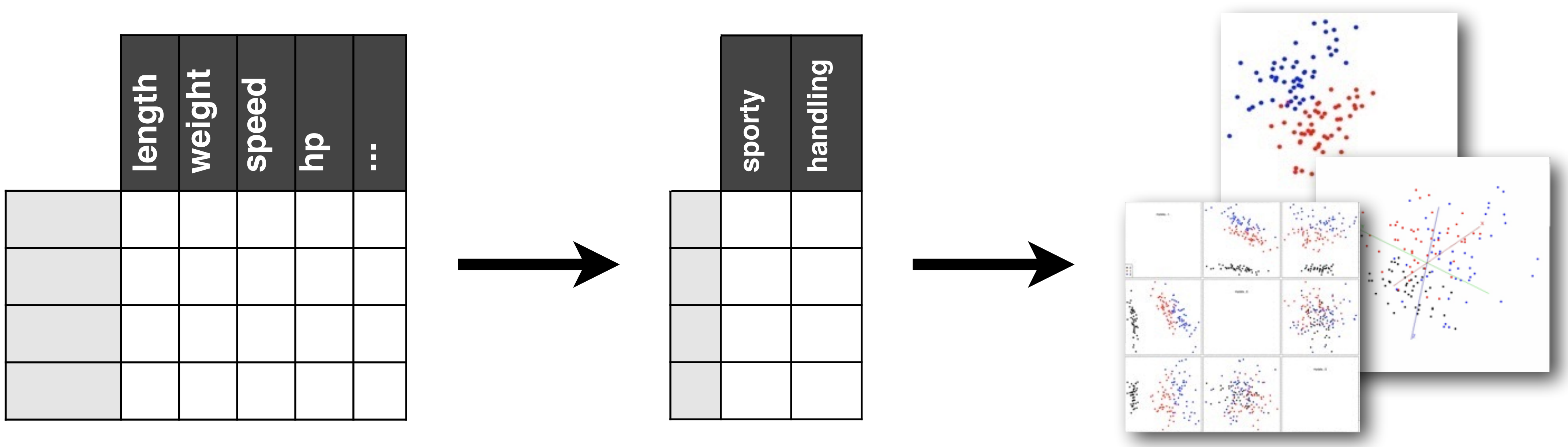
M. Sedlmair, T. Munzner, M. Tory

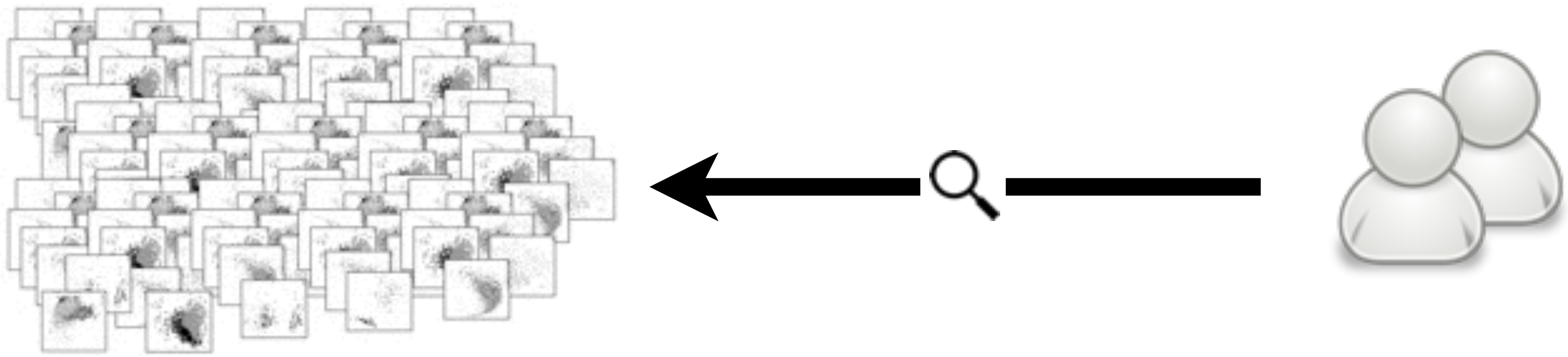
http://www.cs.ubc.ca/labs/imager/tr/2013/ScatterplotEval/



2D vs. 3D vs. SPLOM

Which visual encoding technique to use for visualizing DR data?



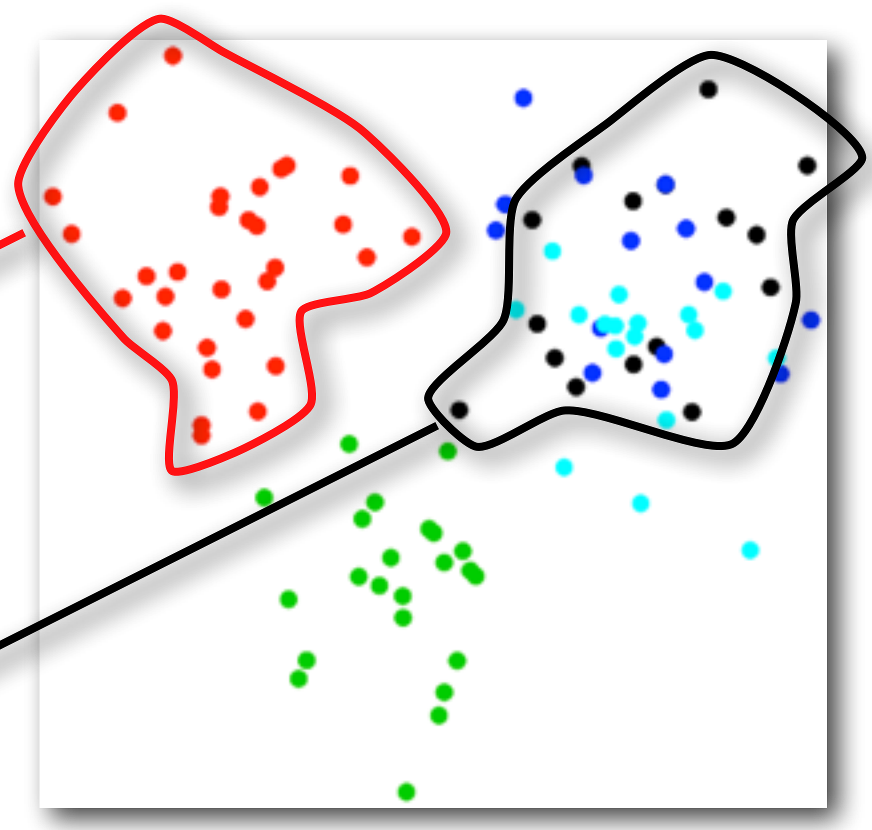


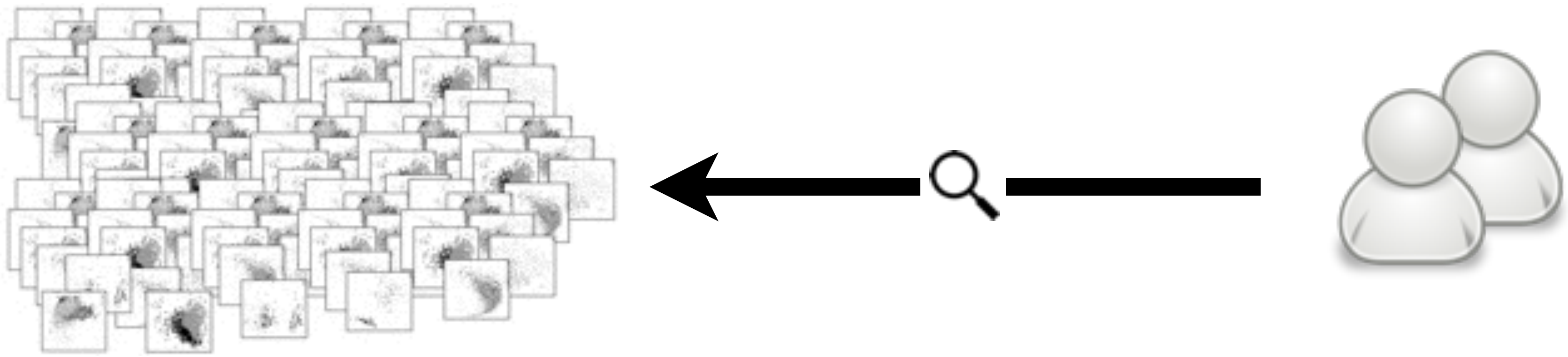
data study with 2 coders

inspect all 816 plots

quantitatively judge all 5460 clusters:

5 = *nicely separated*
4 ...
3 ...
2 ...
1 = *not separated*



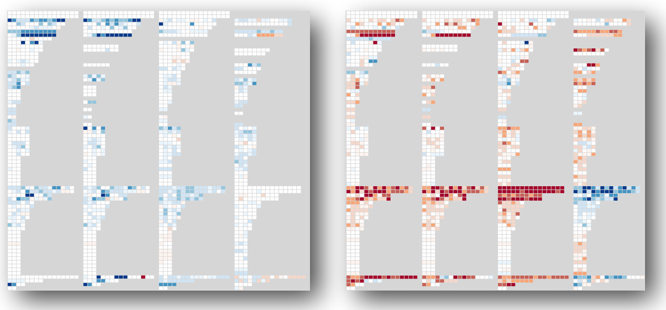


judging reliability

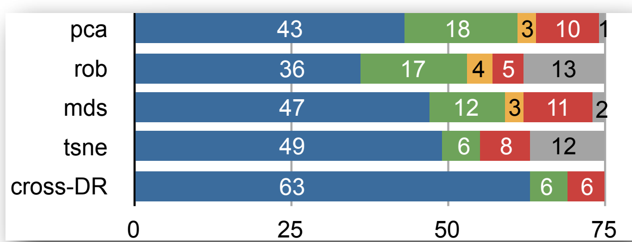
high inter-coder reliability (Krippendorff's alpha = 0.86)

"The Krippendorff's alpha coefficient is a statistical measure of the extent of agreement among coders" [Gwet, 2011]

data analysis



- Heatmaps approach



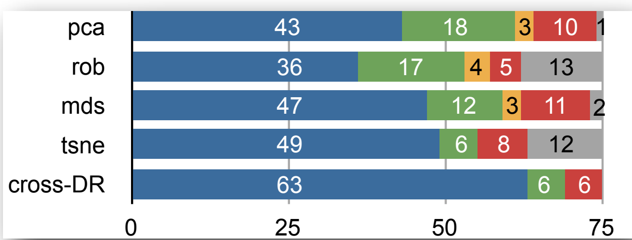
- Descriptive statistics

$p < .05$

- Significance tests

data analysis

- Heatmaps approach



- Descriptive statistics

$p < .05$

- Significance tests

cost assumption

- 2D < SPLOM < 3D
  - Based on rich body of previous work*

*** previous work:**

Drawbacks of 3D

Chalmers: Using a landscape metaphor to represent a corpus of documents [COSIT'93]

Cockburn and McKenzie: An evaluation of cone trees [British Conf. on HCI'00]

Cockburn and McKenzie: Evaluating the effectiveness of spatial memory in 2D and 3D physical and virtual environments [CHI'02]

Newby: Empirical study of a 3D visualization for information retrieval tasks. J. Intelligent Information Systems, 18(1):31–53, 2002.

Tory et al.: Spatialization design: comparing points and landscapes [InfoVis'07]

Tory et al.: Comparing dot and landscape spatializations for visual memory differences [InfoVis'09]

Westerman and Cribbin: Mapping semantic information in virtual space: dimensions, variance and individual differences [IJHCS'00]

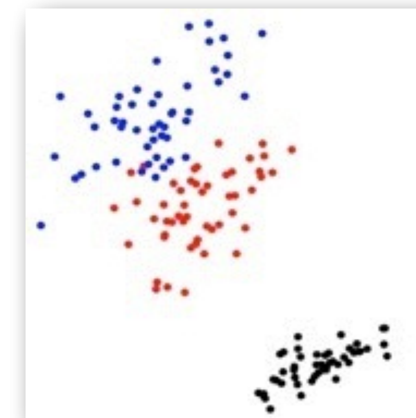
Interaction Costs

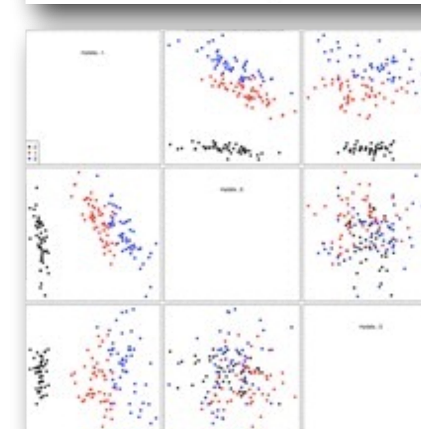
Lam: A framework of interaction costs in information visualization [InfoVis'08]

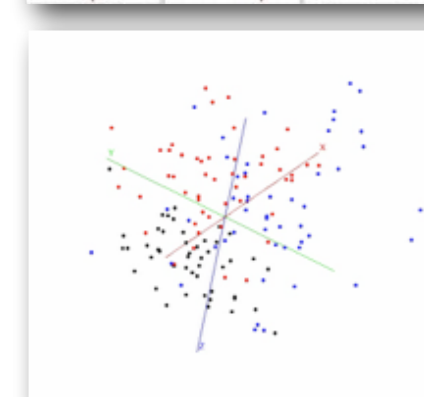
Van Wijk: Views on visualization [TVCG'06]

cost assumption

- 2D < SPLOM < 3D
  - Based on rich body of previous work*
- **Reasons:**
  - 2D (low): static, directly visible
  - SPLOM (medium): switching attention between views
  - 3D (high): interaction to resolve occlusions







cost assumption

- Use a higher cost visual encoding **only** if it provides notably better class separation

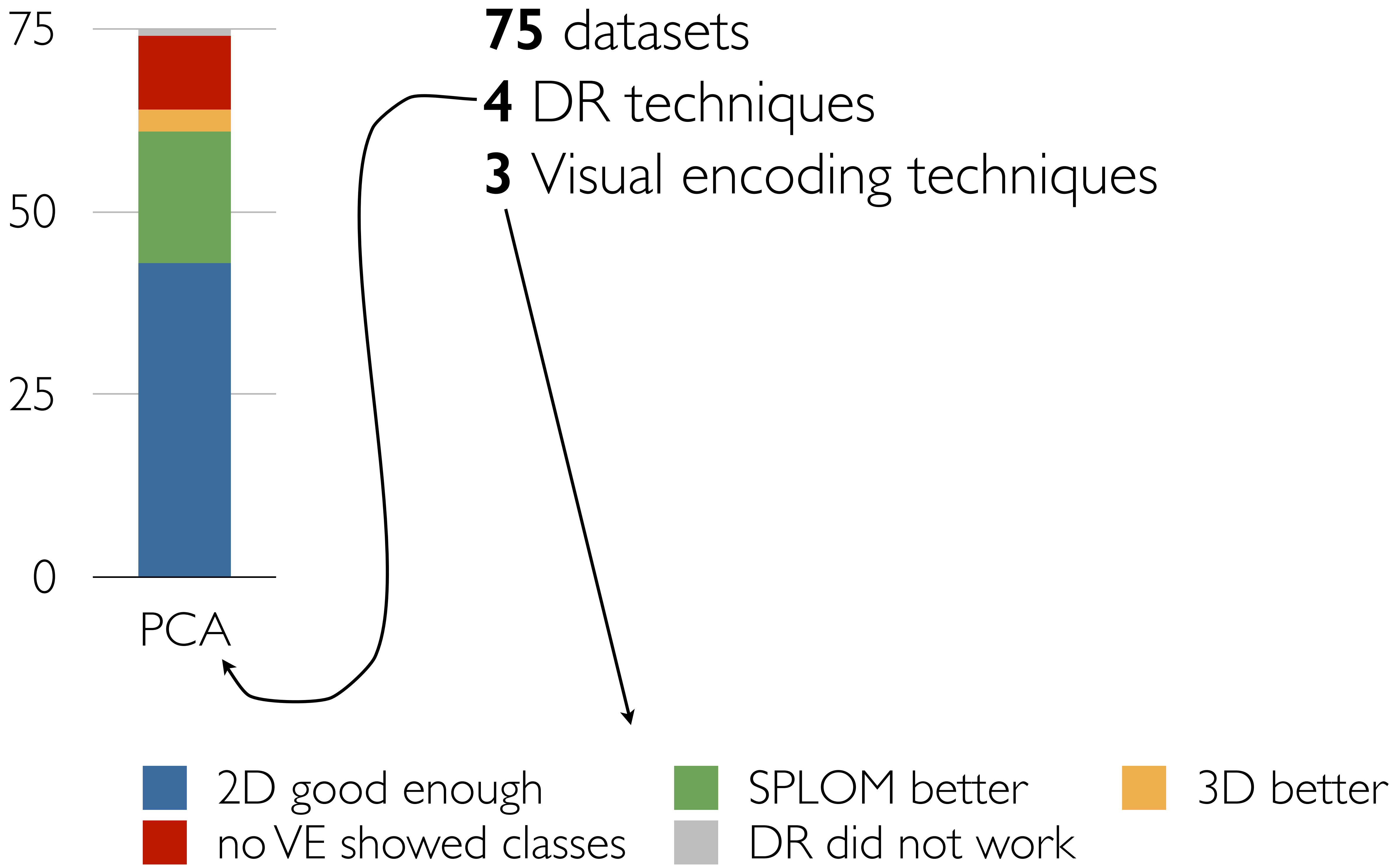
- Use 2D if **“good enough”**, if not then SPLOM, then 3D

results

75 datasets

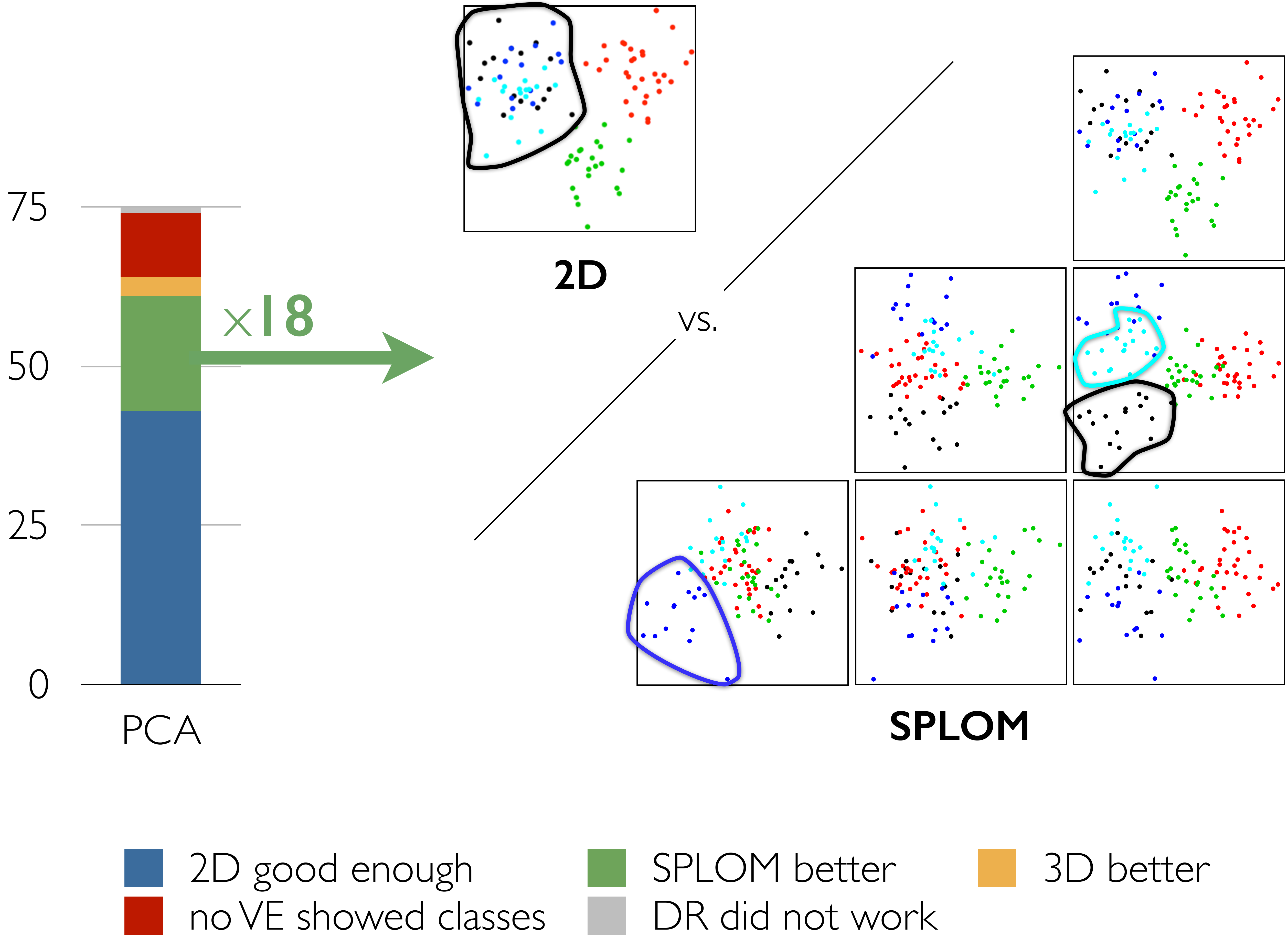
4 DR techniques

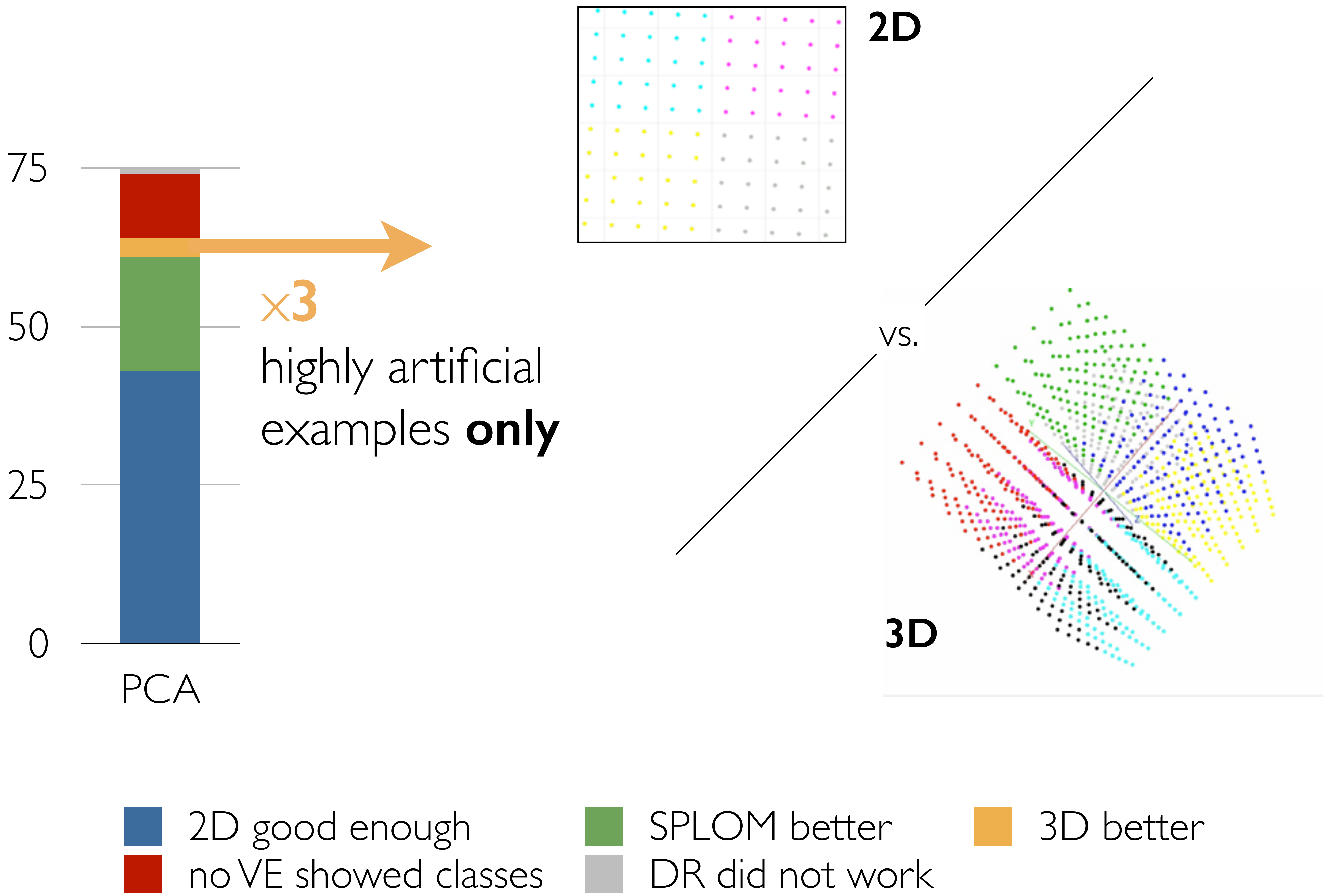
3 Visual encoding techniques



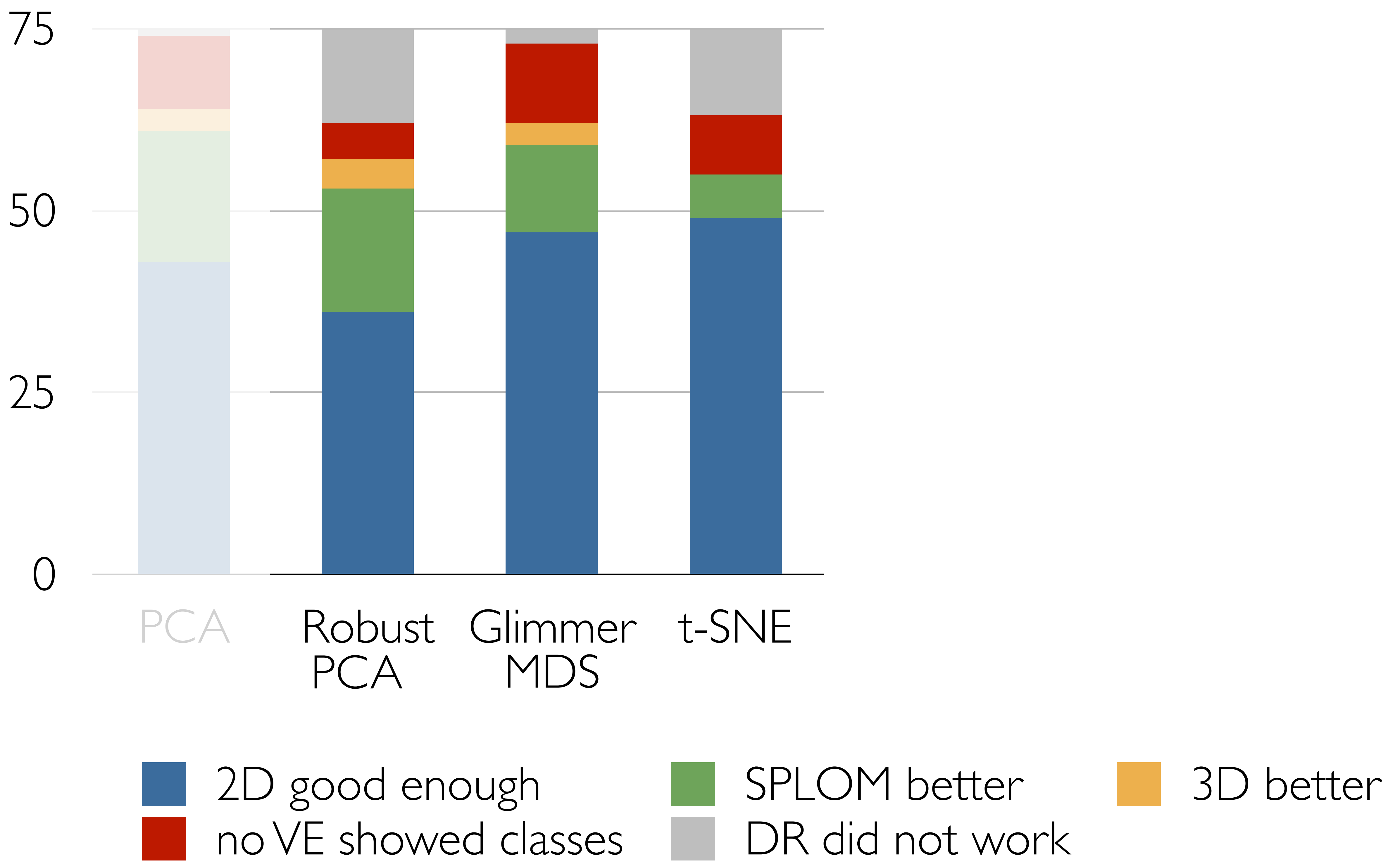
results

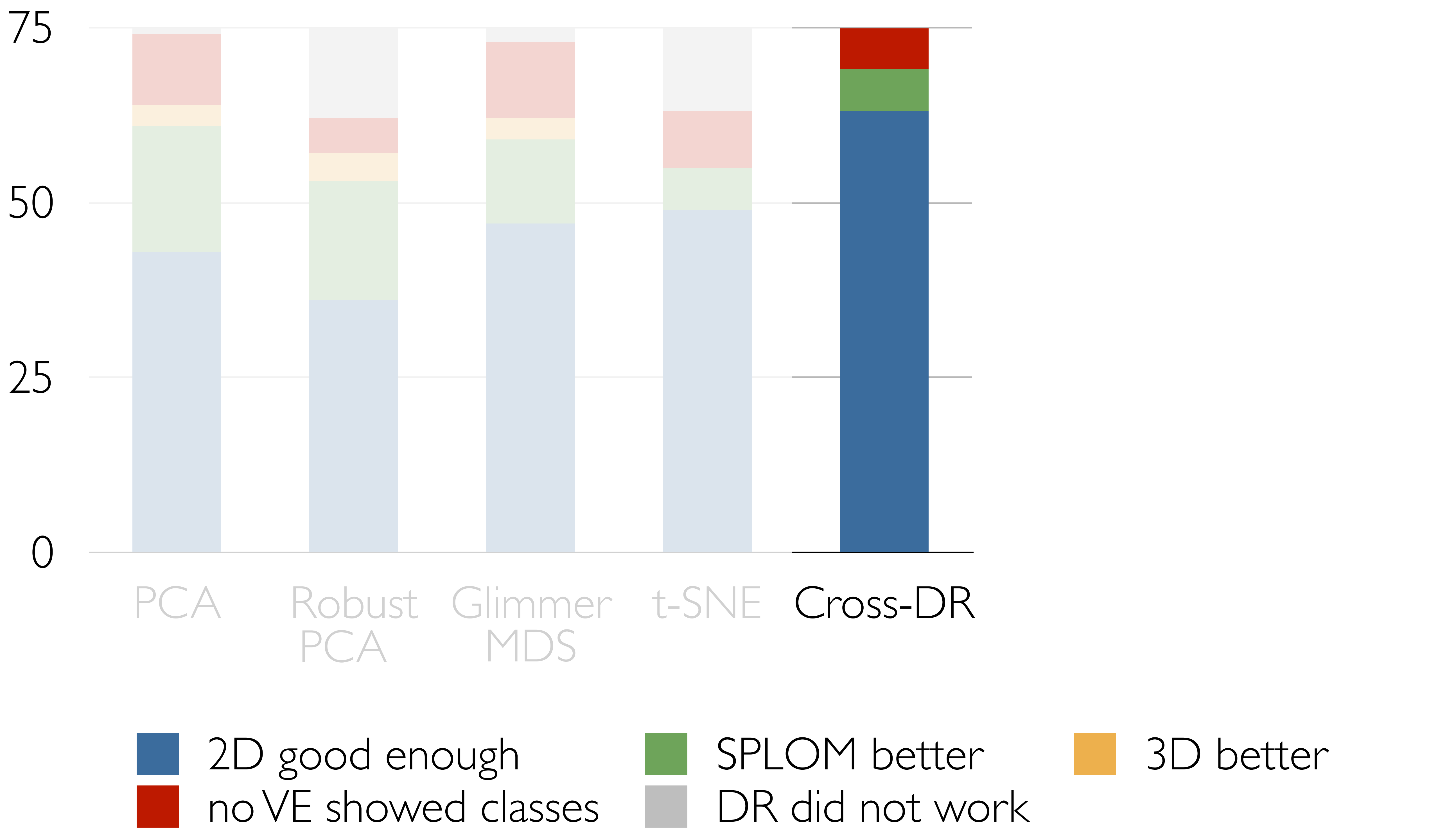
“better” = at least one class is notably more separable


75
50
25
0
PCA
×18
2D
vs.
SPLOM
2D good enough
SPLOM better
3D better
no VE showed classes
DR did not work



75
50
25
0
PCA
×3
highly artificial examples **only**
2D
vs.
3D
2D good enough
SPLOM better
3D better
no VE showed classes
DR did not work


75
50
25
0
PCA
Robust PCA
Glimmer MDS
t-SNE
2D good enough
SPLOM better
3D better
no VE showed classes
DR did not work



75
50
25
0
PCA
Robust PCA
Glimmer MDS
t-SNE
Cross-DR
2D good enough
SPLOM better
3D better
no VE showed classes
DR did not work

implications

Use 2D: 2D often good enough

Change DR: if not, change DR technique

Then SPLOM: SPLOM occasionally helps

No 3D: 3D rarely helps and often hurts

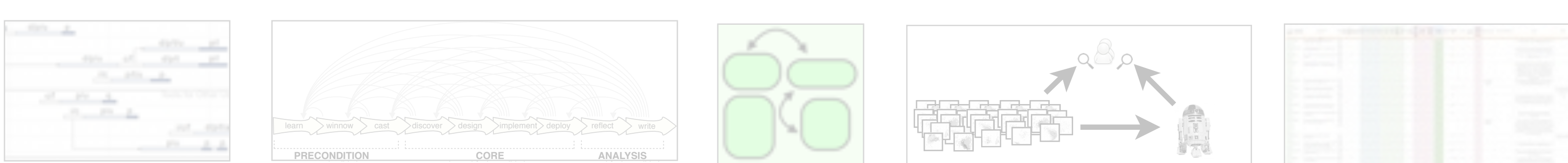
real users/real data:

Studies on high-dimensional data analysis techniques

Applied visualization projects (9 BMW, 3 others)

right methods:

Novel and refined research methods/methodologies

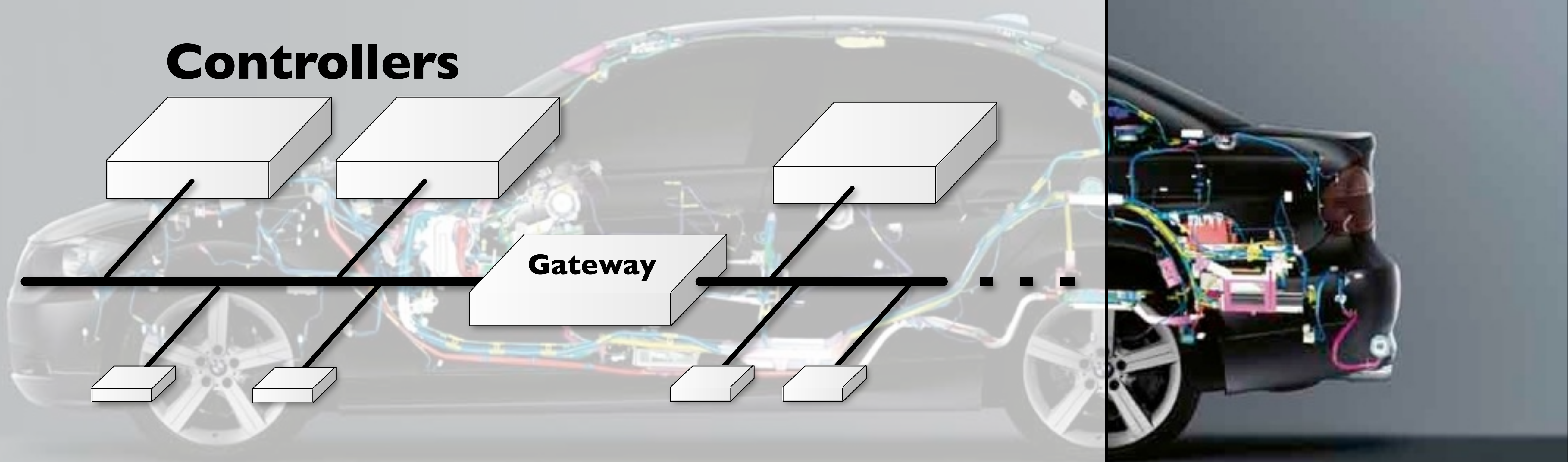


Applied Visualization Projects:

Automotive Engineers

more and more electronics...

... enabled by in-car communication networks



~70 Controllers / Car

Cardiogram: Visual Analytics for Automotive Engineers

[CHI 2011]

M. Sedlmair, P. Isenberg, D. Baur, M. Mauerer, C. Pigorsch, A. Butz

http://homepage.univie.ac.at/michael.sedlmair/papers/sedlmair2011chi.pdf





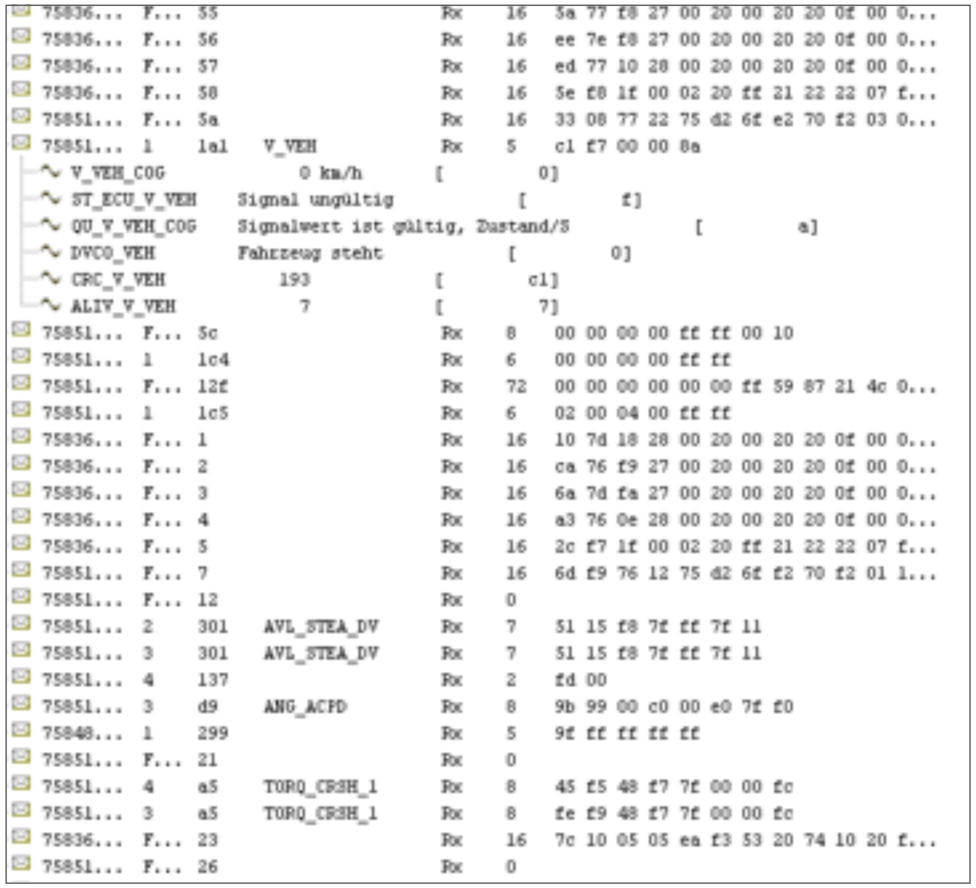

problem characterization

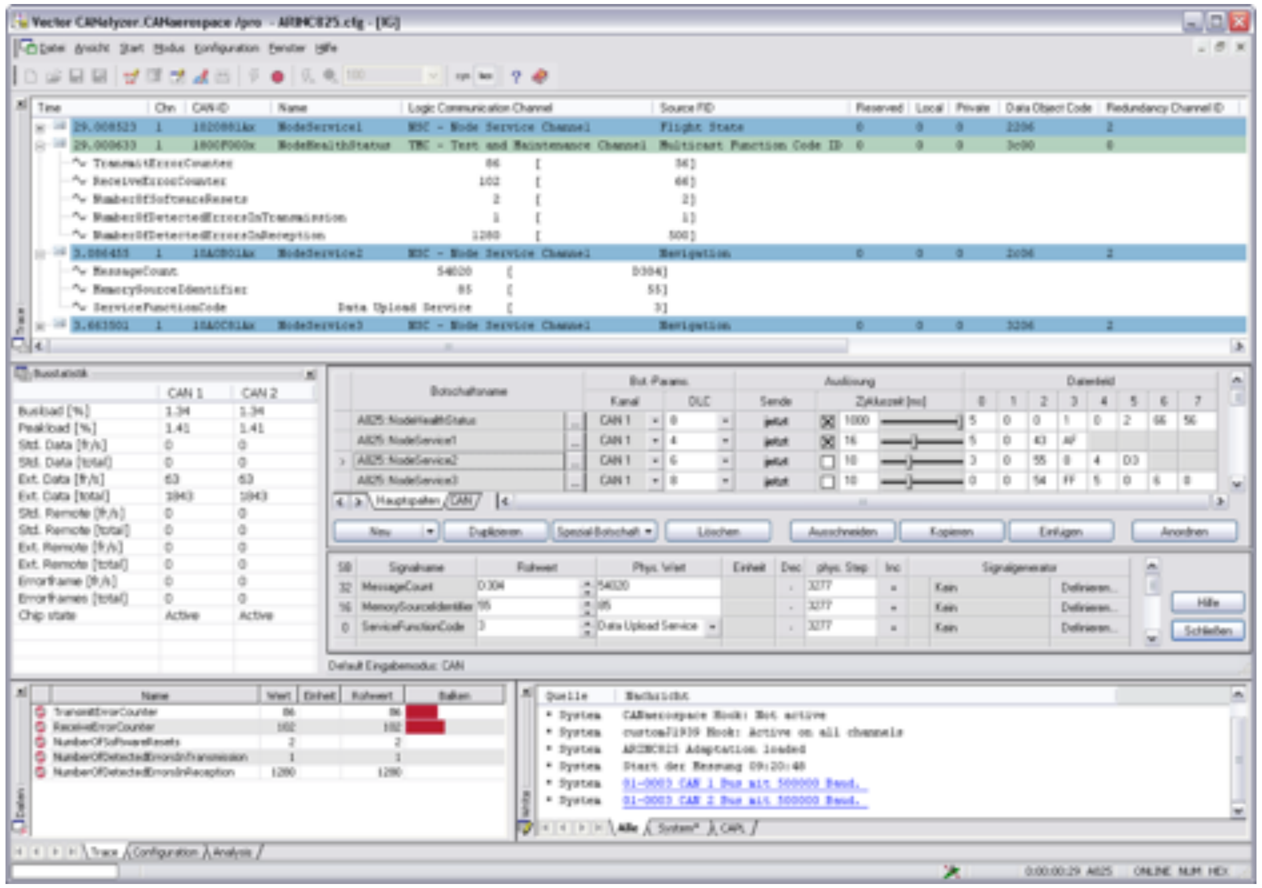
task: finding errors

process: test drives

data: recorded traces (15k messages/sec)

current practices: mainly textual lists





problem characterization

task: finding errors

process: test drives

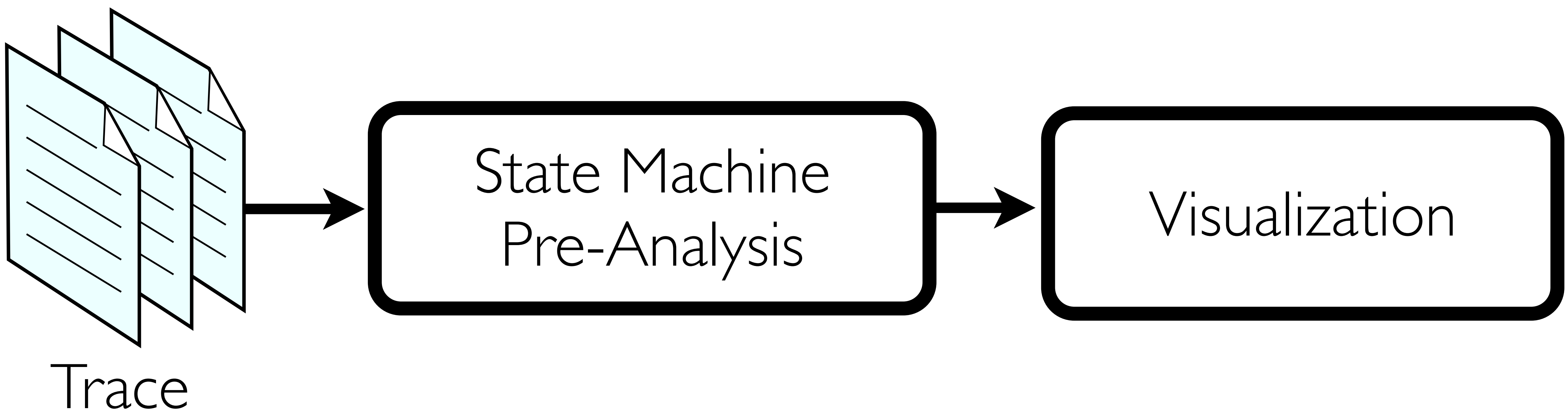
data: recorded traces (15k messages/sec)

current practices: mainly textual lists

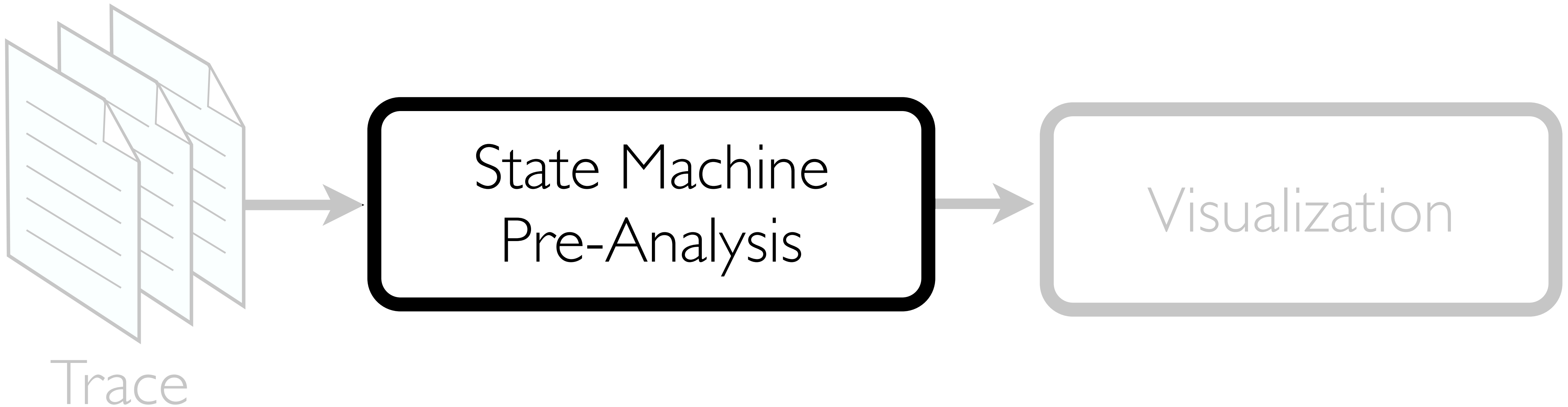
problems:

- handling masses of test traces (large and many)
- understanding correlation between trace and car behaviour
- ...

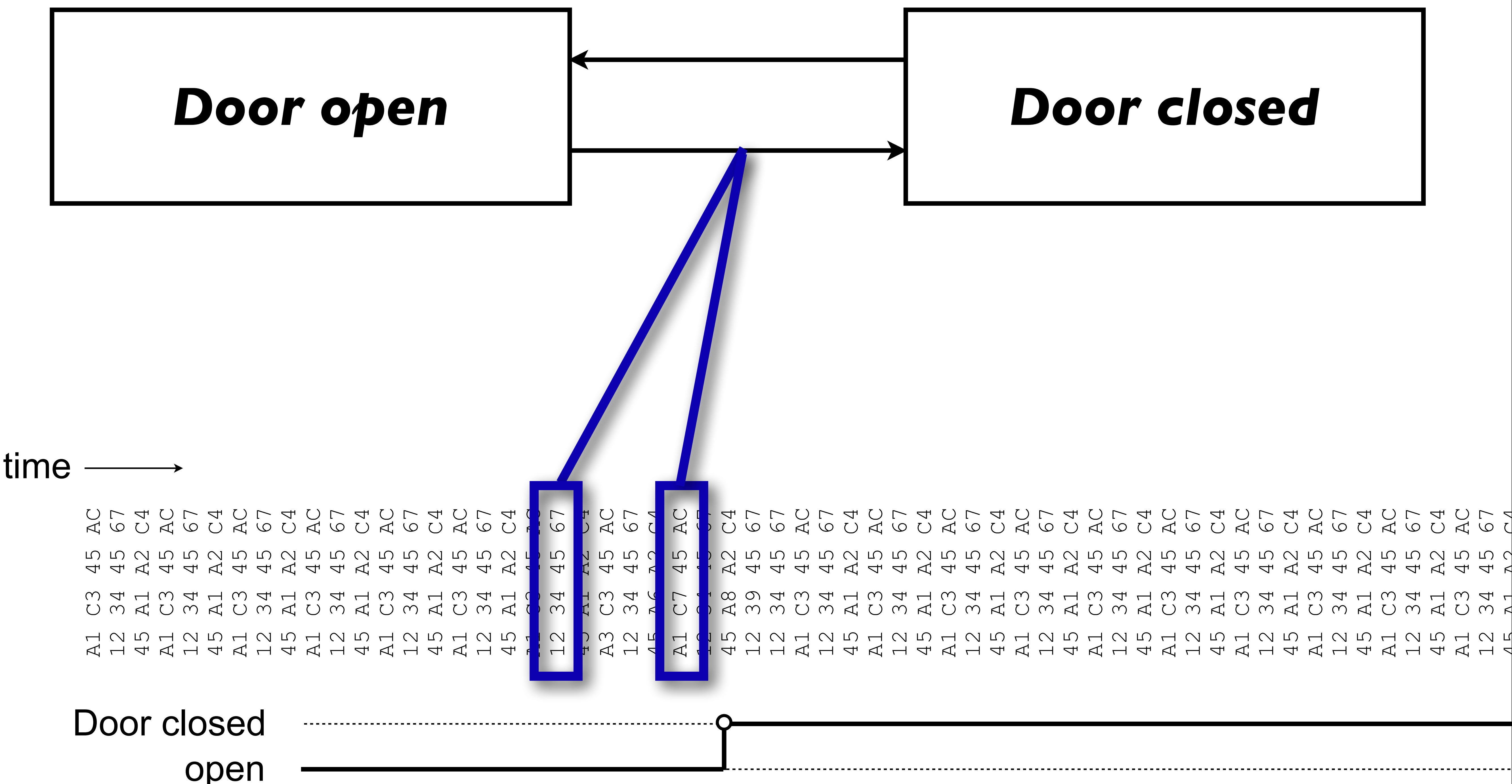
cardiogram:
overview



cardiogram:
state machine pre-analysis

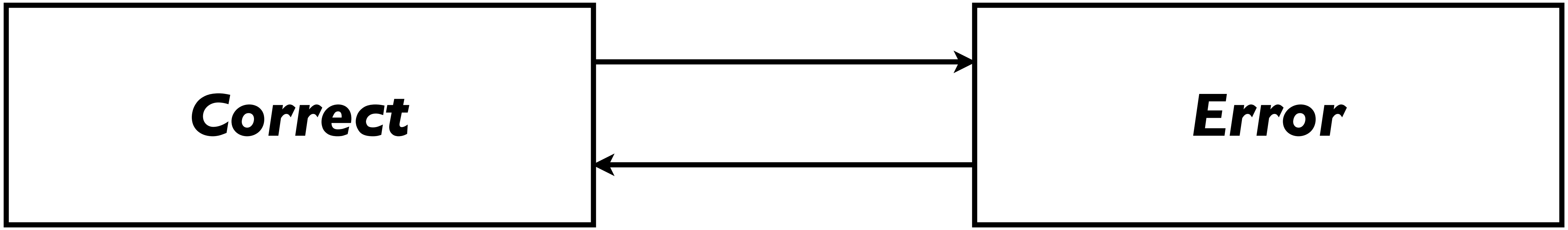


state machine:
behaviour abstraction

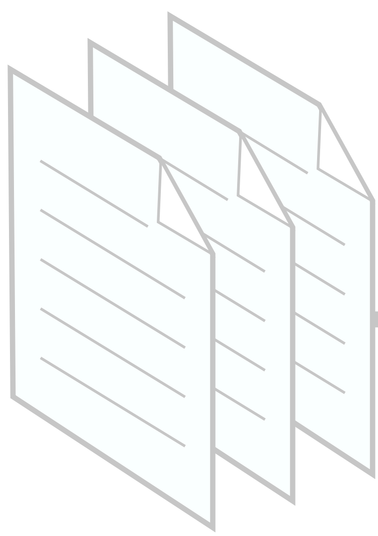


state machine:

automatic error detection



cardiogram:
create/select state machines

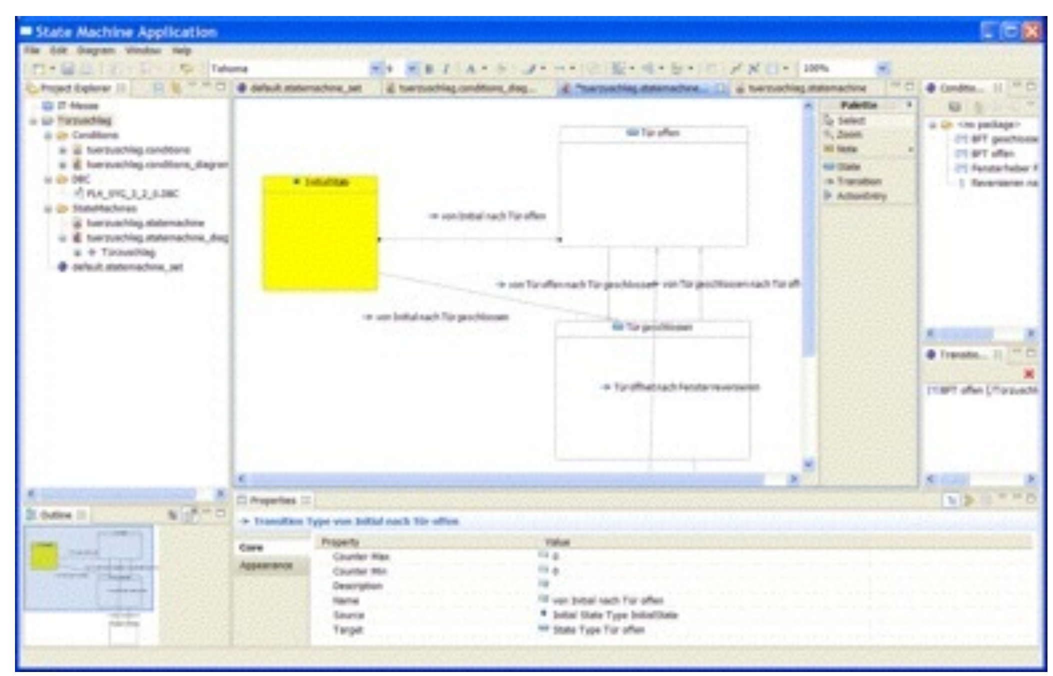


Trace

State Machine
Pre-Analysis

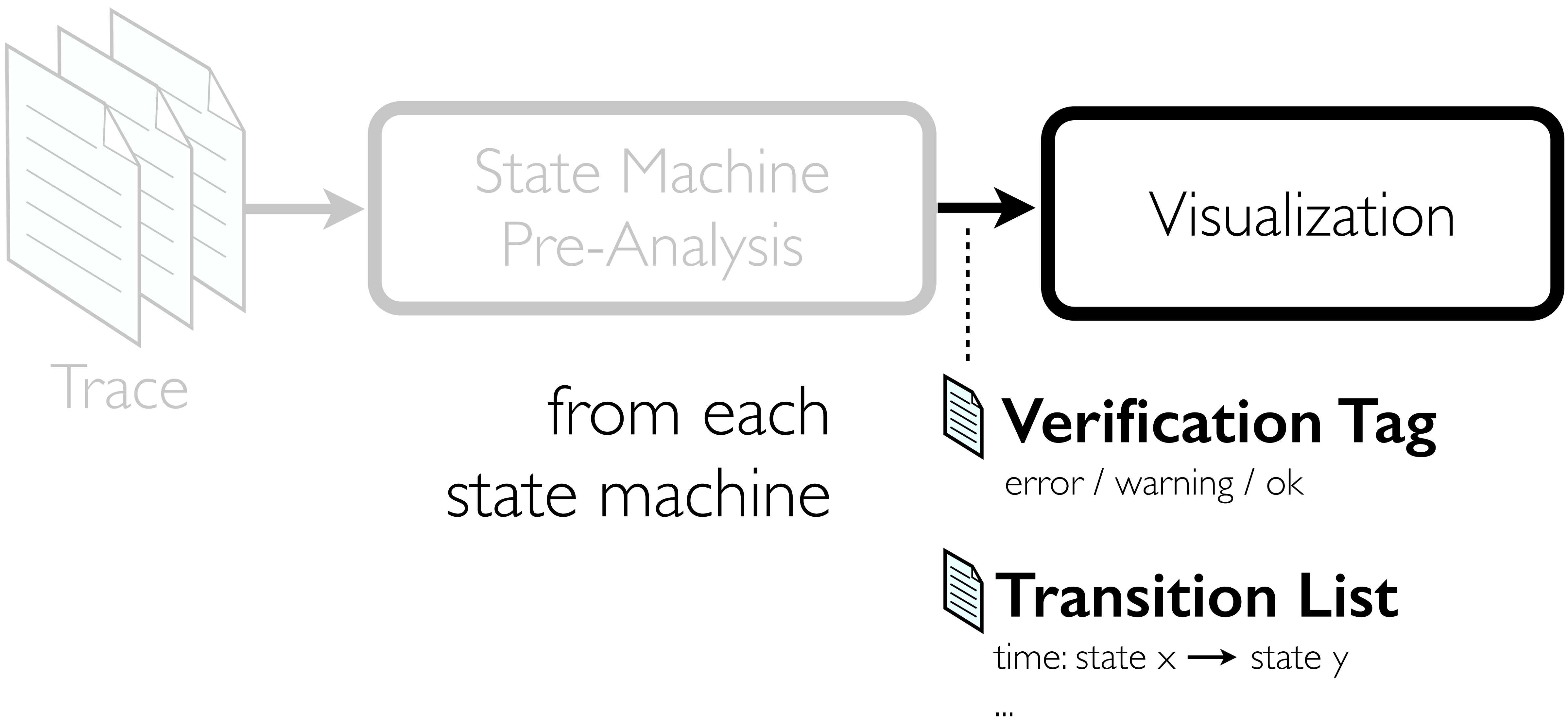
Visualization

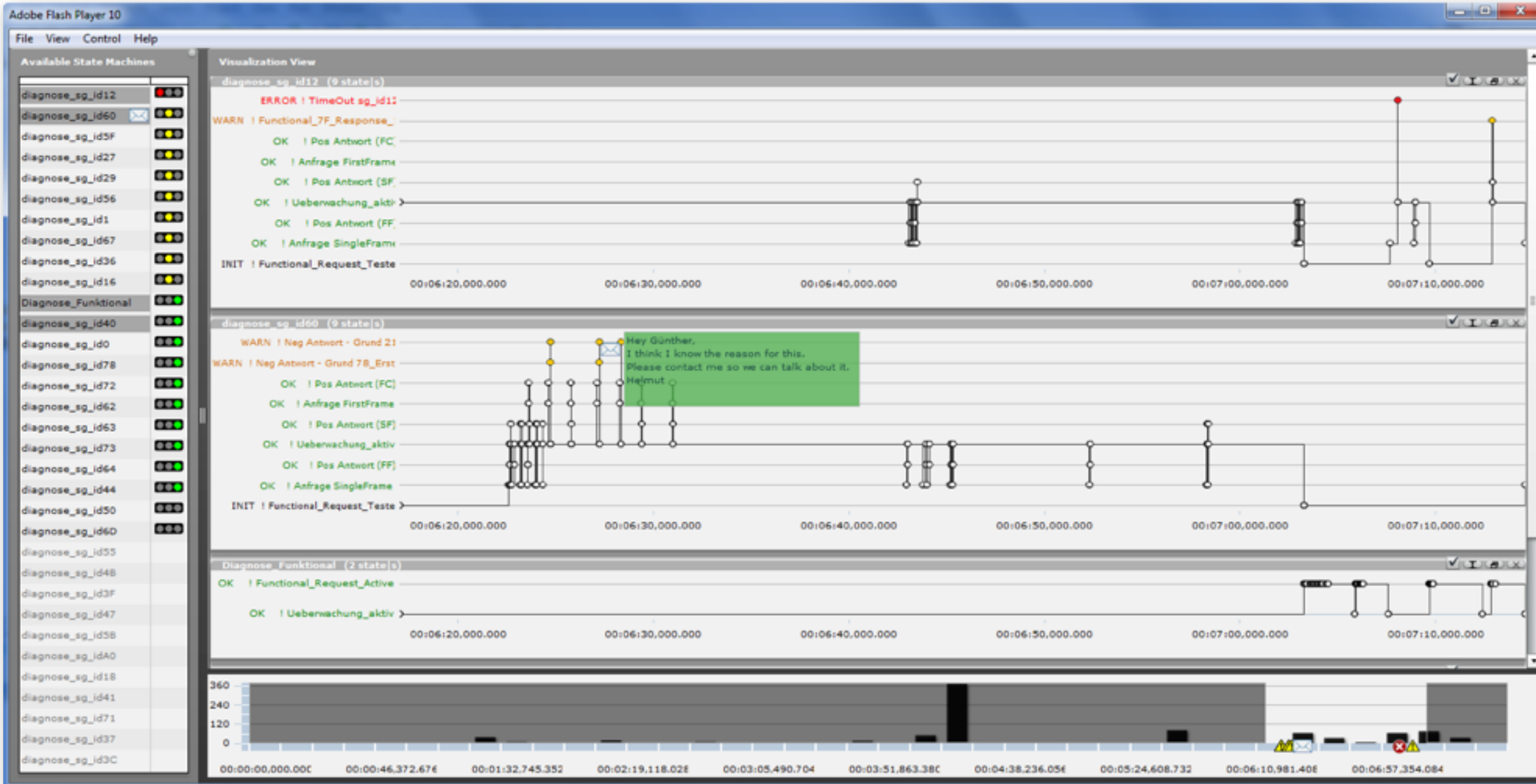
Multiple State Machines
- State Machine 1
- State Machine 2
- State Machine 3
... (dozens)



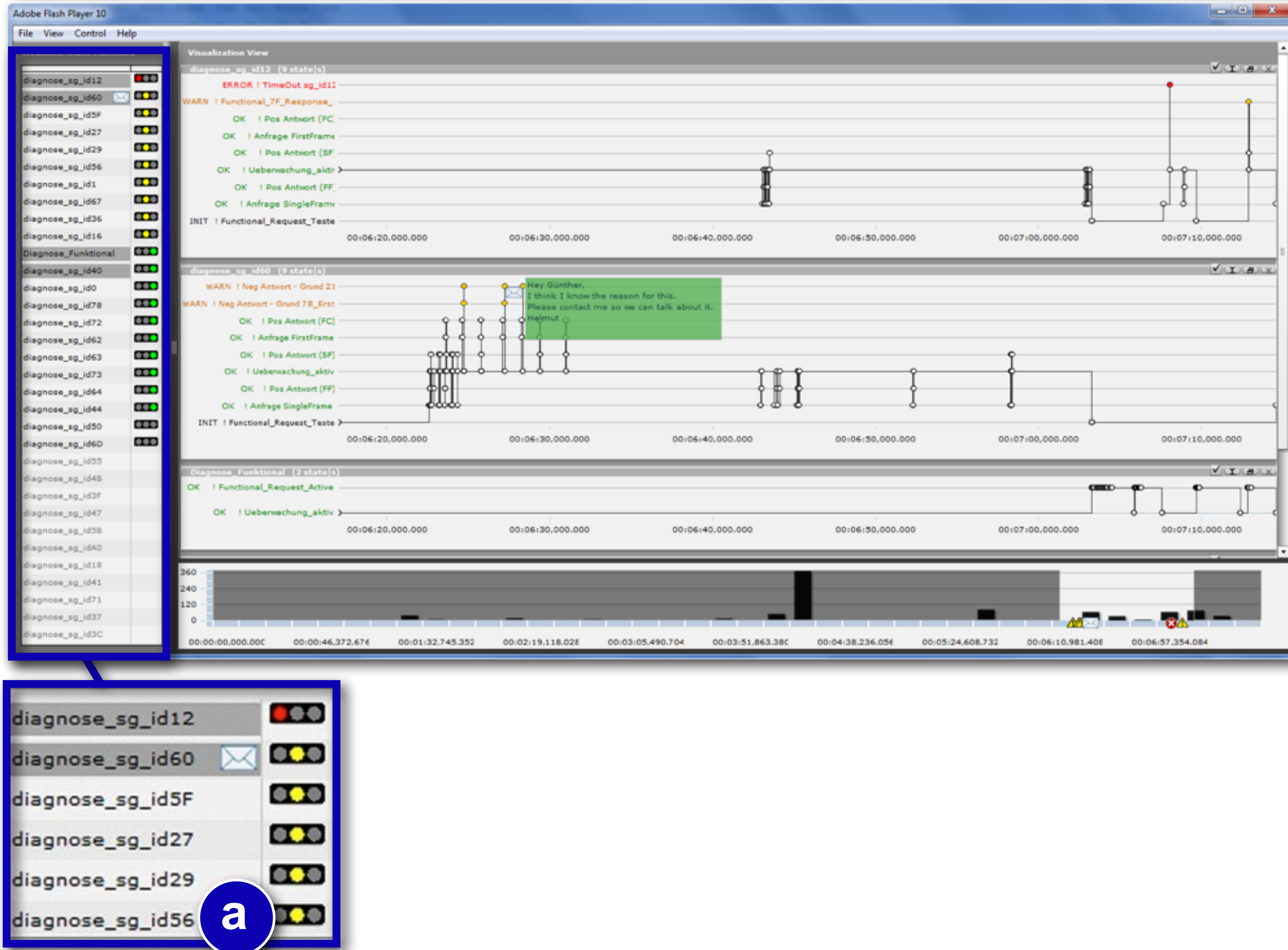
cardiogram:

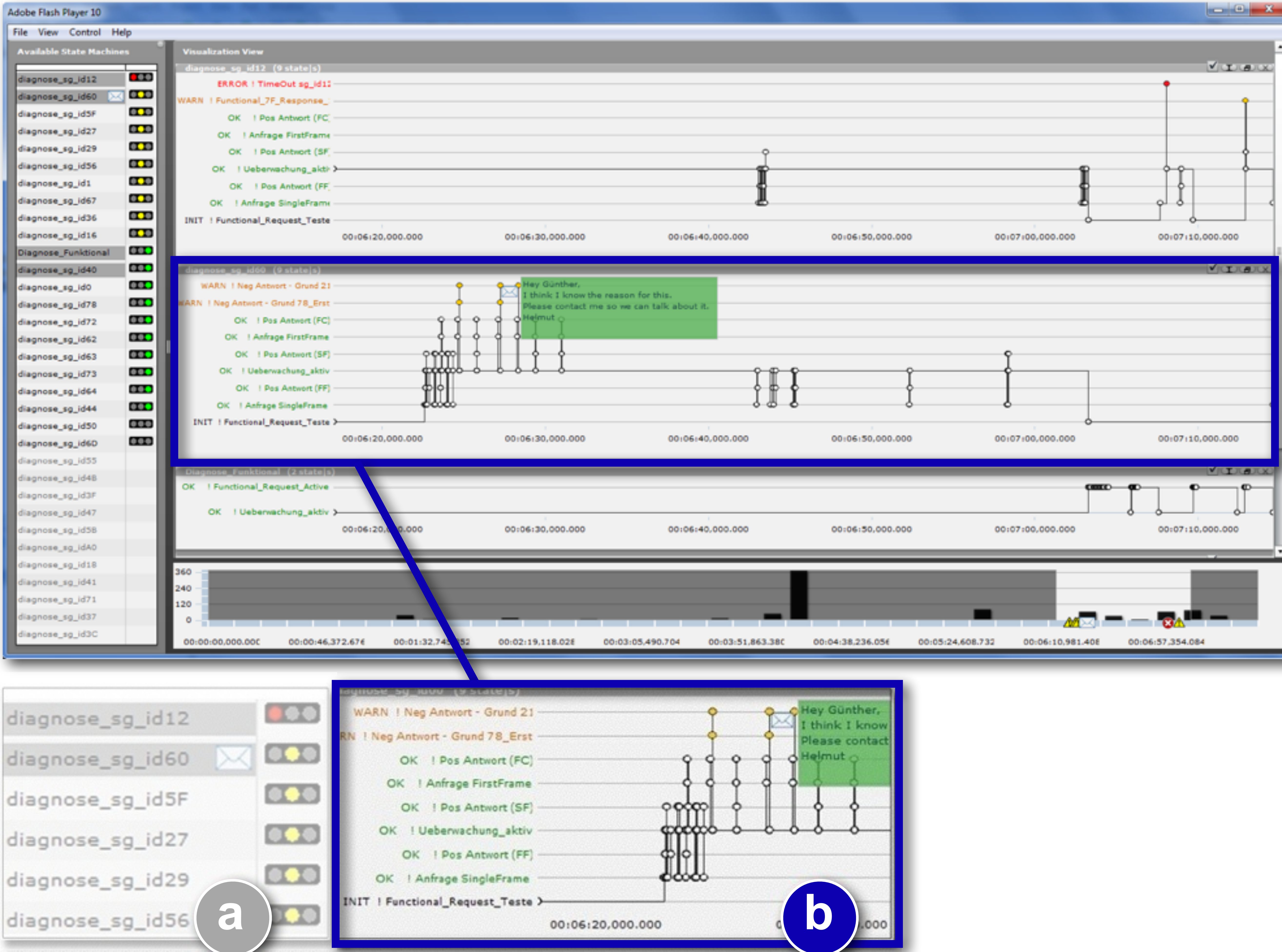
- data interpretation
- data reduction

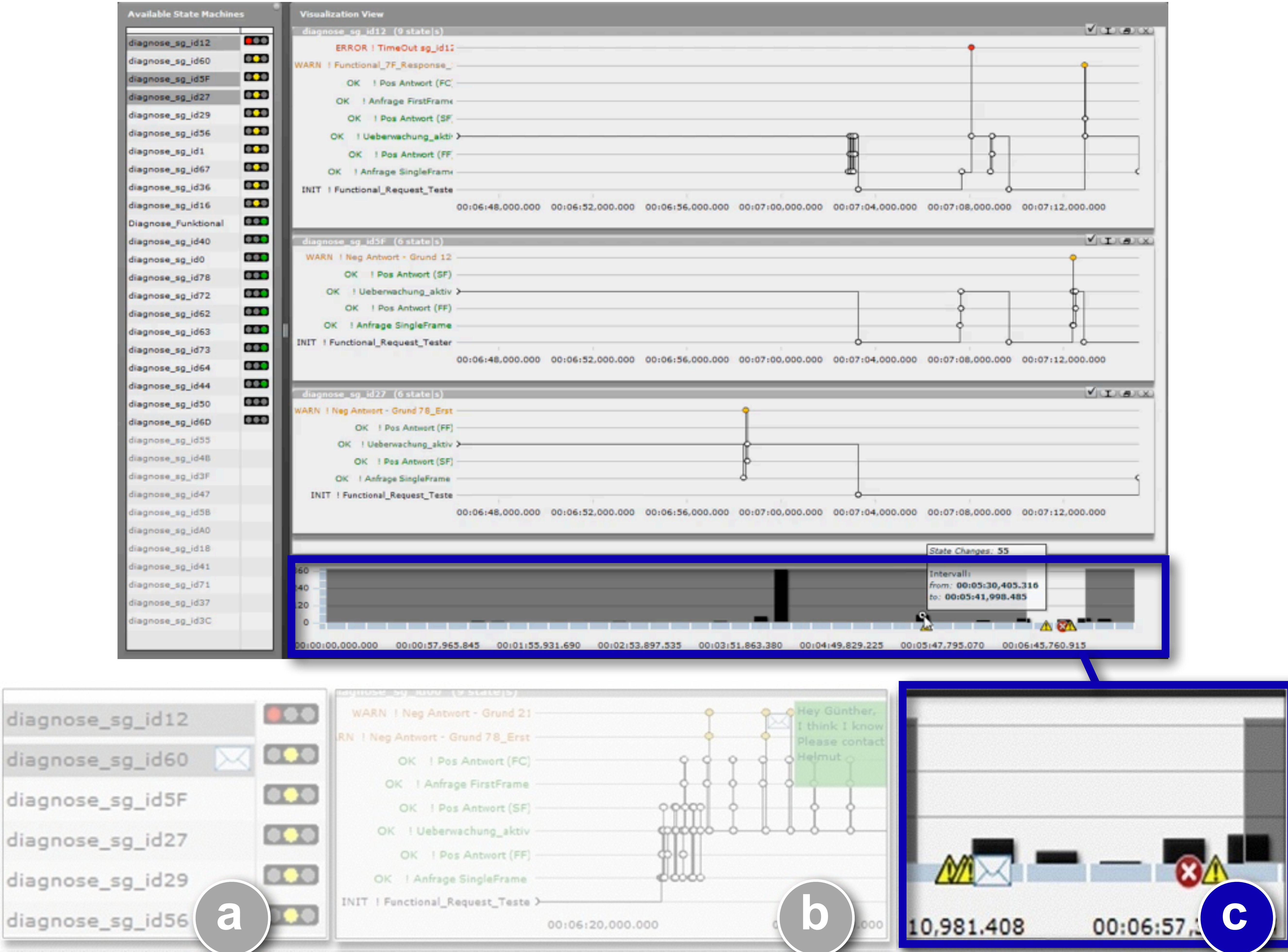




Adobe Flash Player 10
File View Control Help
Available State Machines
Visualization View
diagnose_sg_id12 (9 state(s))
ERROR ! TimeOut sg_id12
WARN ! Functional_7F_Response_
OK ! Pos Antwort (FC)
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
diagnose_sg_id60 (9 state(s))
WARN ! Neg Antwort - Grund 21
WARN ! Neg Antwort - Grund 78_Erst
Hey Günther,
I think I know the reason for this.
Please contact me so we can talk about it.
Helmut
Diagnose_Funktional (2 state(s))
OK ! Functional_Request_Active
OK ! Ueberwachung_aktiv
00:06:20,000.000
00:06:30,000.000
00:06:40,000.000
00:06:50,000.000
00:07:00,000.000
00:07:10,000.000
360
240
120
0
00:00:00,000.000
00:00:46,372.676
00:01:32,745.352
00:02:19,118.028
00:03:05,490.704
00:03:51,863.380
00:04:38,236.056
00:05:24,608.732
00:06:10,981.408
00:06:57,354.084


Adobe Flash Player 10
File View Control Help
Visualization View
diagnose_sg_id12 (9 state(s))
ERROR ! TimeOut sg_id12
WARN ! Functional_7F_Response_
OK ! Pos Antwort (FC
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF
OK ! Ueberwachung_akti
OK ! Pos Antwort (FF
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
diagnose_sg_id60 (9 state(s))
WARN ! Neg Antwort - Grund 21
WARN ! Neg Antwort - Grund 78_Erst
OK ! Pos Antwort (FC)
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
Hey Günther,
I think I know the reason for this.
Please contact me so we can talk about it.
Helmut
Diagnose_Funktional (2 state(s))
OK ! Functional_Request_Active
OK ! Ueberwachung_aktiv
00:06:20,000.000
00:06:30,000.000
00:06:40,000.000
00:06:50,000.000
00:07:00,000.000
00:07:10,000.000
360
240
120
0
00:00:00,000.000
00:00:46,372.676
00:01:32,745.352
00:02:19,118.028
00:03:05,490.704
00:03:51,863.380
00:04:38,236.056
00:05:24,608.732
00:06:10,981.408
00:06:57,354.084
diagnose_sg_id12
diagnose_sg_id60
diagnose_sg_id5F
diagnose_sg_id27
diagnose_sg_id29
diagnose_sg_id56
diagnose_sg_id1
diagnose_sg_id67
diagnose_sg_id36
diagnose_sg_id16
Diagnose_Funktional
diagnose_sg_id40
diagnose_sg_id0
diagnose_sg_id78
diagnose_sg_id72
diagnose_sg_id62
diagnose_sg_id63
diagnose_sg_id73
diagnose_sg_id64
diagnose_sg_id44
diagnose_sg_id50
diagnose_sg_id6D
diagnose_sg_id55
diagnose_sg_id4B
diagnose_sg_id3F
diagnose_sg_id47
diagnose_sg_id5B
diagnose_sg_idA0
diagnose_sg_id18
diagnose_sg_id41
diagnose_sg_id71
diagnose_sg_id37
diagnose_sg_id3C
a


Adobe Flash Player 10
File View Control Help
Available State Machines
diagnose_sg_id12
diagnose_sg_id60
diagnose_sg_id5F
diagnose_sg_id27
diagnose_sg_id29
diagnose_sg_id56
diagnose_sg_id1
diagnose_sg_id67
diagnose_sg_id36
diagnose_sg_id16
Diagnose_Funktional
diagnose_sg_id40
diagnose_sg_id0
diagnose_sg_id78
diagnose_sg_id72
diagnose_sg_id62
diagnose_sg_id63
diagnose_sg_id73
diagnose_sg_id64
diagnose_sg_id44
diagnose_sg_id50
diagnose_sg_id6D
diagnose_sg_id55
diagnose_sg_id48
diagnose_sg_id3F
diagnose_sg_id47
diagnose_sg_id58
diagnose_sg_idA0
diagnose_sg_id18
diagnose_sg_id41
diagnose_sg_id71
diagnose_sg_id37
diagnose_sg_id3C
Visualization View
ERROR ! TimeOut sg_id12
WARN ! Functional_7F_Response_
OK ! Pos Antwort (FC
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
00:06:20,000.000
00:06:30,000.000
00:06:40,000.000
00:06:50,000.000
00:07:00,000.000
00:07:10,000.000
WARN ! Neg Antwort - Grund 21
WARN ! Neg Antwort - Grund 78_Erst
OK ! Pos Antwort (FC)
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
Hey Günther,
I think I know the reason for this.
Please contact me so we can talk about it.
Helmut
OK ! Functional_Request_Active
OK ! Ueberwachung_aktiv
360
240
120
0
00:00:00,000.000
00:00:46,372.676
00:01:32,745.352
00:02:19,118.028
00:03:05,490.704
00:03:51,863.380
00:04:38,236.056
00:05:24,608.732
00:06:10,981.408
00:06:57,354.084
a
b


Available State Machines
Visualization View
diagnose_sg_id12
diagnose_sg_id60
diagnose_sg_id5F
diagnose_sg_id27
diagnose_sg_id29
diagnose_sg_id56
diagnose_sg_id1
diagnose_sg_id67
diagnose_sg_id36
diagnose_sg_id16
Diagnose_Funktional
diagnose_sg_id40
diagnose_sg_id0
diagnose_sg_id78
diagnose_sg_id72
diagnose_sg_id62
diagnose_sg_id63
diagnose_sg_id73
diagnose_sg_id64
diagnose_sg_id44
diagnose_sg_id50
diagnose_sg_id6D
diagnose_sg_id55
diagnose_sg_id48
diagnose_sg_id3F
diagnose_sg_id47
diagnose_sg_id58
diagnose_sg_idA0
diagnose_sg_id18
diagnose_sg_id41
diagnose_sg_id71
diagnose_sg_id37
diagnose_sg_id3C
diagnose_sg_id12 (9 state(s))
ERROR ! TimeOut sg_id12
WARN ! Functional_7F_Response_
OK ! Pos Antwort (FC
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
00:06:48.000.000
00:06:52.000.000
00:06:56.000.000
00:07:00.000.000
00:07:04.000.000
00:07:08.000.000
00:07:12.000.000
diagnose_sg_id5F (6 state(s))
WARN ! Neg Antwort - Grund 12
OK ! Pos Antwort (SF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Tester
diagnose_sg_id27 (6 state(s))
WARN ! Neg Antwort - Grund 78_Erst
OK ! Pos Antwort (FF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (SF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
State Changes: 55
Intervall:
from: 00:05:30,405.316
to: 00:05:41,998.485
60
40
20
0
00:00:00.000.000
00:00:57.965.845
00:01:55.931.690
00:02:53.897.535
00:03:51.863.380
00:04:49.829.225
00:05:47.795.070
00:06:45.760.915
WARN ! Neg Antwort - Grund 21
RN ! Neg Antwort - Grund 78_Erst
OK ! Pos Antwort (FC)
OK ! Anfrage FirstFrame
OK ! Pos Antwort (SF)
OK ! Ueberwachung_aktiv
OK ! Pos Antwort (FF)
OK ! Anfrage SingleFrame
INIT ! Functional_Request_Teste
Hey Günther,
I think I know
Please contact
Helmut
00:06:20.000.000
10,981.408
a
b
c

longitudinal field study:

1 year, 15 engineers

results

- externalization and sharing of expert knowledge

longitudinal field study:

1 year, 15 engineers

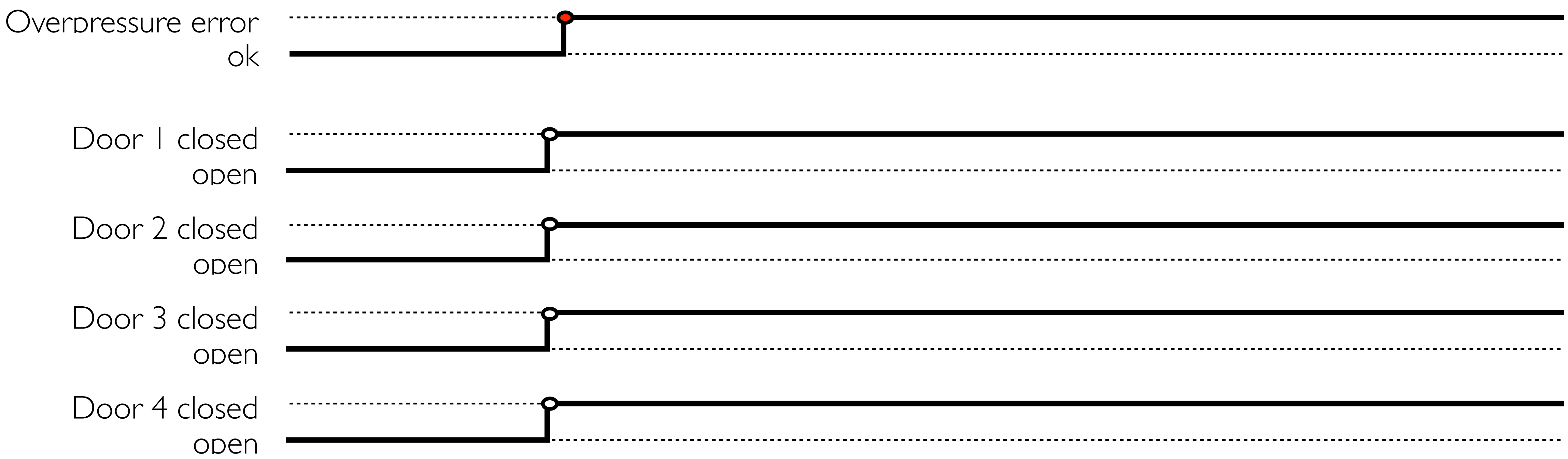
results

- externalization and sharing of expert knowledge
- complete coverage of traces vs. sparse sampling

longitudinal field study:
1 year, 15 engineers

results

- externalization and sharing of expert knowledge
- complete coverage of traces vs. sparse sampling
- understand behavioral correlations



longitudinal field study:

1 year, 15 engineers

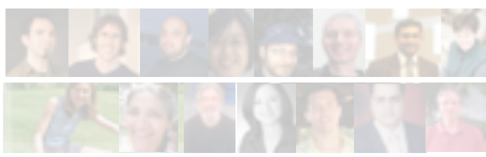
results

- externalization and sharing of expert knowledge
- complete coverage of traces vs. sparse sampling
- understand behavioral correlations

deployed and adopted

real users/real data:

Studies on high-dimensional data analysis techniques

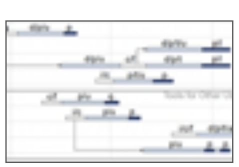
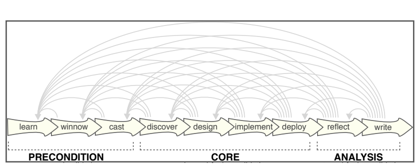
 

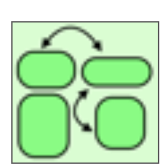
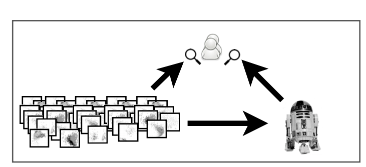
Applied visualization projects (9 BMW, 3 others)

right methods:

Novel and refined research methods/methodologies


design studies:
long and winding road with many pitfalls!

Information Visualization Evaluation in Large Companies: Challenges, Experiences and Recommendations

[Information Visualization 10(3), 2011]

M. Sedlmair, P. Isenberg, D. Baur, A. Butz

http://homepage.univie.ac.at/michael.sedlmair/papers/sedlmair2011ivs.pdf




Design Study Methodology: Reflections from the Trenches and the Stacks

[InfoVis 2012]

M. Sedlmair, M. Meyer, T. Munzner

http://www.cs.ubc.ca/nest/imager/tr/2012/dsm/



how to?

*"A **design study** is a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines."*

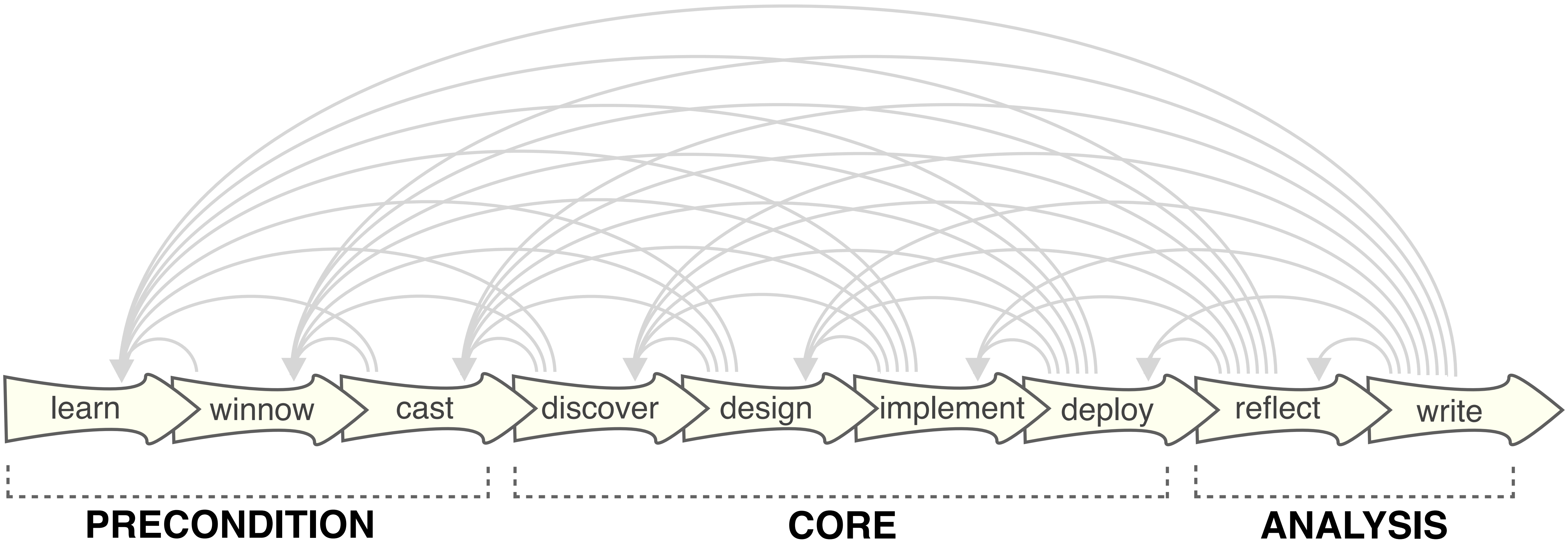
[Sedlmair et al.: Design Study Methodology: Reflections from the Trenches and the Stacks, InfoVis 2012]

Design Study Methodology: Reflections from the Trenches and the Stacks

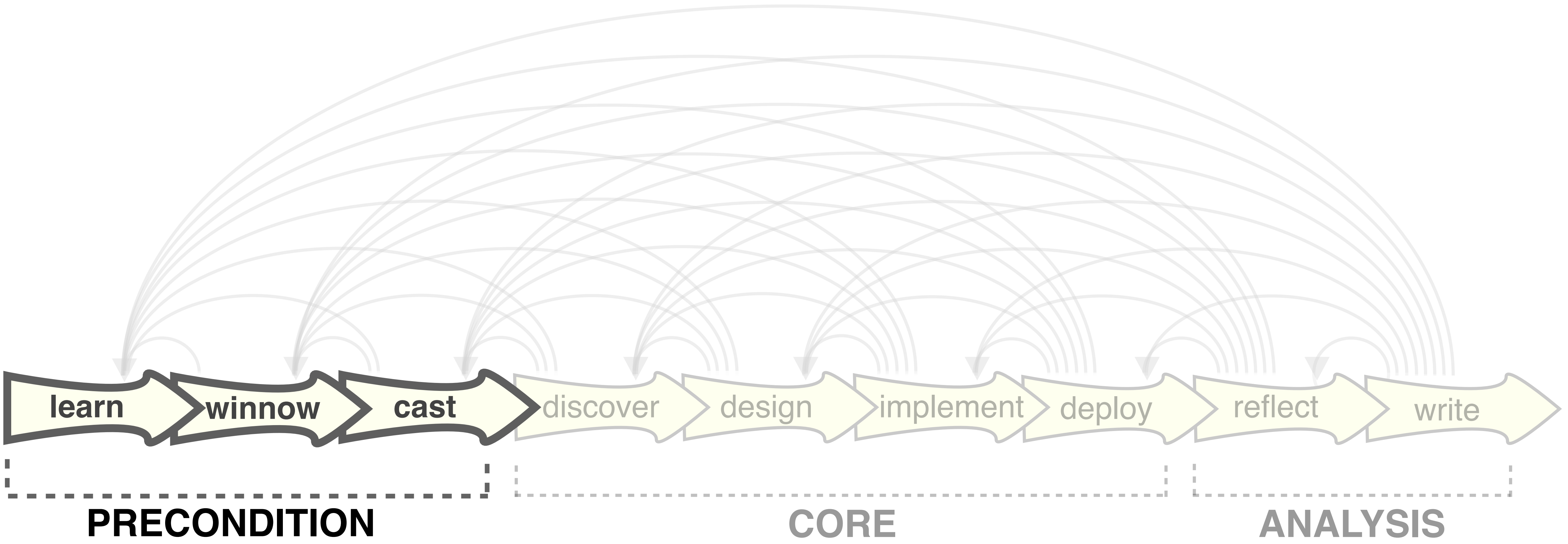
[InfoVis 2012]

M. Sedlmair, M. Meyer, T. Munzner

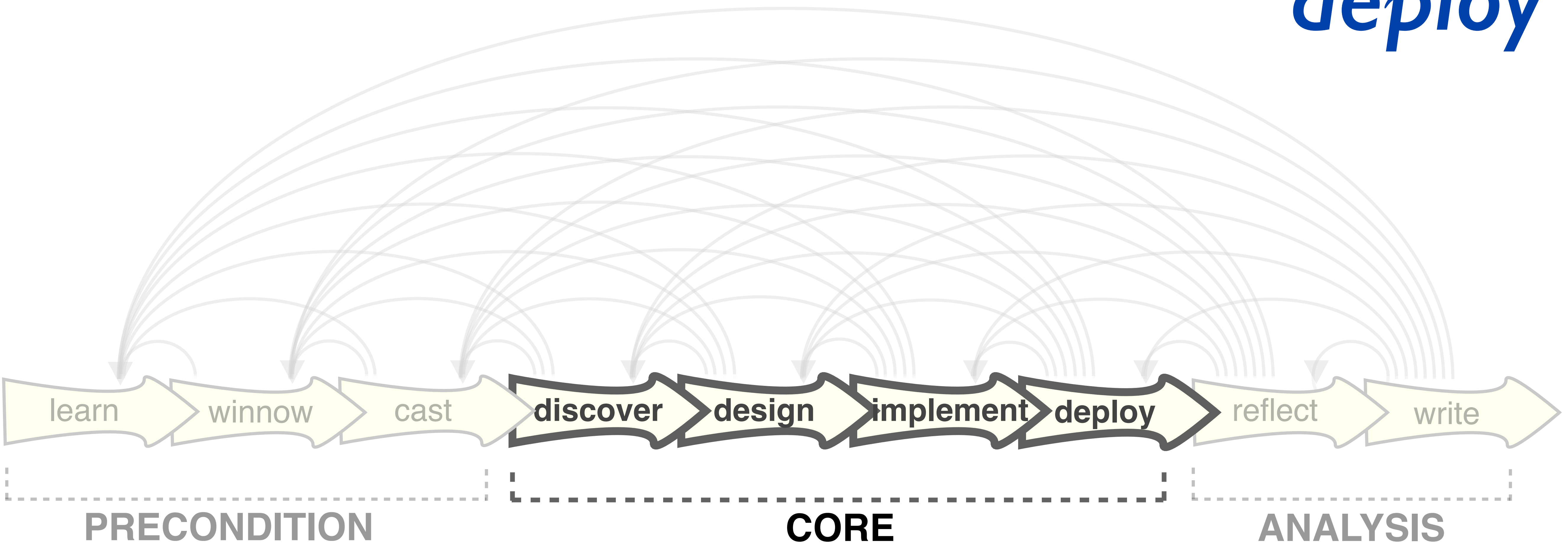
http://www.cs.ubc.ca/nest/imager/tr/2012/dsm/


learn
winnow
cast
discover
design
implement
deploy
reflect
write
PRECONDITION
CORE
ANALYSIS

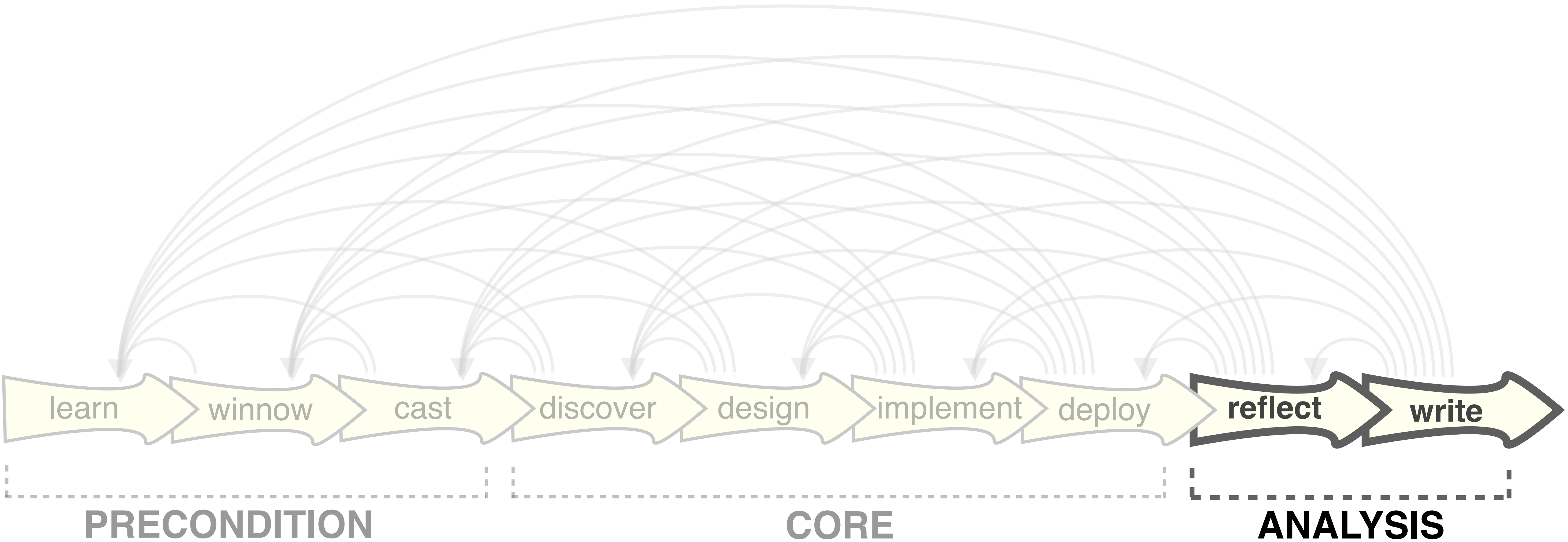
learn
winnow
cast



discover
design
implement
deploy

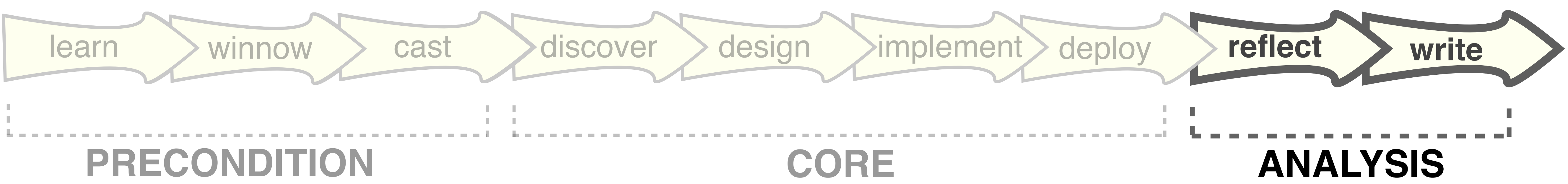


reflect
write



32 pitfalls along the way

Example: Premature publishing



I can write a design study **paper** in a week!

"writing is research"

[Wolcott: Writing up qualitative research, 2009] metaphor

horse race vs. music debut

Must be first!

Am I ready?

http://www.alaineknipes.com/interests/violin_concert.jpg

technique-driven

http://www.prlog.org/10480334-wolverhampton-horse-racing-live-streaming-wolverhampton-handicap-8-jan-2010.html

problem-driven

vision

design studies

"the visualization and data analysis cookbook"

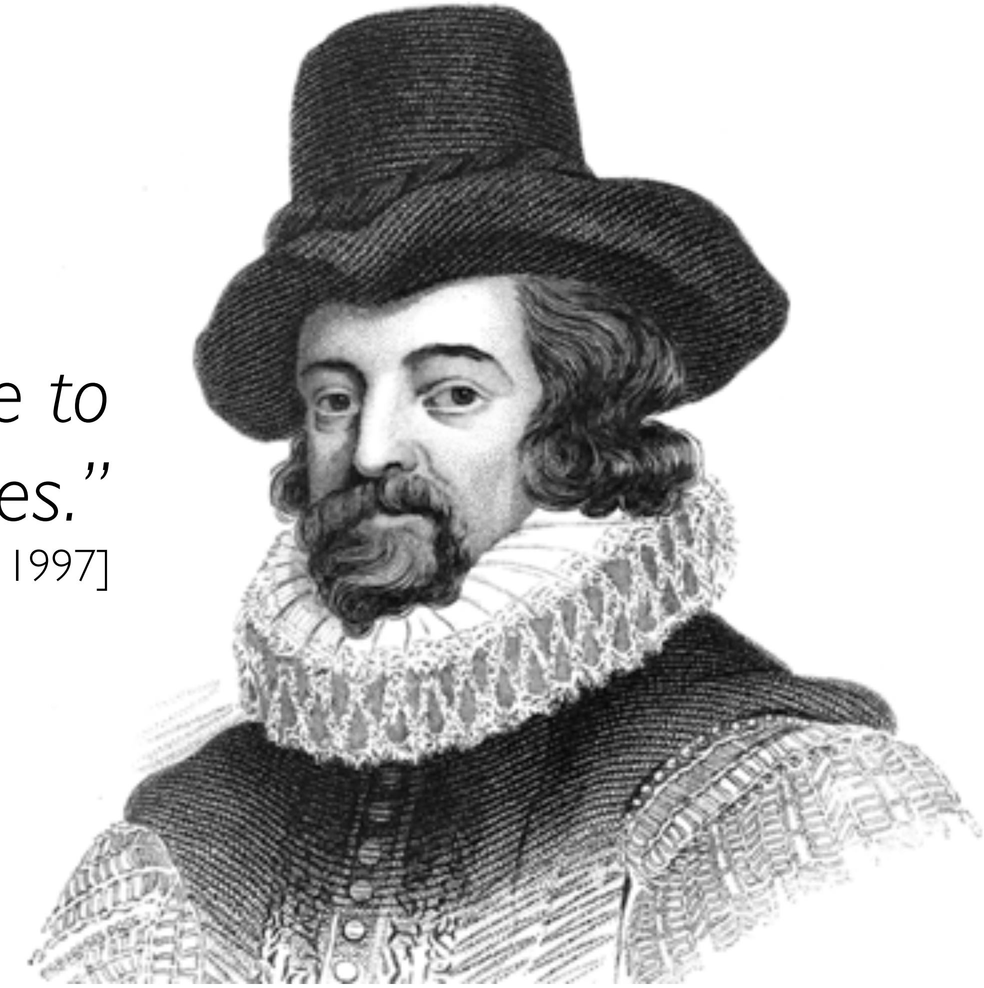
abstract data & task

↓

data analysis technique

“the visualization and data analysis cookbook”

“Real practical experiments [...] are indispensable to an understanding of natural processes.”
[Brewer, 1997]

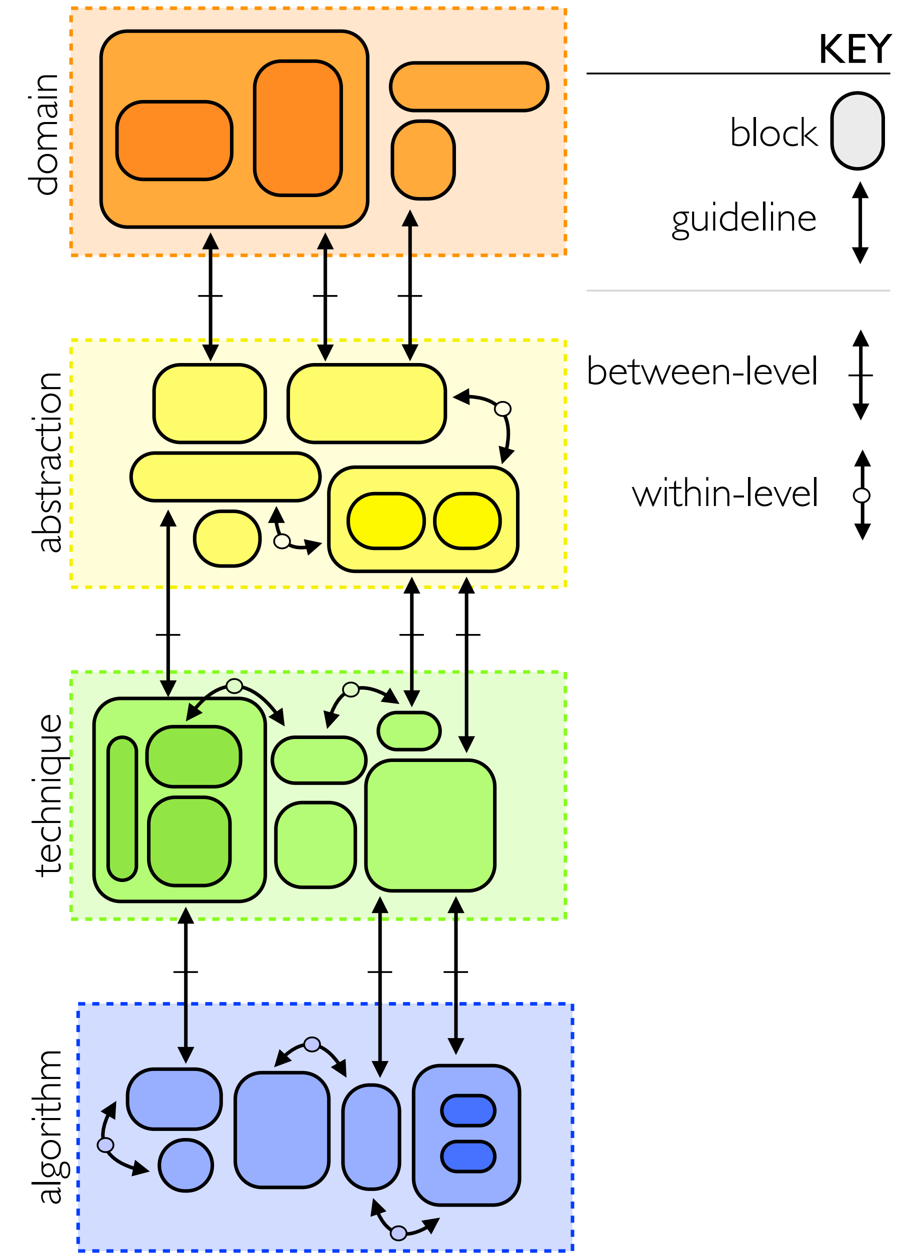

[Sir Francis Bacon 1561-1626]

vast amounts of real users/ real data work necessary

natural science
vs. design research

“the visualization and data analysis cookbook”

blocks and guidelines

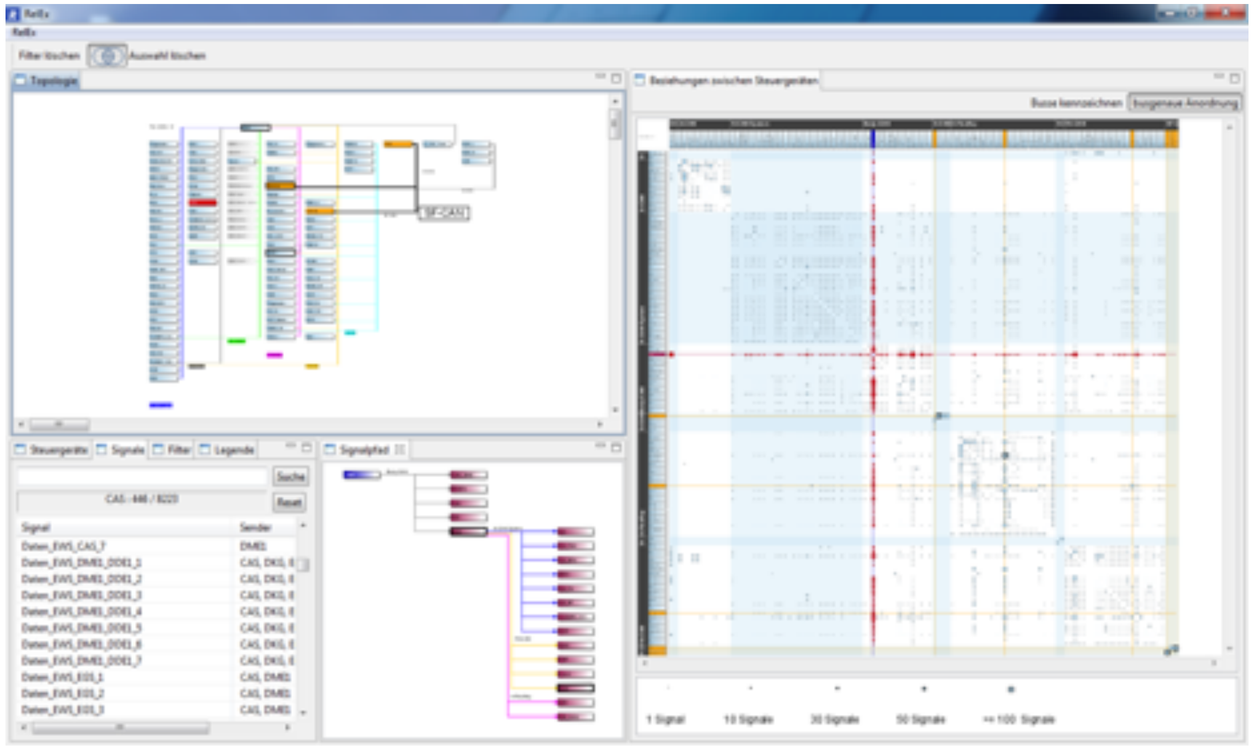


The Nested Blocks and Guidelines Model

M. Meyer, M. Sedlmair, T. Munzner [IVI 2013, to appear]

“the visualization and data analysis cookbook”

abstraction crucial!



RelEx: Visualization for Actively Changing Overlay Network Specifications

M. Sedlmair, A. Frank, T. Munzner, A. Butz [InfoVis 2012]

http://www.cs.ubc.ca/labs/imager/tr/2012/RelEx/relex.pdf

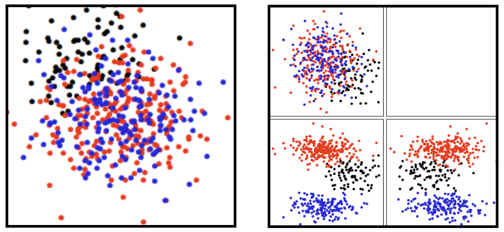
summary

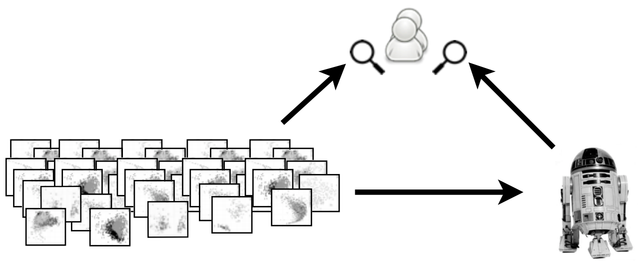
real data:

- taxonomy of separation factors / evaluation of measures
- evaluation of 2D vs. 3D vs. SPLOM

right methods:

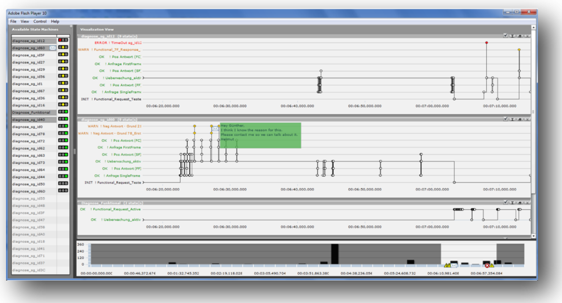
- data study





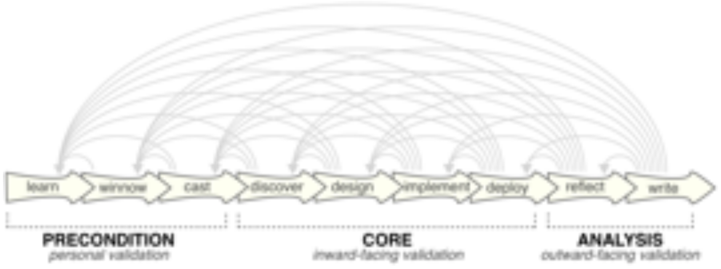
real users:

- Cardiogram



right methods:

- design study



vision:

- the visualization cook book

Visual Data Analysis:
real users, real data, right methods

thank you!

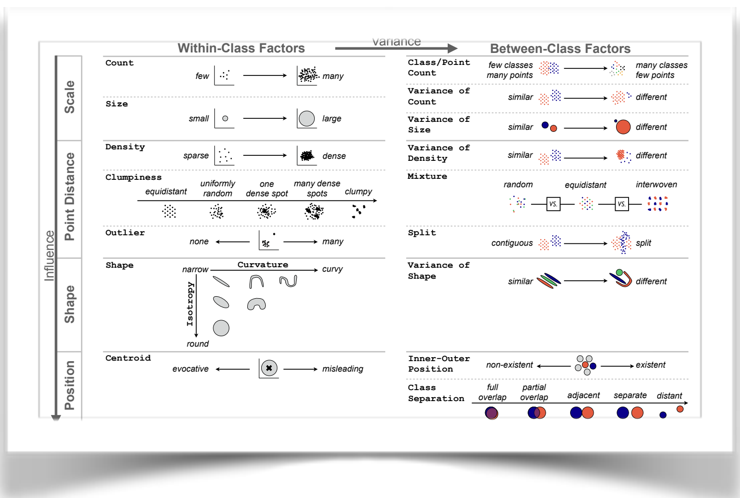
Michael Sedlmair

https://homepage.univie.ac.at/michael.sedlmair
michael.sedlmair@univie.ac.at

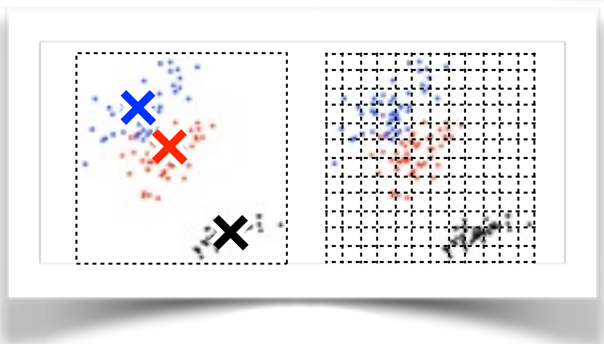
appendix

A Taxonomy of Visual Cluster Separation Factors [EuroVis 2012]

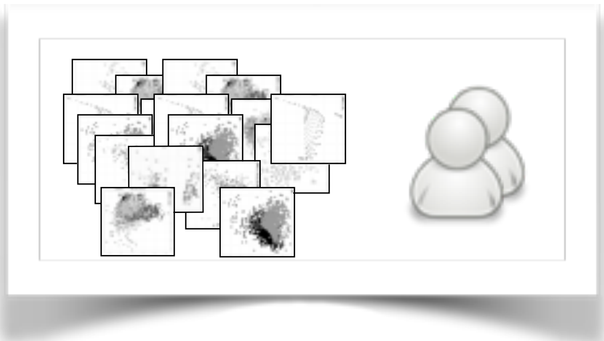
Contributions



Taxonomy of visual cluster separation factors



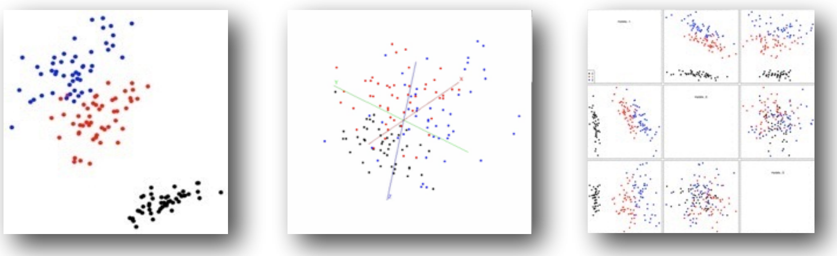
In-depth evaluation of 2 state-of-the-art separation measures



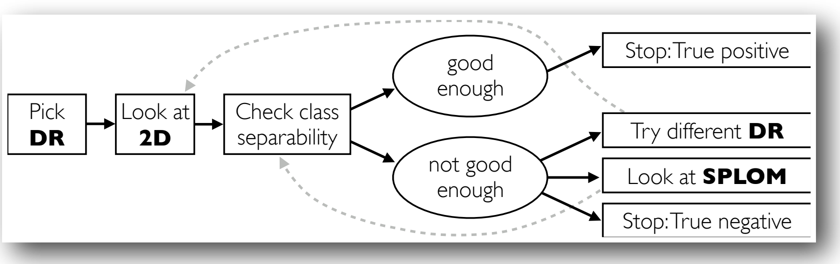
Qualitative data study

Empirical Guidance on Scatterplot and Dimension Reduction Technique Choices [InfoVis 2013]

Contributions



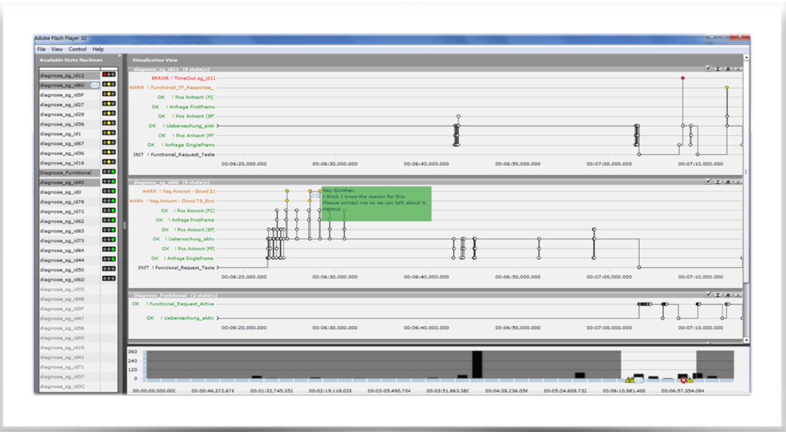
In-depth evaluation of 3 visual encoding techniques for DR data



Workflow model (see paper)

Contributions

Problem and requirements analysis

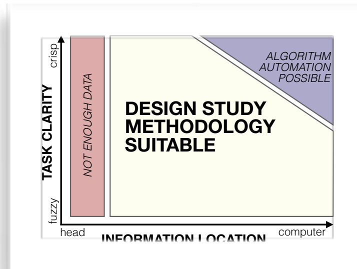


Cardiogram: computational and visual analysis approach

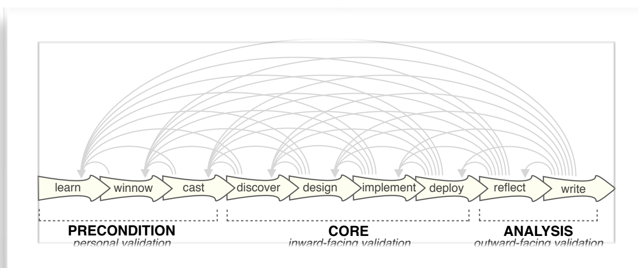
Longitudinal evaluation and adoption

Design Study Methodology [InfoVis 2012]

Contributions



Definitions



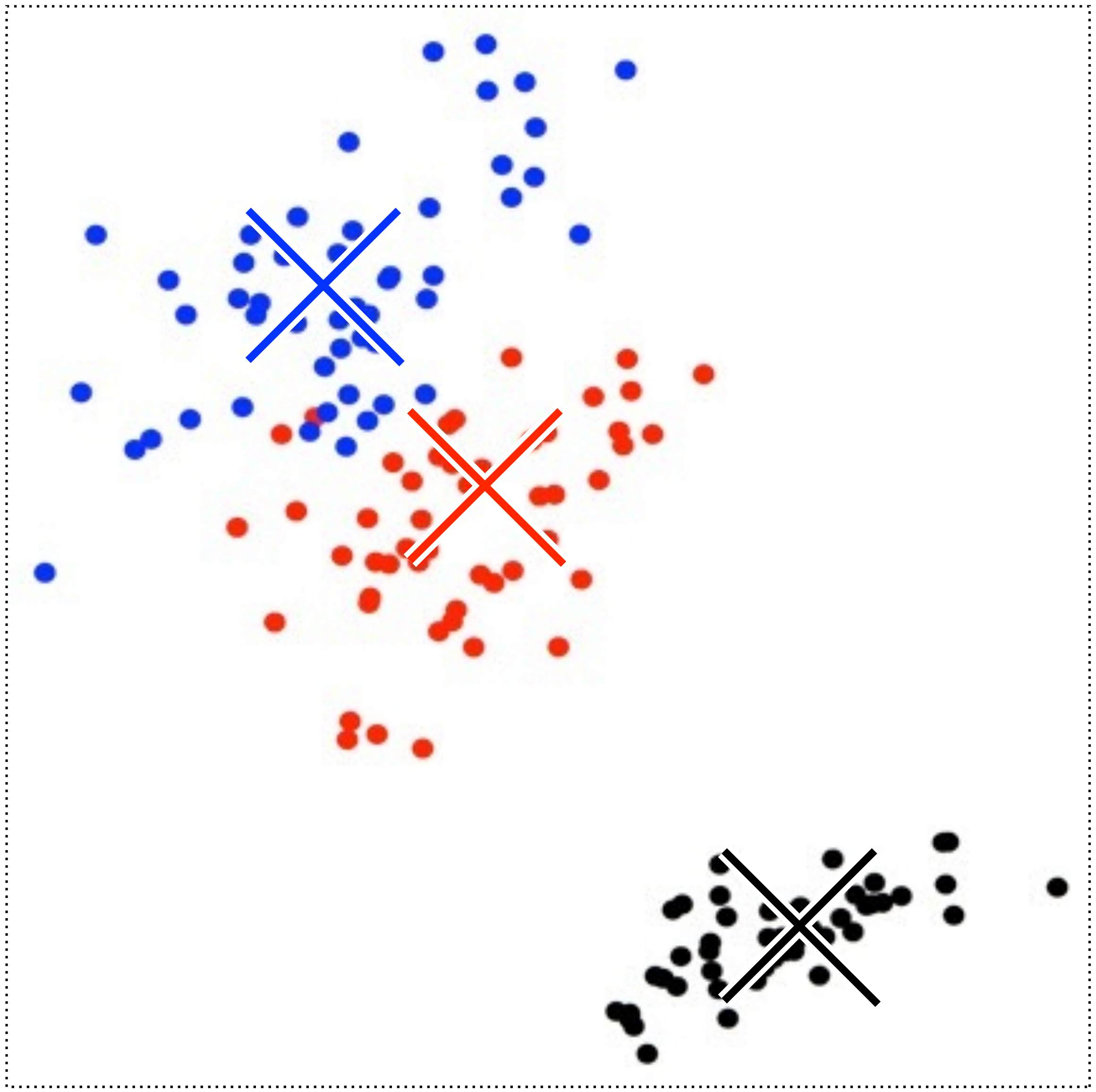
9-stage framework

PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
PF-6	no need for visualization: problem can be automated	winnow
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow

32 pitfalls

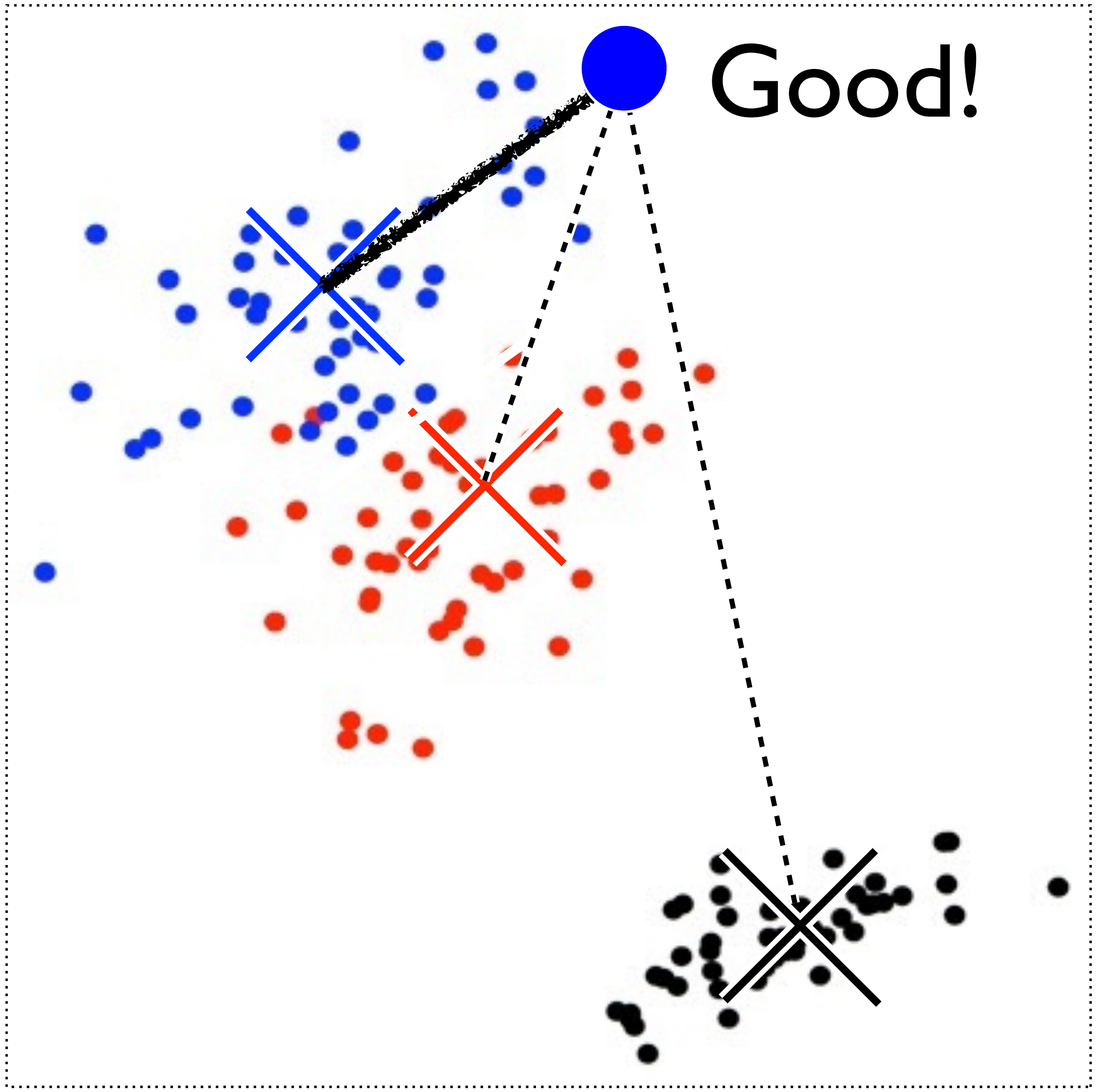
Comparison to related methodologies

Centroid Measure



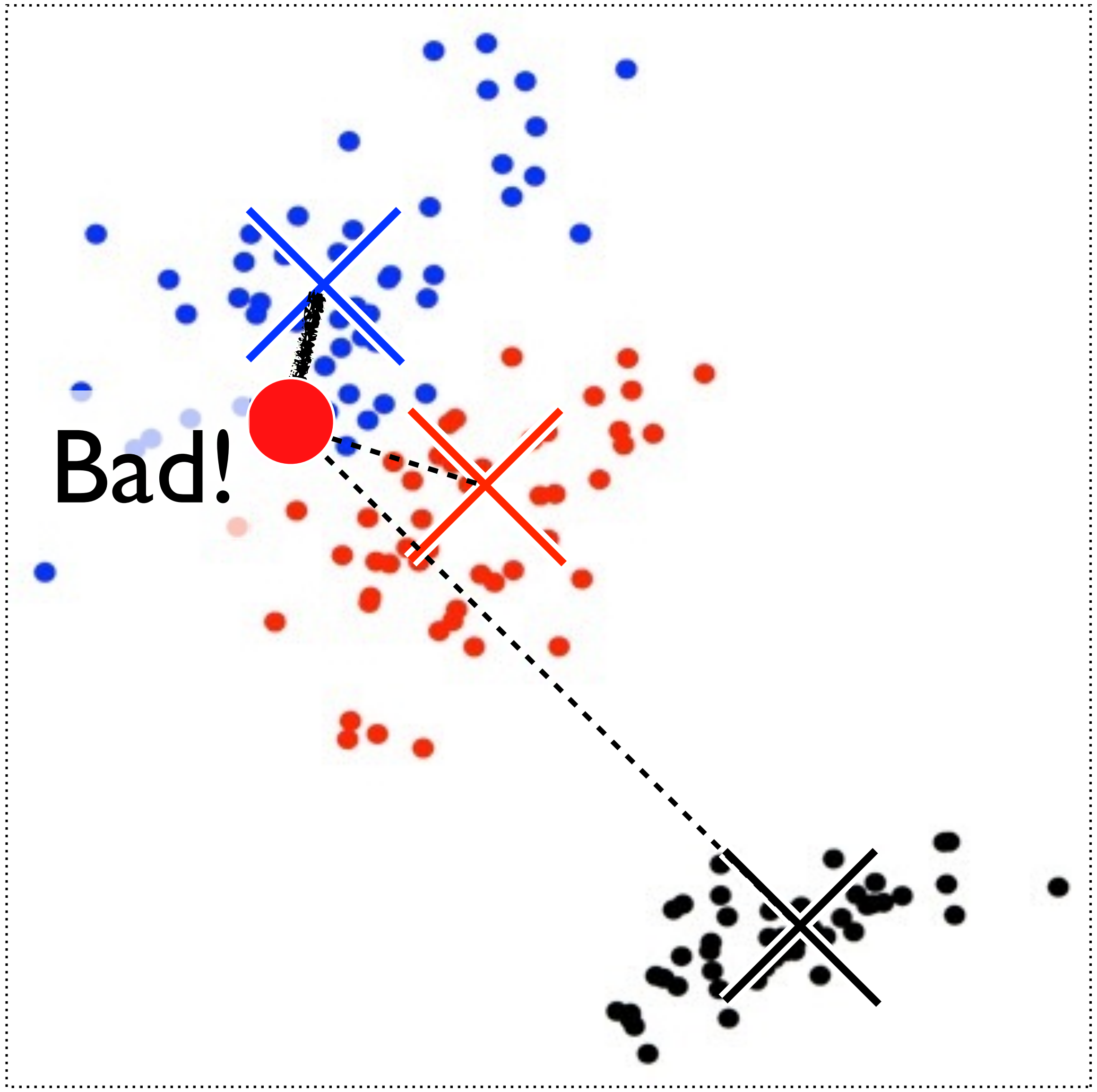
Centroid: 93

Centroid Measure



Centroid: 93

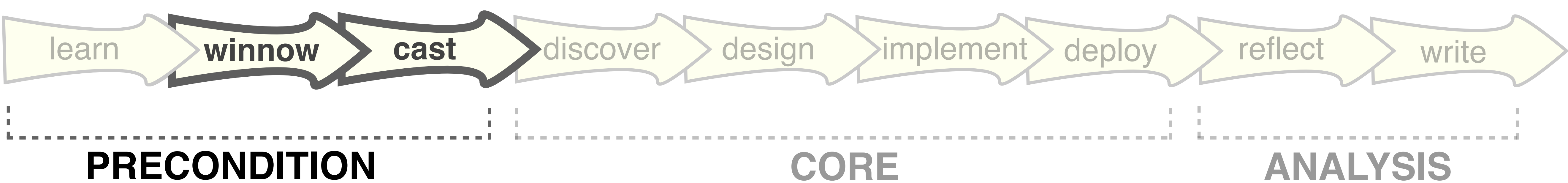
Centroid Measure

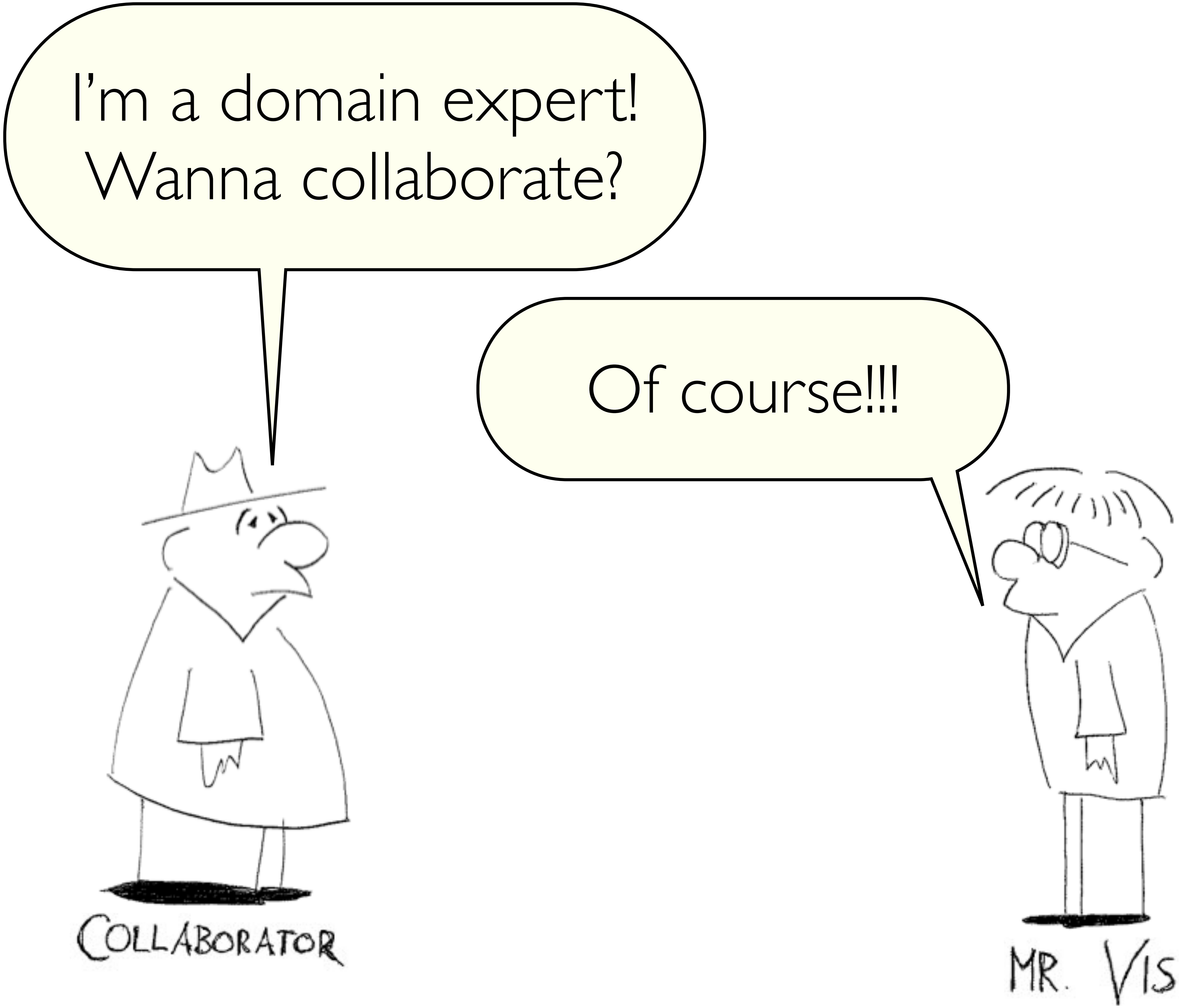


Centroid: 93

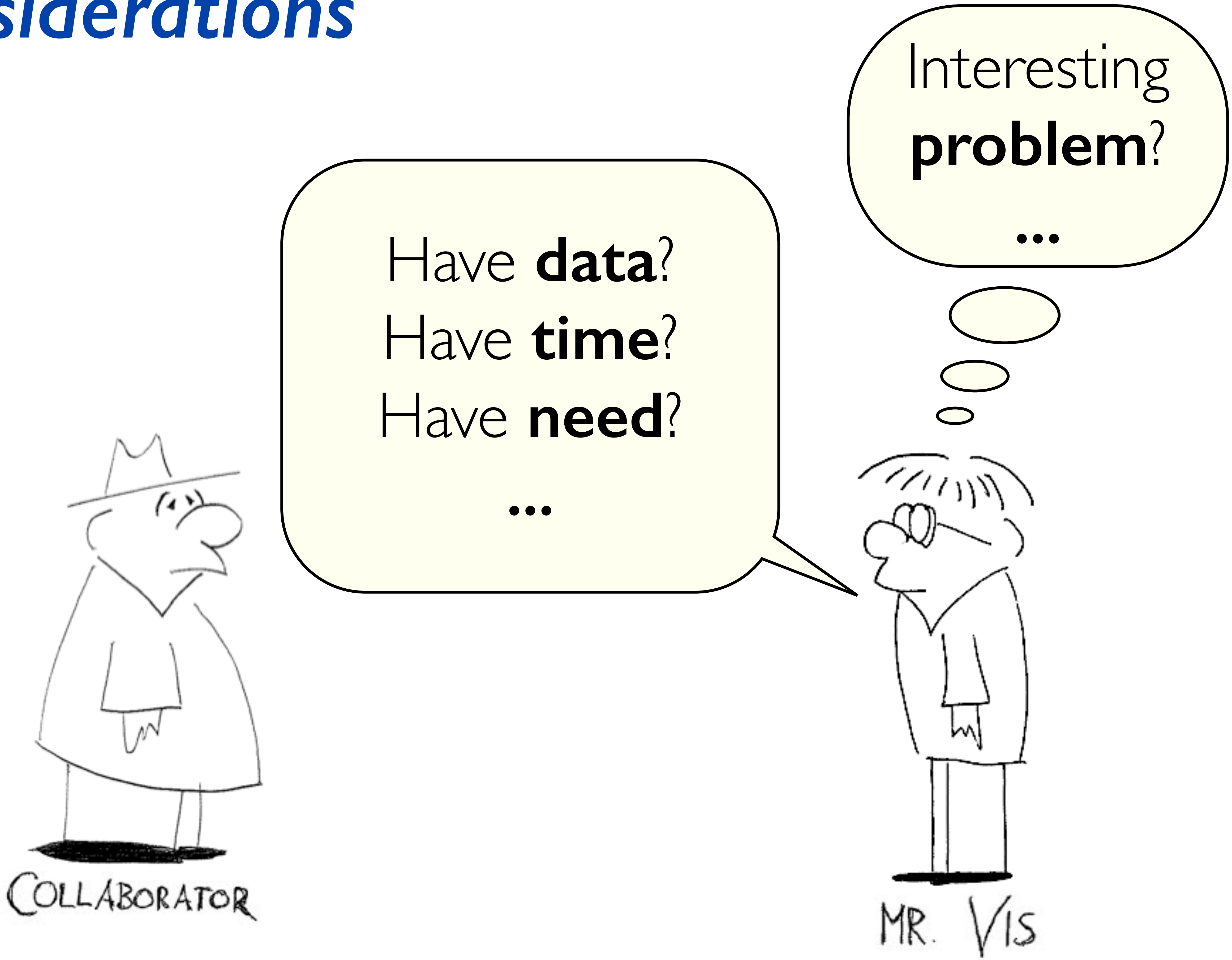
32 pitfalls

Example: Premature collaboration

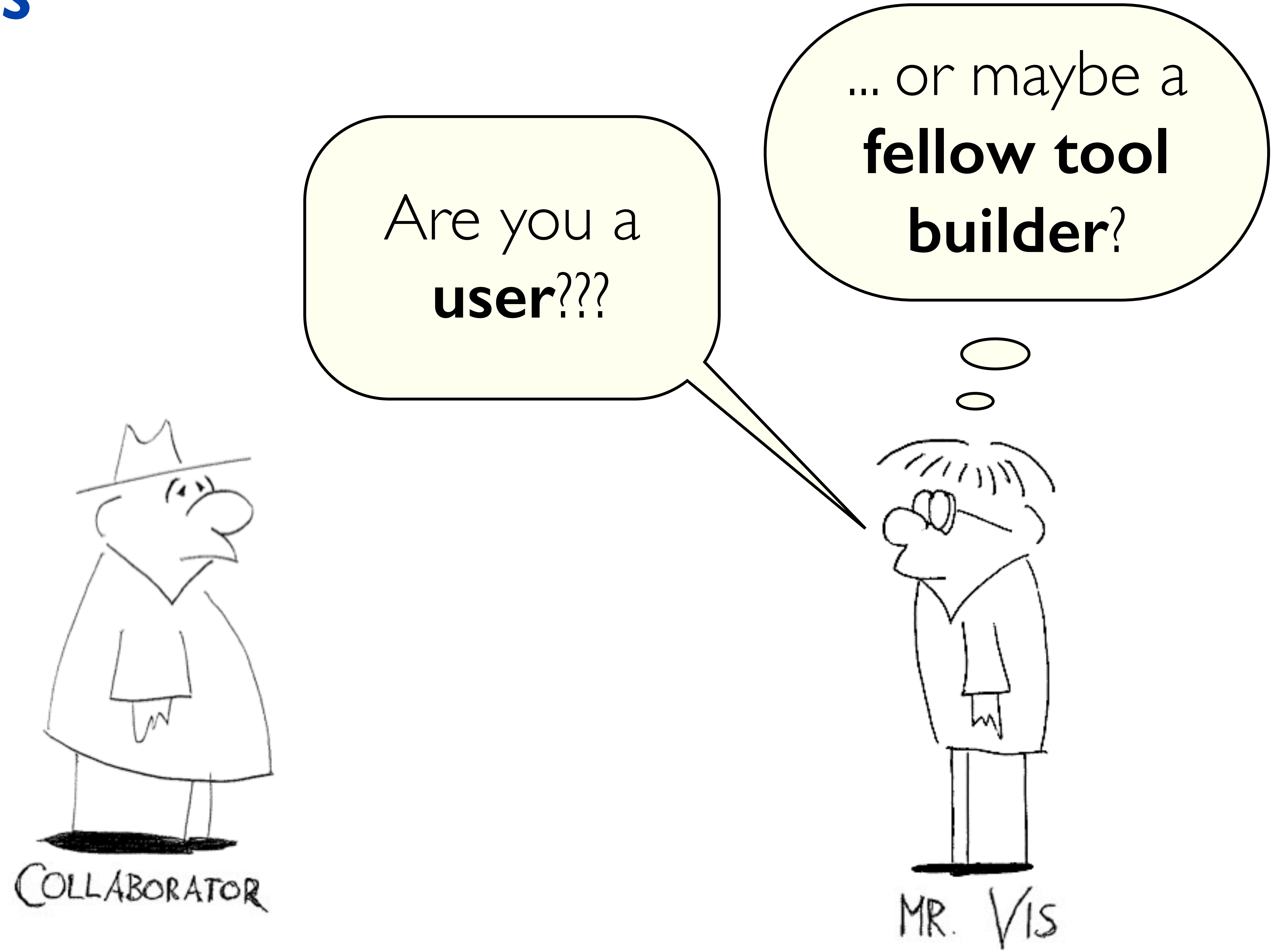



I'm a domain expert!
Wanna collaborate?
Of course!!!
COLLABORATOR
MR. VIS

considerations



roles


Are you a **user**???
... or maybe a **fellow tool builder**?
COLLABORATOR
MR. VIS