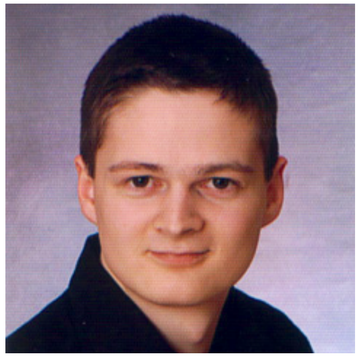
Visual Parameter Space Analysis: A Conceptual Framework


Michael Sedlmair[1]


Christoph Heinzl[2]

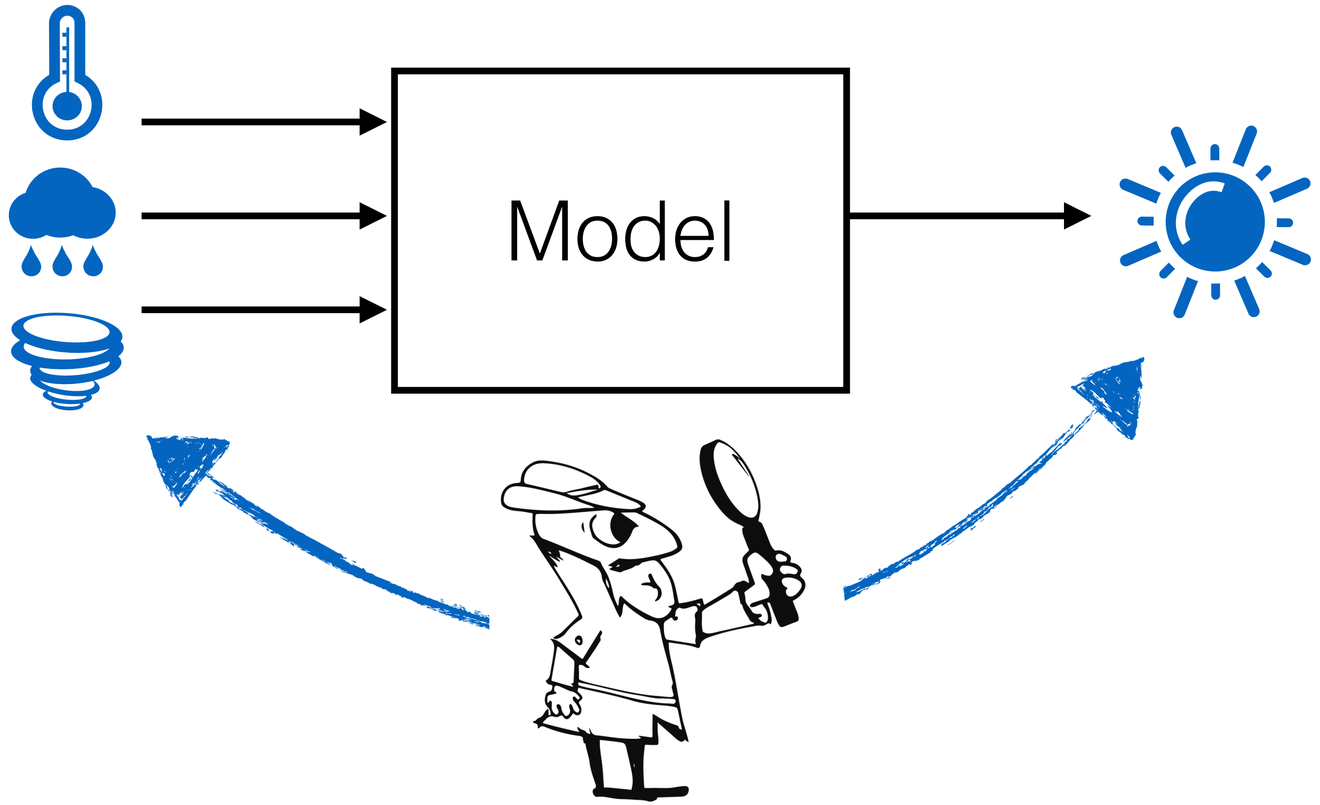

Stefan Bruckner[3]


Harald Piringer[4]

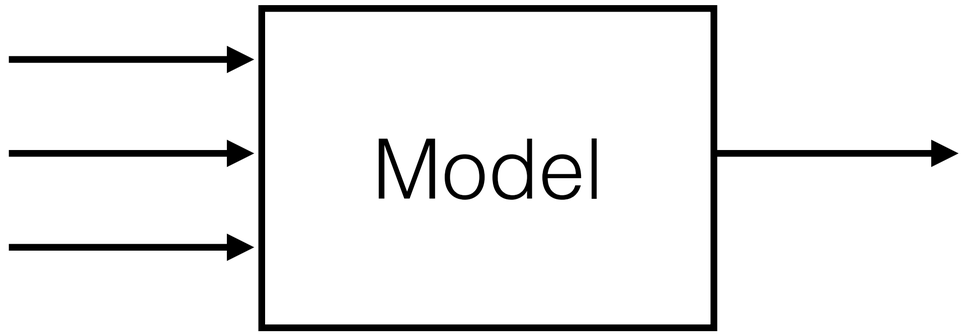

Torsten Möller[1]

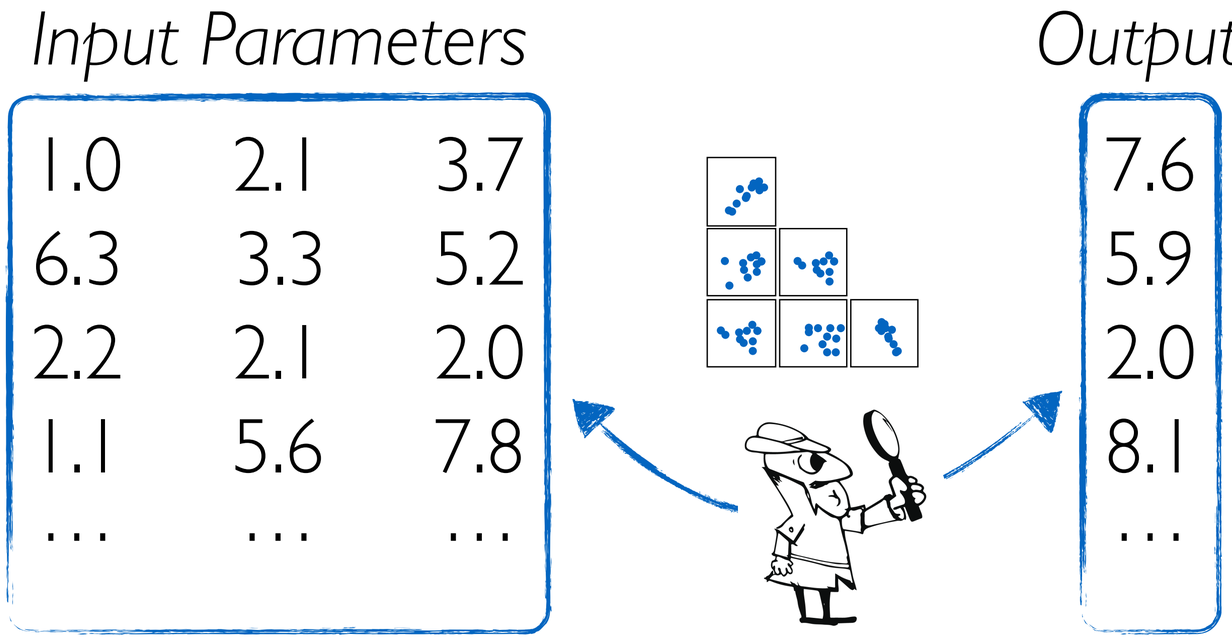
1) University of Vienna, Austria
2) University of Applied Sciences Upper Austria
3) University of Bergen, Norway
4) VRVis, Austria

Models



Visual Parameter Space Analysis (vPSA)

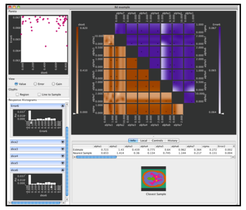


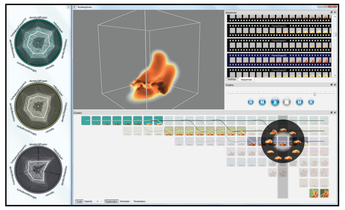


- systematic variation of model input parameters
- generating outputs for each combination of parameters
- visually inspecting relations between inputs & outputs

Much recent attention in vPSA

- Image segmentation *[Torsney Weir et al. 2011]*
- Weather forecast *[Potter et al. 2009]*
- Disaster simulation *[Waser et al. 2010]*
- *many more …*


[Torsney-Weir et al. 2011]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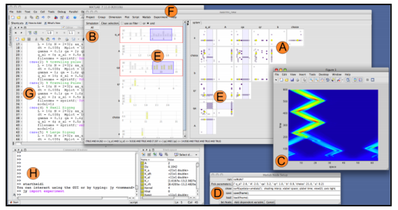
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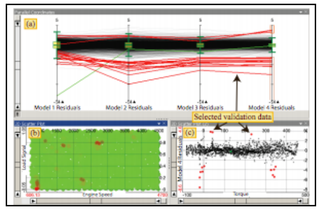
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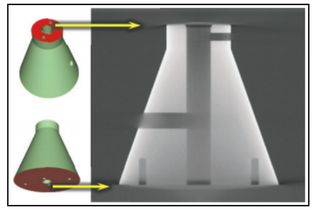
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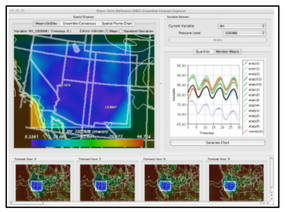
…etc. (us)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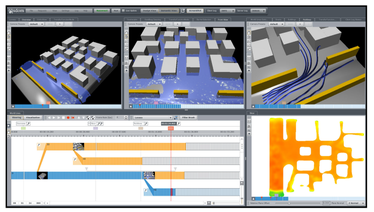
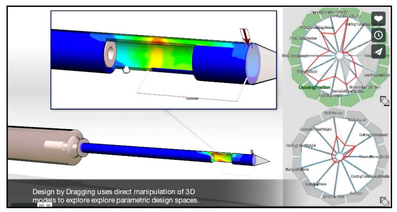
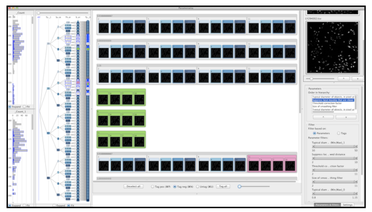

[Waser et al. 2010]


[Coffey et al. 2013]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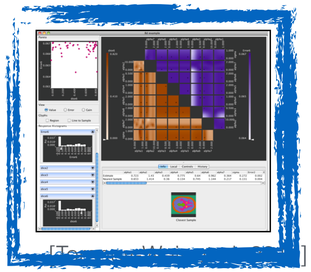
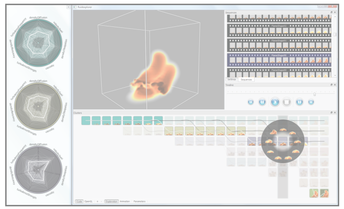

[T… …]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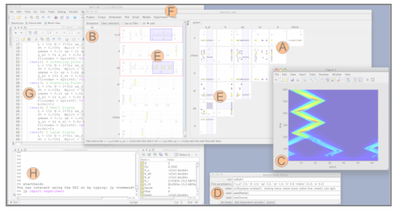
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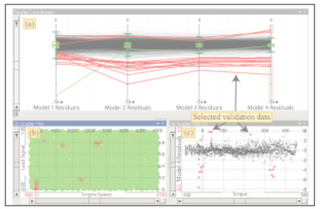
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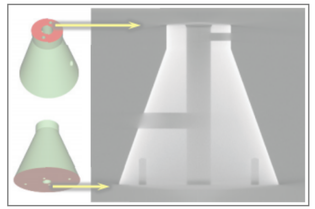
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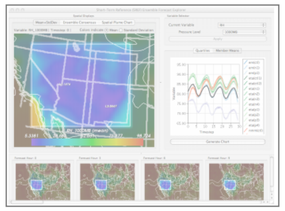
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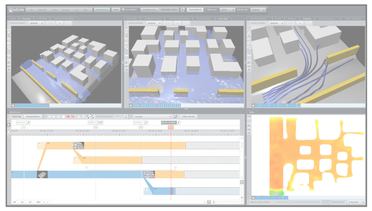
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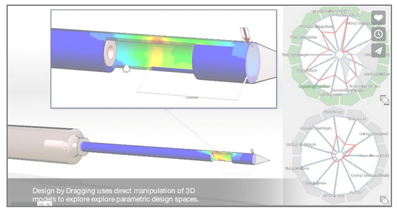
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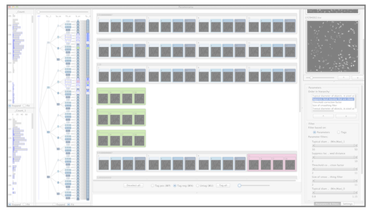
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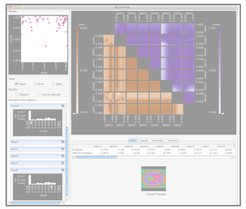
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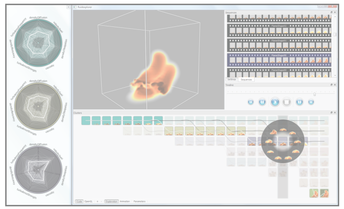
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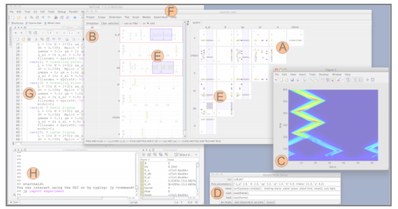
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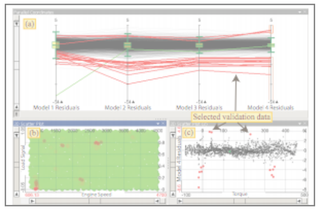
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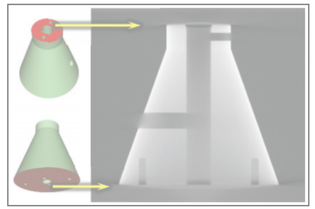
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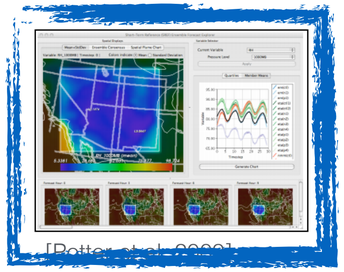
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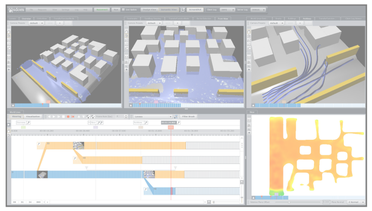
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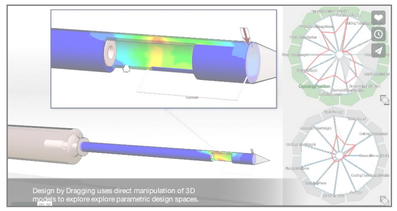
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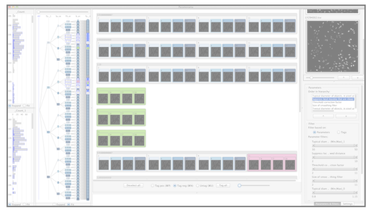
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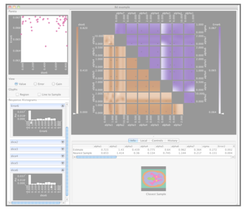
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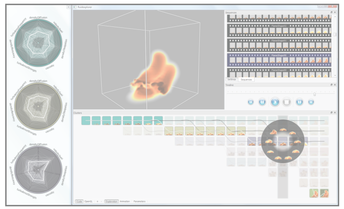
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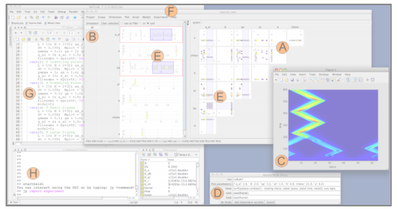
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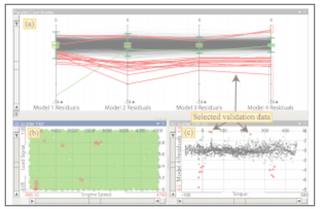
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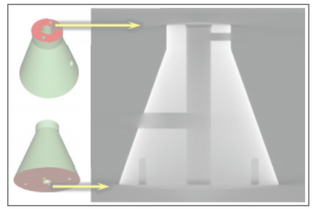
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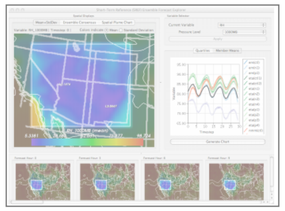
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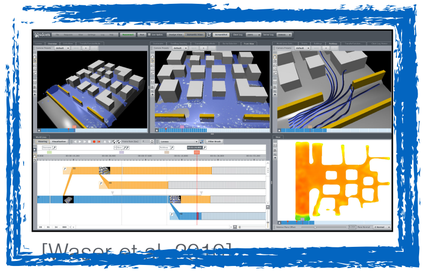
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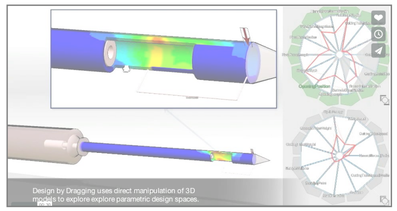
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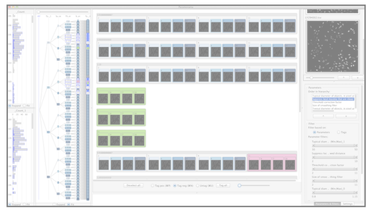
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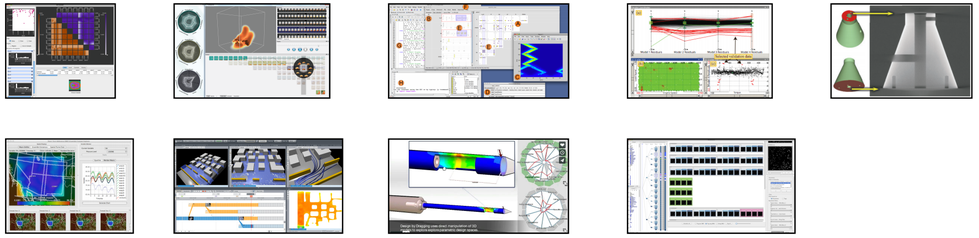
…*etc. (others)*

Challenges

- Current body of work: domain-specific applications



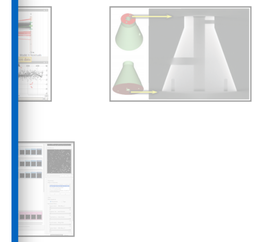
- Makes it hard to …
  - transfer knowledge across application areas
  - building up higher-level understanding of vPSA

Challenges

- Curre
  doma
- Make
  - unde
  - trans
  - build

Hypothesis:

Domain-specific applications share a common abstract *framework* characterizing vPSA

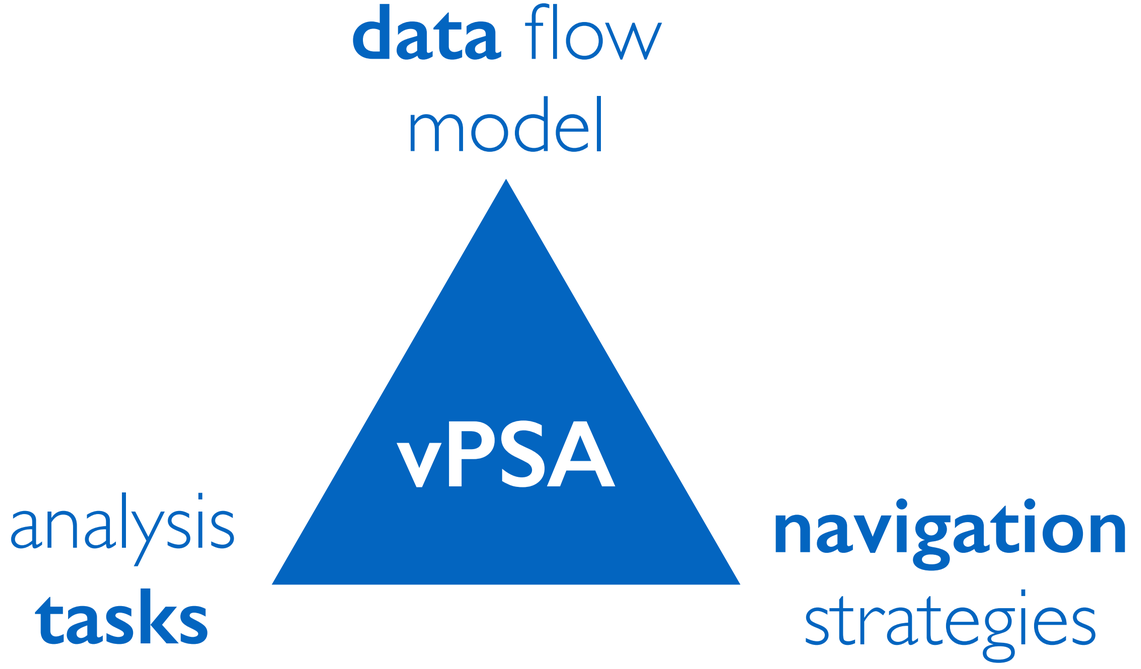


Our goal:

Carve this *framework* out!

Contributions

- Structured analysis of the vPSA literature
- **Conceptual framework**
- Terminology / Definitions
- Research Gaps



Outline

Method

Conceptual framework

How to use the framework?

Research gaps

Structured literature analysis

112 candidate papers

- informed initial ideas

21 core-relevant papers

- Iterative analysis by 5 coders (authors, 2-3 coders/paper)

Outline

Method

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Research gaps

Data flow model

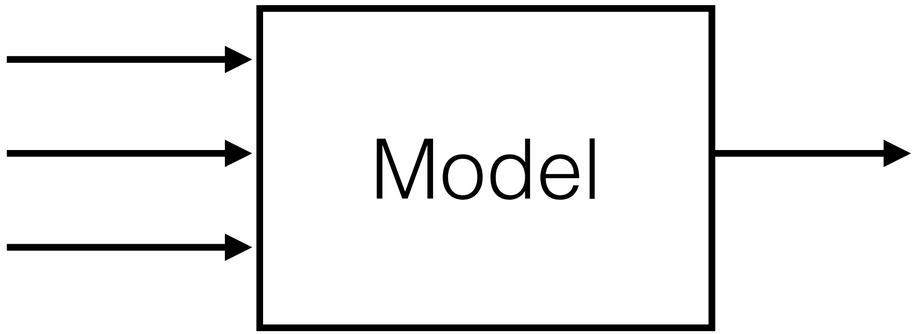
What does the data look like?

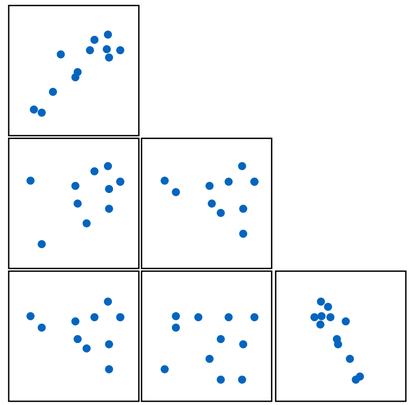
data flow
model

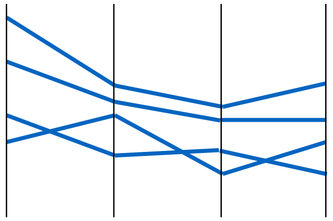
analysis
tasks

navigation
strategies

Numerical inputs & outputs

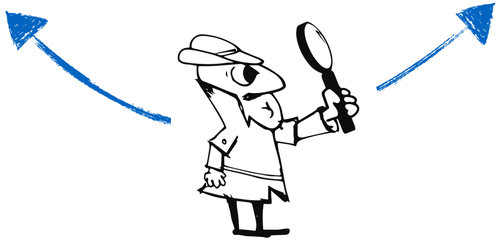






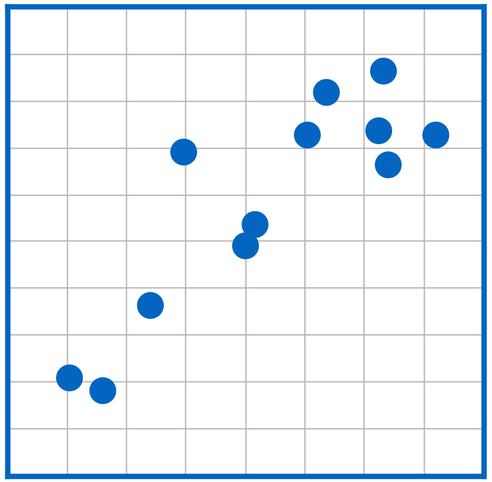
Input Parameters

1.0	2.1	3.7
6.3	3.3	5.2
2.2	2.1	2.0
1.1	5.6	7.8
…	…	…

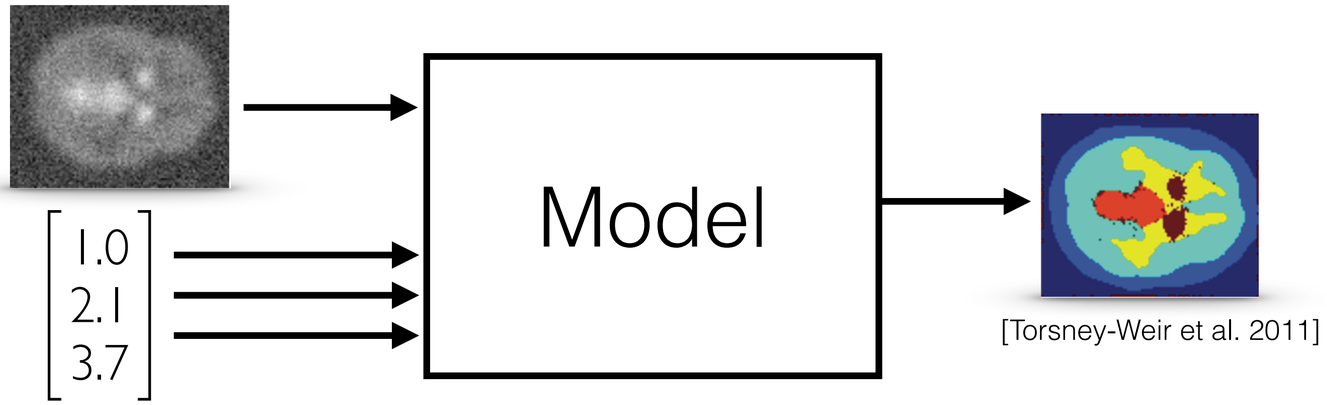


Outputs

7.6
5.9
2.0
8.1
…



Complex objects (in 18/21 papers)



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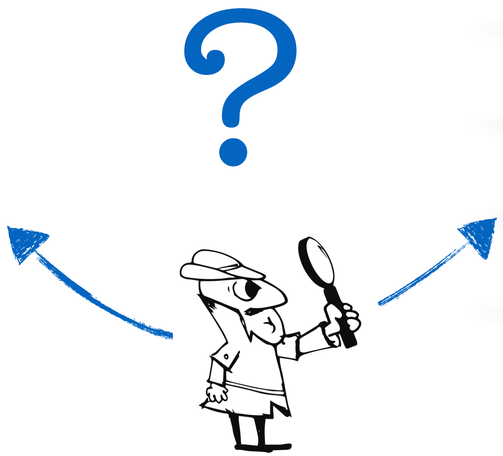
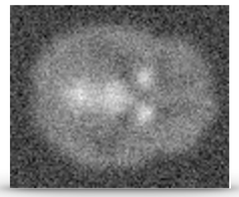
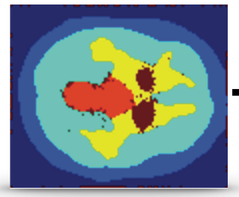


Derive objective measures



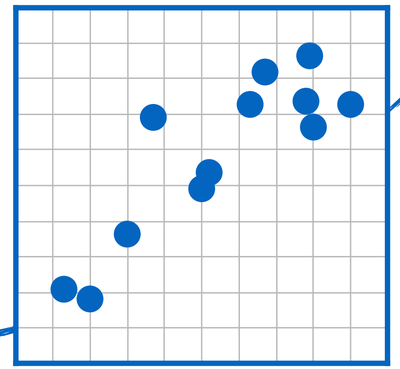
1.0
2.1
3.7

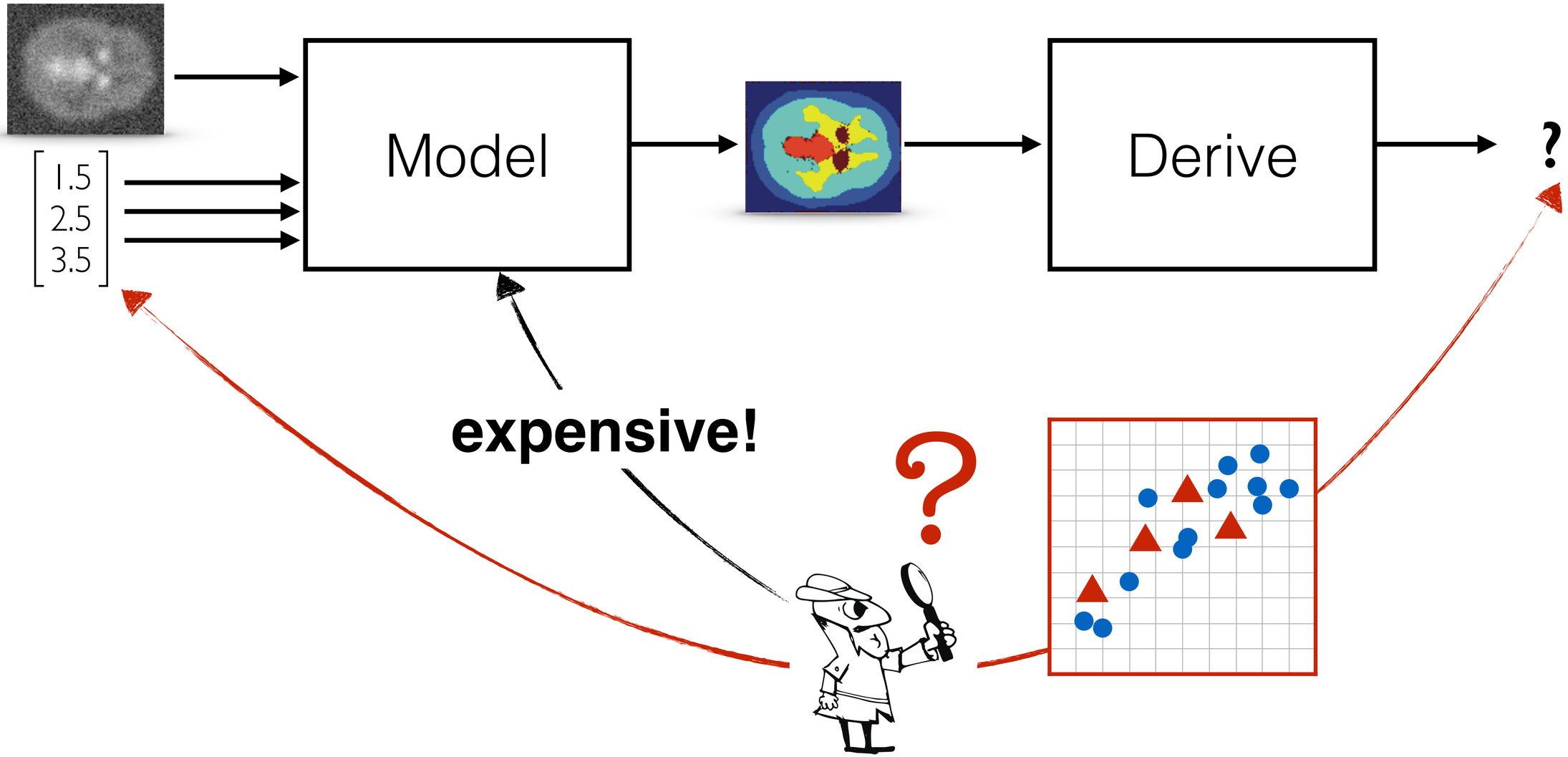
Model



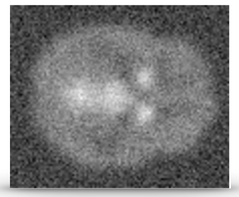
Derive

7.1



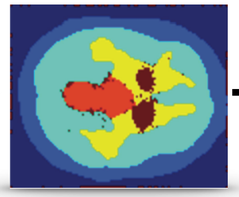

Model
Derive
?
1.5
2.5
3.5
expensive!
?

Surrogate models



$$\begin{bmatrix} 1.5 \\ 2.5 \\ 3.5 \end{bmatrix}$$

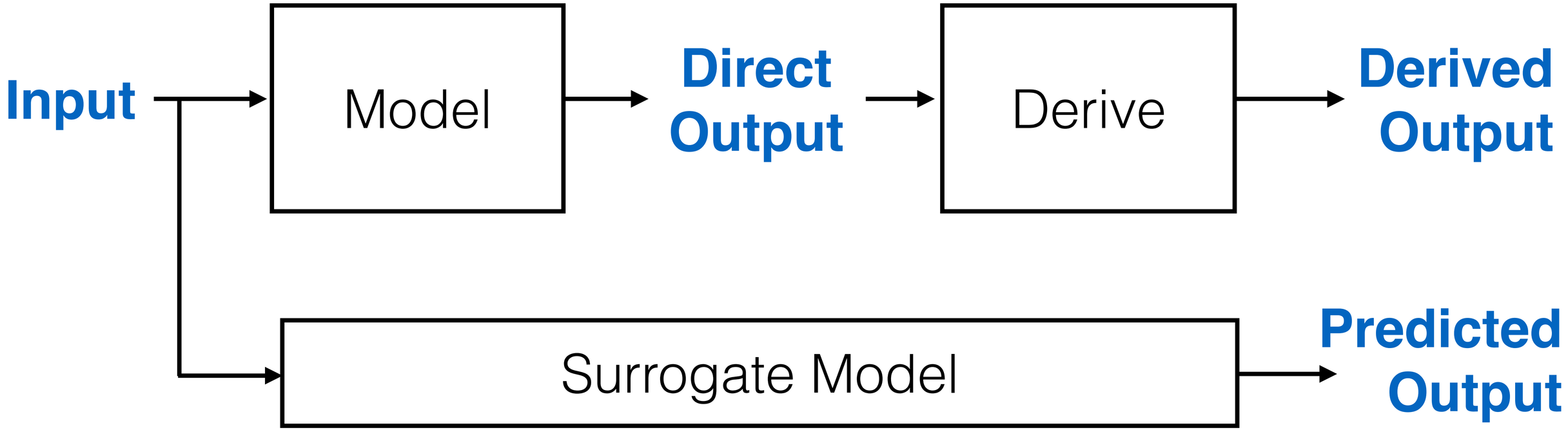
Model

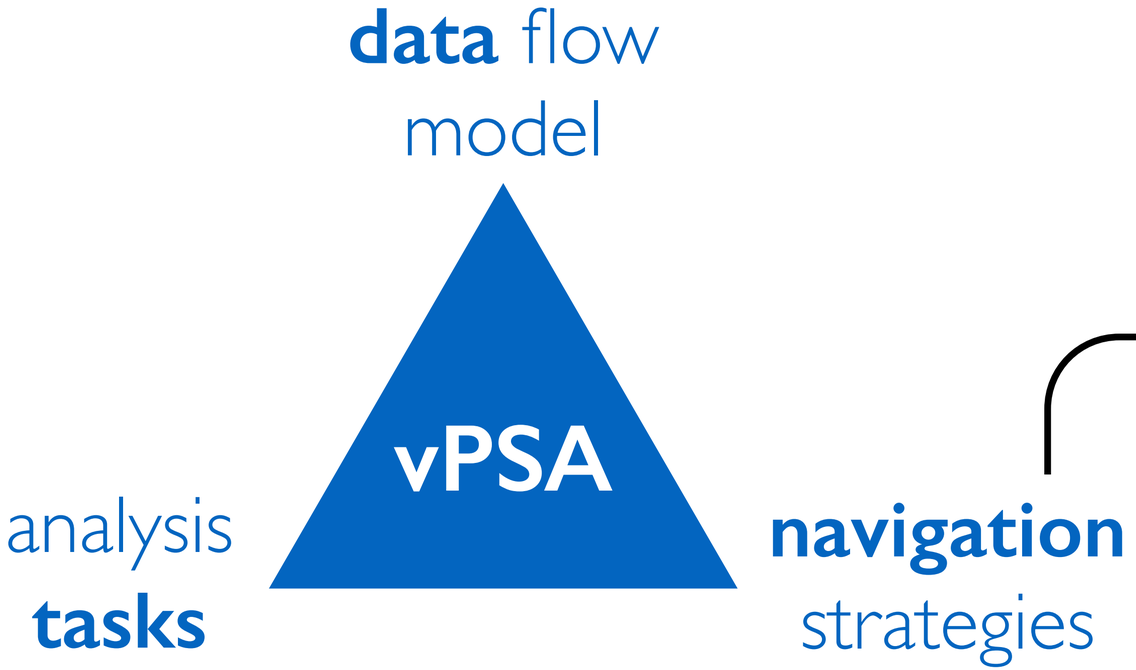


Derive

Surrogate Model

Data flow model





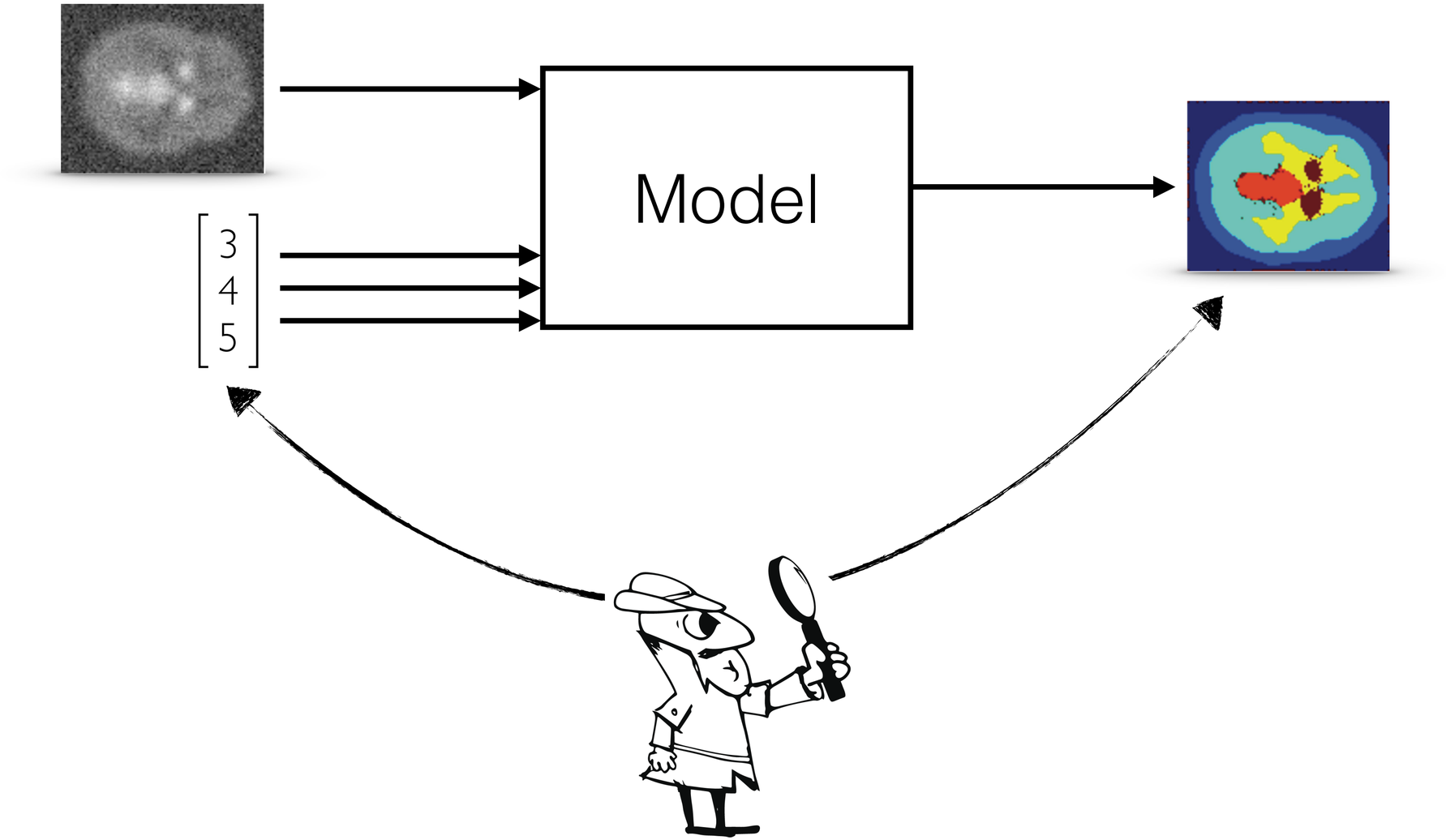
Navigation Strategies

How to explore the parameter space?

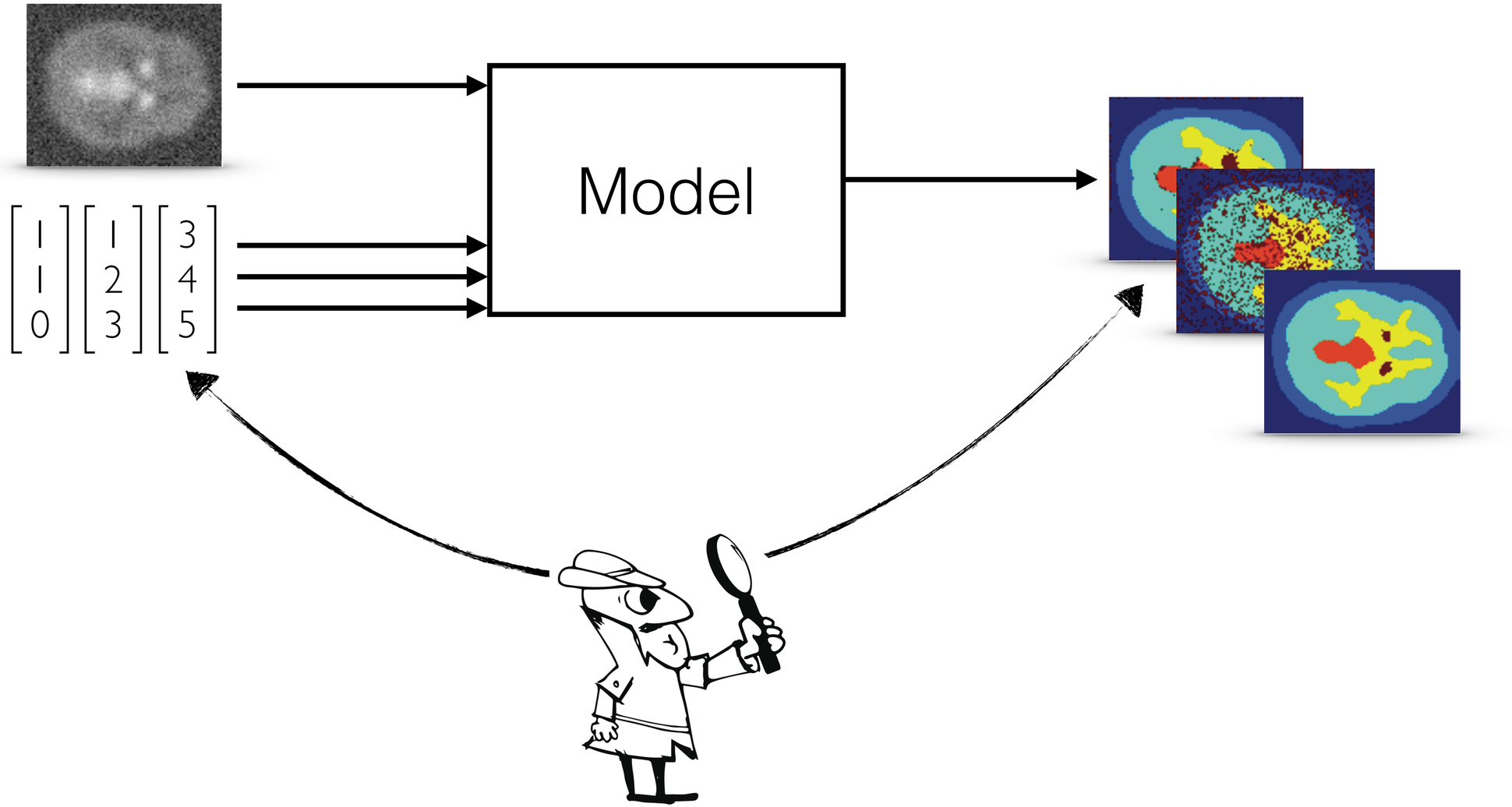
Navigation strategies

1. Informed trial & error — *(traditional)*
2. Local-to-global — *(vPSA)*
3. Global-to-local — *(vPSA)*
4. Steering — *(vPSA)*

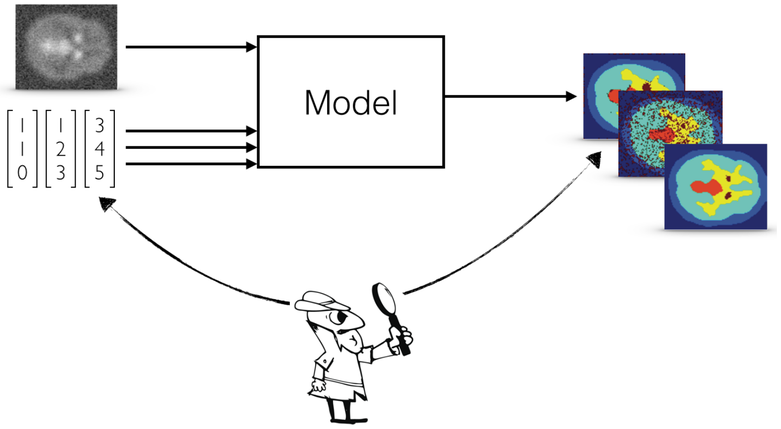
Informed trial & error (traditional)



Informed trial & error (traditional)



Informed trial & error (traditional)



- Comes with severe problems:
  - *interruptive*
  - *not systematic*

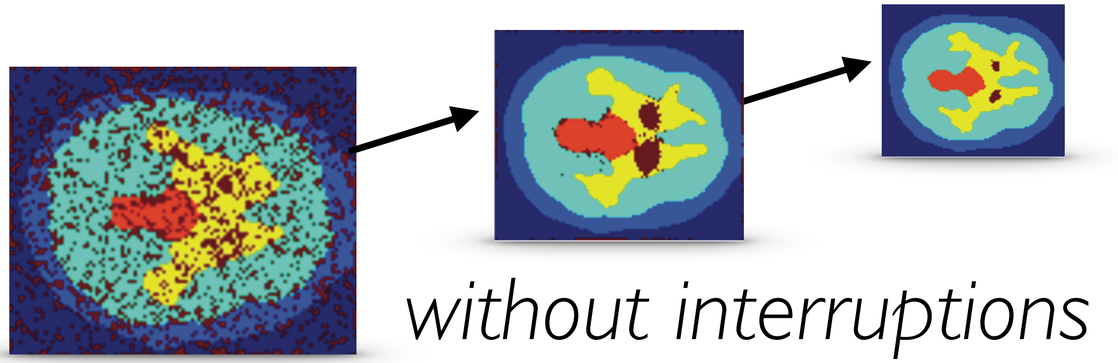
1. Informed trial & error

*found in **3 (of 21)** papers*

2. Local-to-global

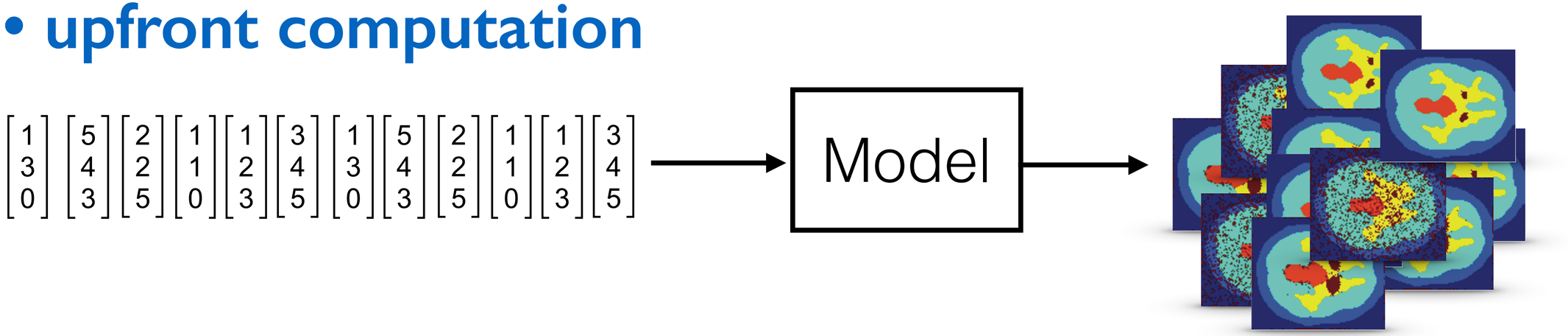
3. Global-to-local

4. Steering

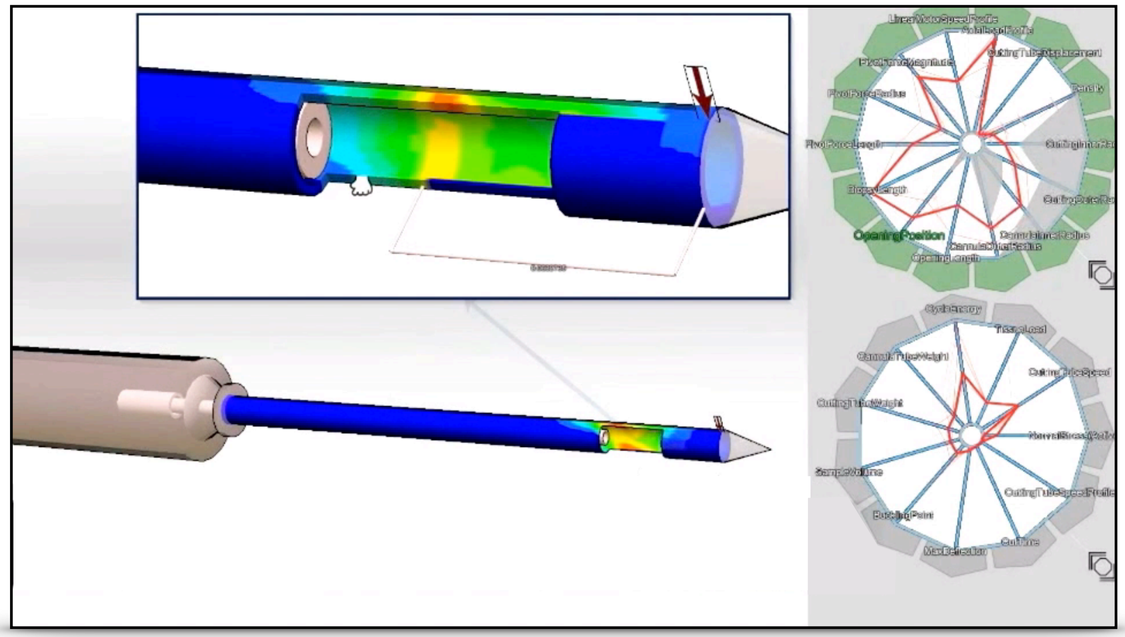


without interruptions

- **space-filling sampling**
- **upfront computation**



Local-to-global — Coffey et al. [SciVis 2013]

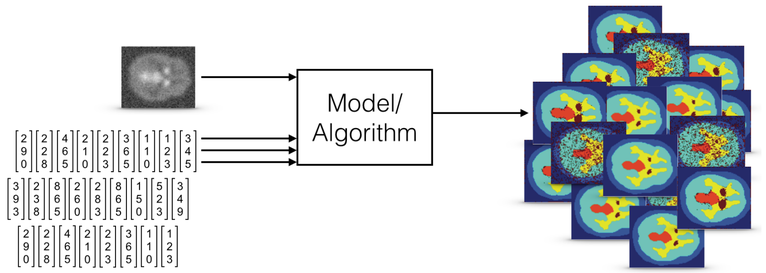


- Input: cutting area
- Output: color map

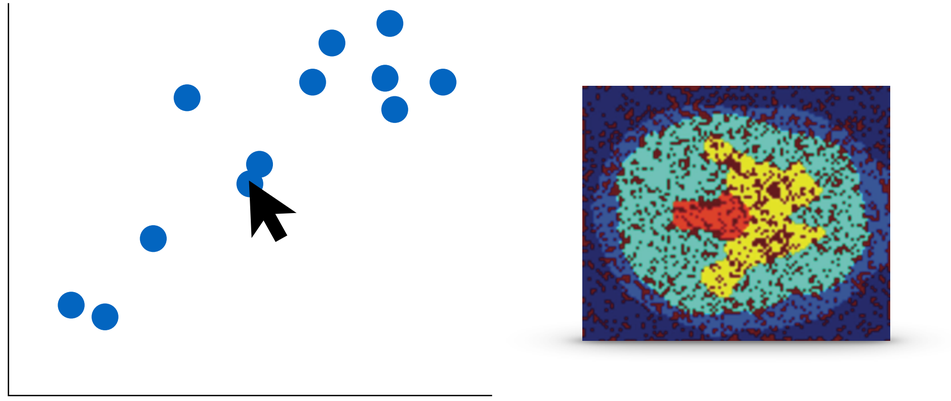
1. Informed trial & error
2. Local-to-global
3. Global-to-local
4. Steering

*found in **16 (of 21)** papers*

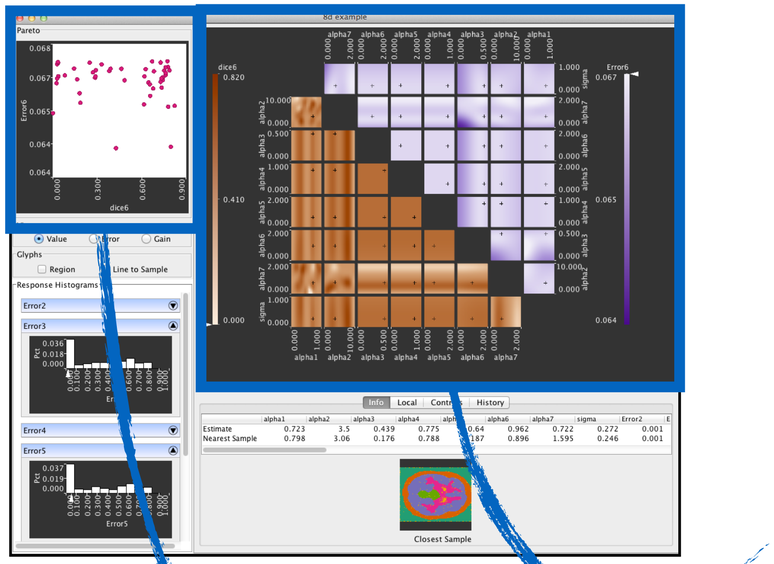
"Overview first,
zoom and filter,
then details on demand"
[Shneiderman 1996]

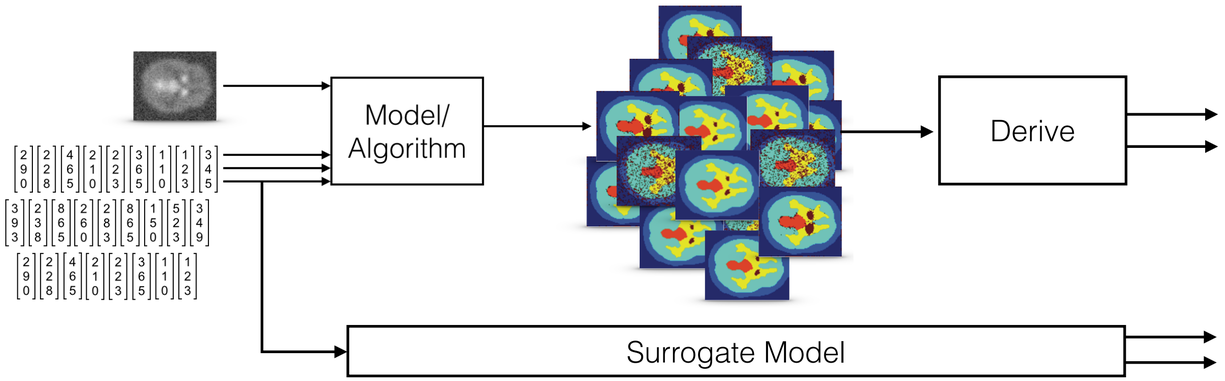


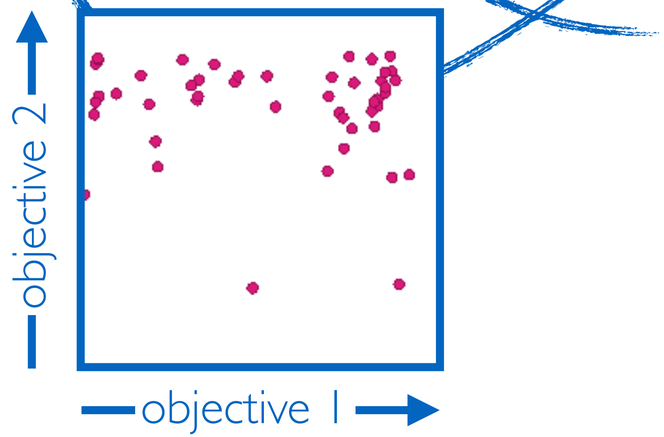
- *space-filling sampling*
- *upfront computation*



Global-to-local — Torsney-Weir et al. [Vis 2011]





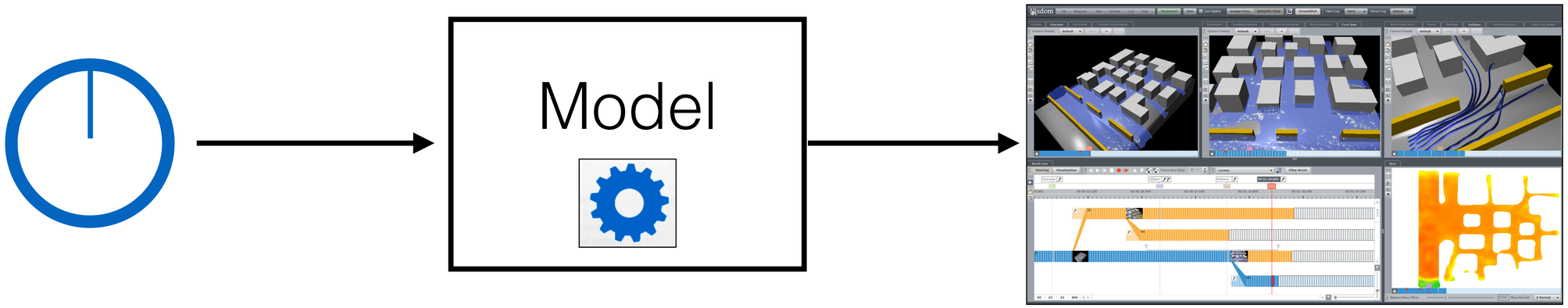


- Derive: *2 objective measures*
- Surrogate: *predicting continuous-to-continuous*

1. Informed trial & error
2. Local-to-global
3. Global-to-local
4. **Steering**

*found in **2 (of 21)** papers*

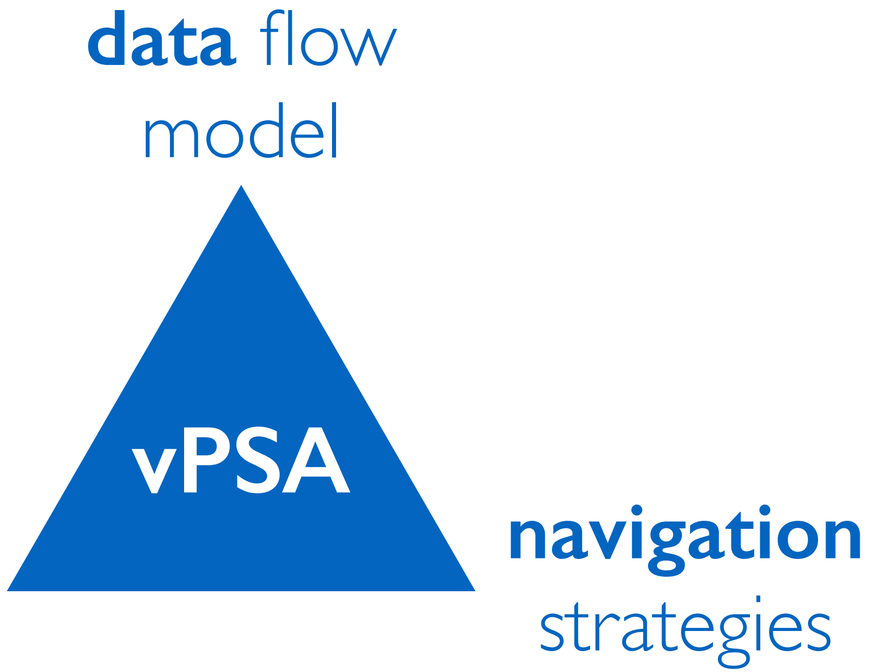
On the fly,
while the model runs!



[Waser et al. 2010]

Analysis Tasks

What do users do?



Analysis tasks

1. Optimization
2. Partitioning
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

Analysis tasks

1. Optimization

2. Partitioning

3. Fitting

4. Outliers

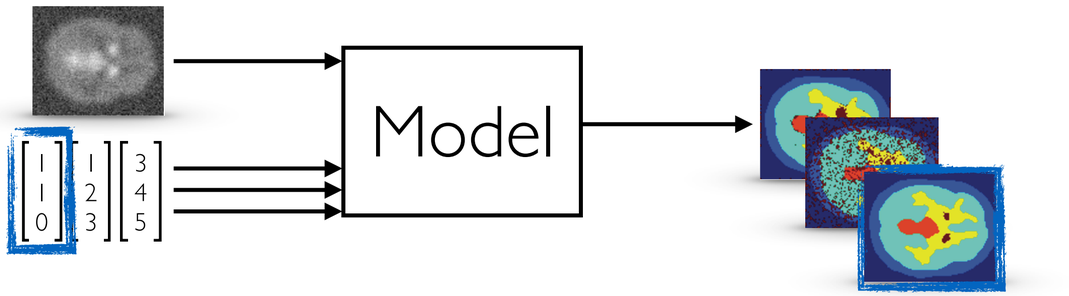
5. Uncertainty

6. Sensitivity

1. Optimization

2. Partitioning
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

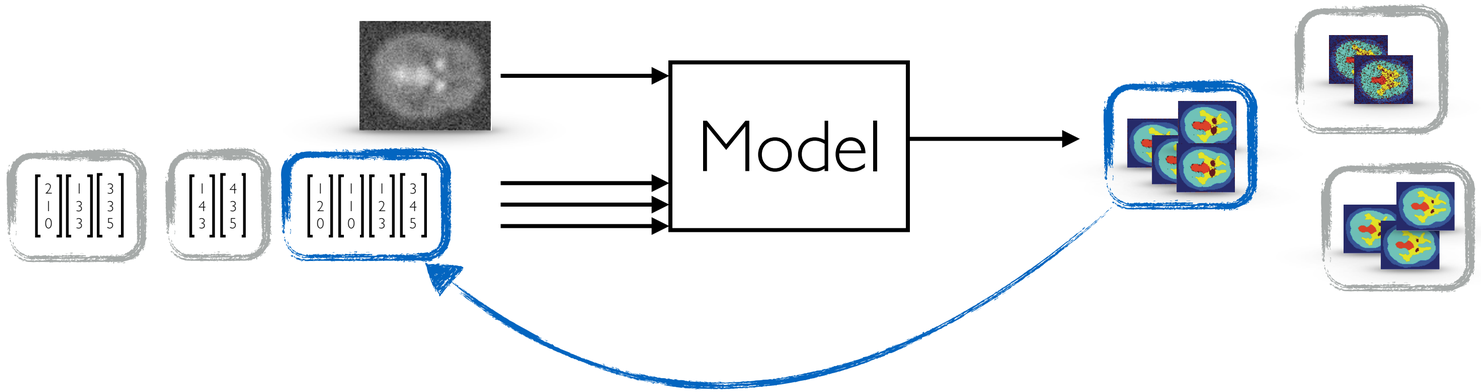
Find the best parameter combination given some objectives.



in 19/21 papers

1. Optimization
2. **Partitioning** aka clustering
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

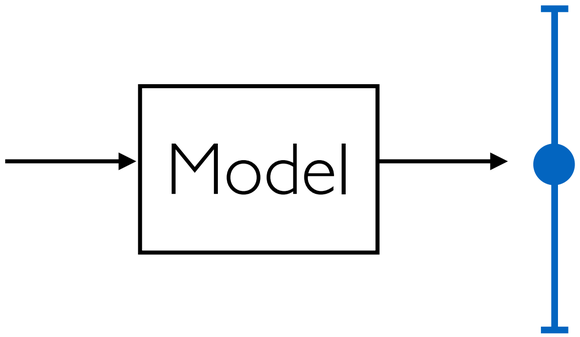
How many different types of model behaviors are possible?



in 6/21 papers

1. Optimization
2. Partitioning
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

How reliable is the output?



- model vs. reality
- non-deterministic model
- model vs. surrogate

in 7/21 papers

Outline

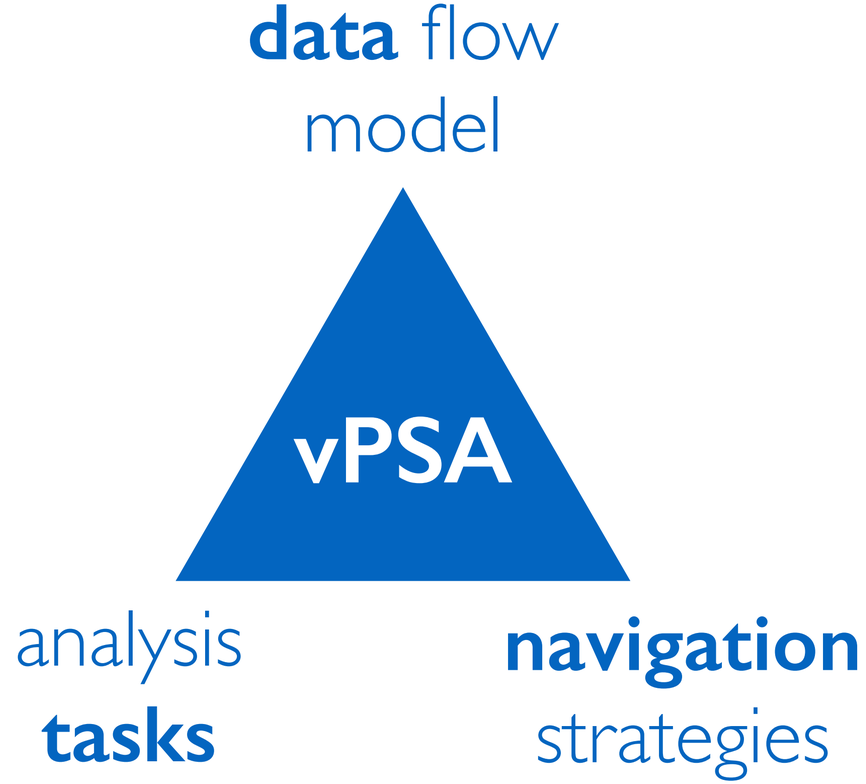
Method

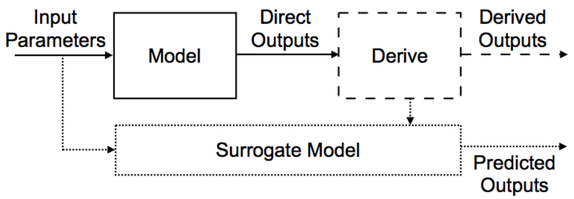
Conceptual framework

How to use the framework?

Research gaps

Guiding design decisions





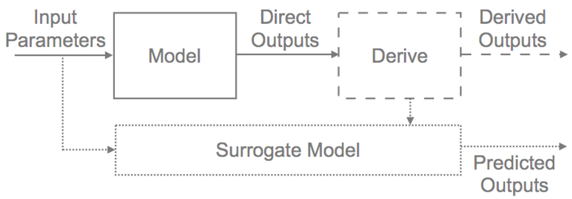
sampling, derive, surrogate as part of the Vis pipeline?

data flow model

vPSA

analysis **tasks**

navigation strategies



sampling, derive, surrogate as part of the Vis pipeline?

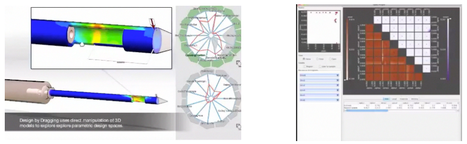
data flow model

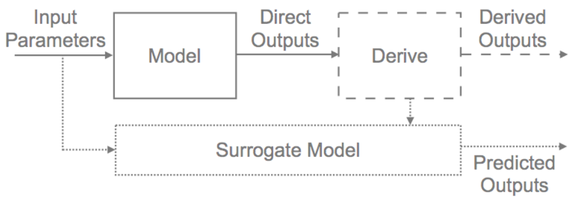
vPSA

analysis **tasks**

navigation strategies

which fits the context?





sampling, derive, surrogate as part of the Vis pipeline?

data flow model

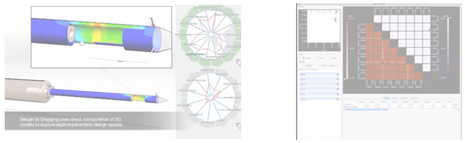
- understand tasks
- extend tasks

vPSA

analysis **tasks**

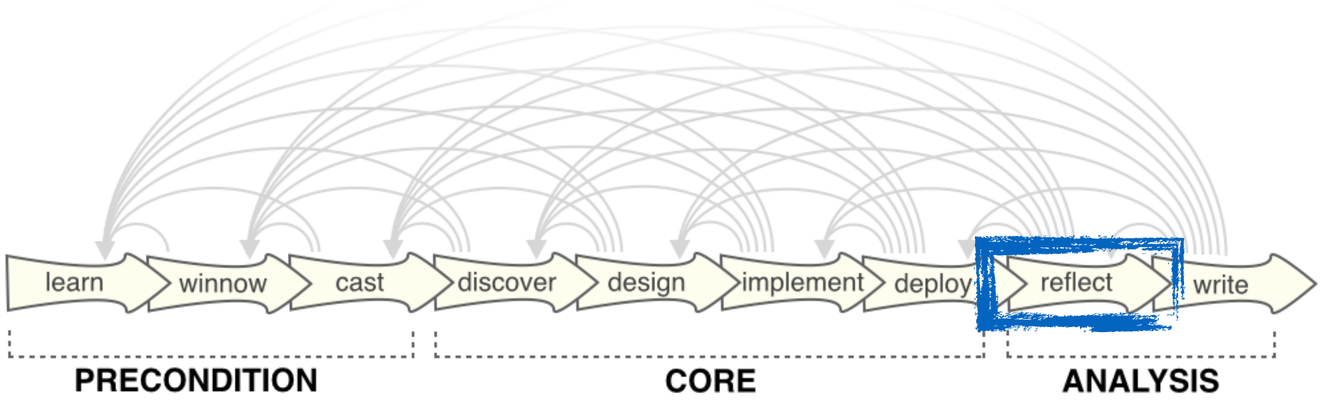
navigation strategies

which fits the context?



Evaluate and communicate

Abstract lens for interpreting vPSA **across domains**



"reflect about lessons learned in order to refine visualization design guidelines"

[Sedlmair et al. 2012]

Theory

From design studies to visualization theory

“The visualization and data analysis cookbook”

abstract data & task

data analysis technique

Outline

Method

Conceptual framework

How to use the framework?

Research gaps

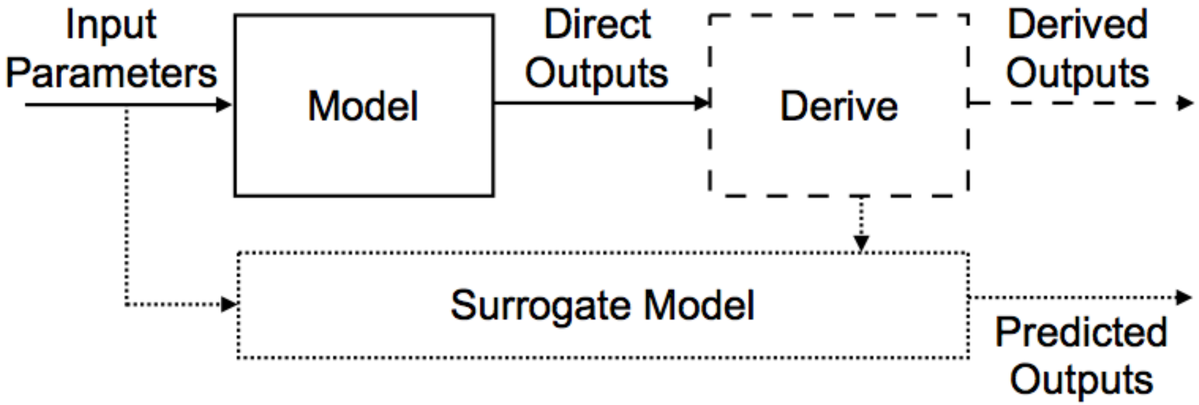
Research gaps

- Data Acquisition & Analysis Gap
- Cognition Gap
- … etc.

Research gaps

- **Data Acquisition & Analysis Gap**
- Cognition Gap
- … etc.

Support integrated sampling, derivation, and prediction



Research gaps

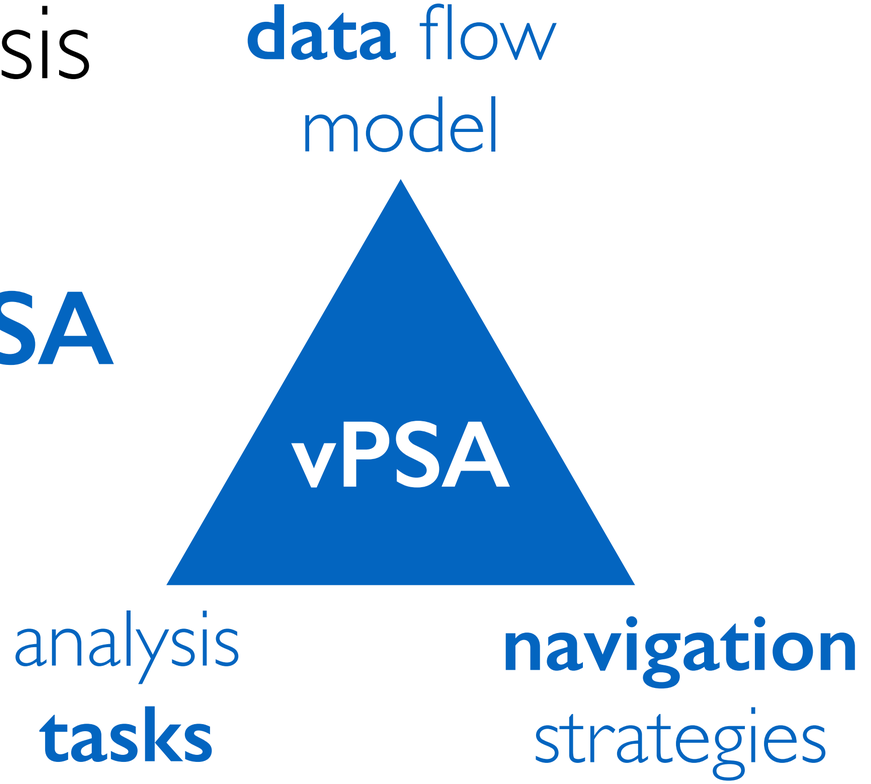
- Data Acquisition & Analysis Gap
- **Cognition Gap**
- … etc.

Understand multi-dim data, given special characteristics of vPSA

Summary

Summary

- vPSA: visual Parameter Space Analysis
- Structured literature analysis
- **A conceptual framework for vPSA**
- How to use it
- Challenges



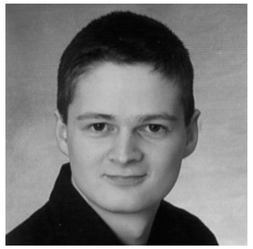
PhD student

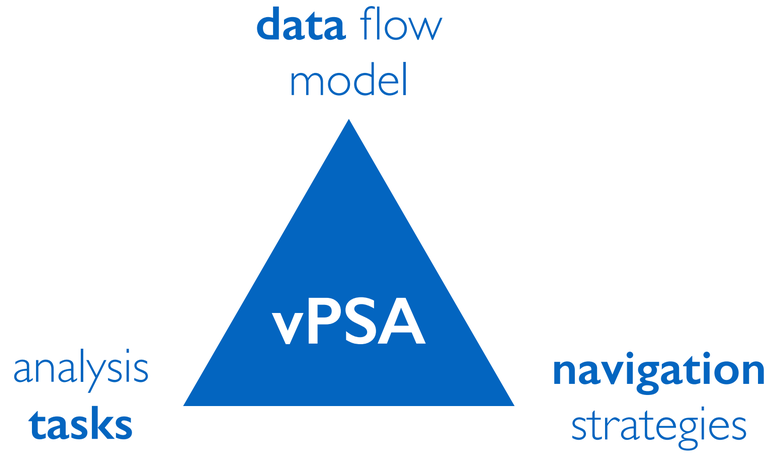
Visual Analysis in Data-driven Journalism

Software Developer

Visual Parameter Space Analysis: A Conceptual Framework

Michael Sedlmair[1] Christoph Heinzl[2] Stefan Bruckner[3] Harald Piringer[4] Torsten Möller[1]

PhD: goo.gl/q7uQDm
Developer: goo.gl/FDtJkk

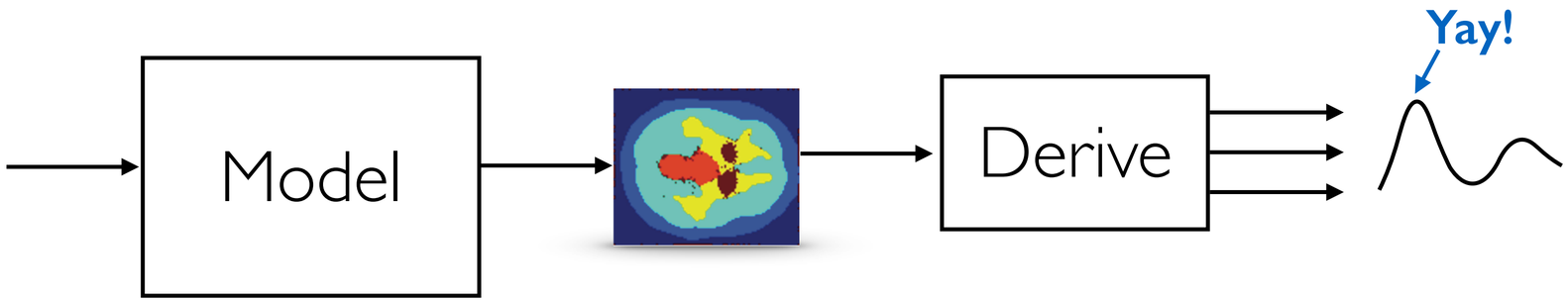
michael.sedlmair@univie.ac.at

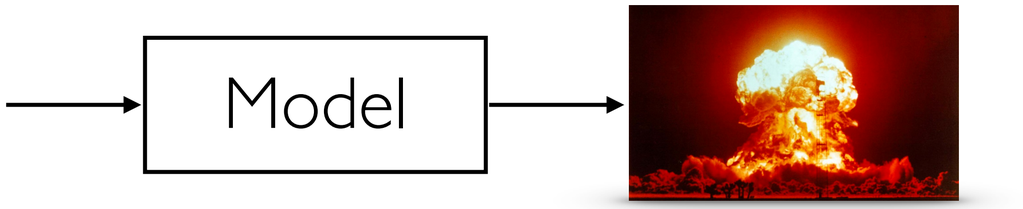
slides: http://homepage.univie.ac.at/michael.sedlmair/talks/vis2014-toi.pdf/

1) University of Vienna, Austria
2) University of Applied Sciences Upper Austria
3) University of Bergen, Norway
4) VRVis, Austria

Appendix

Optimization





[Bruckner & Möller 2010]

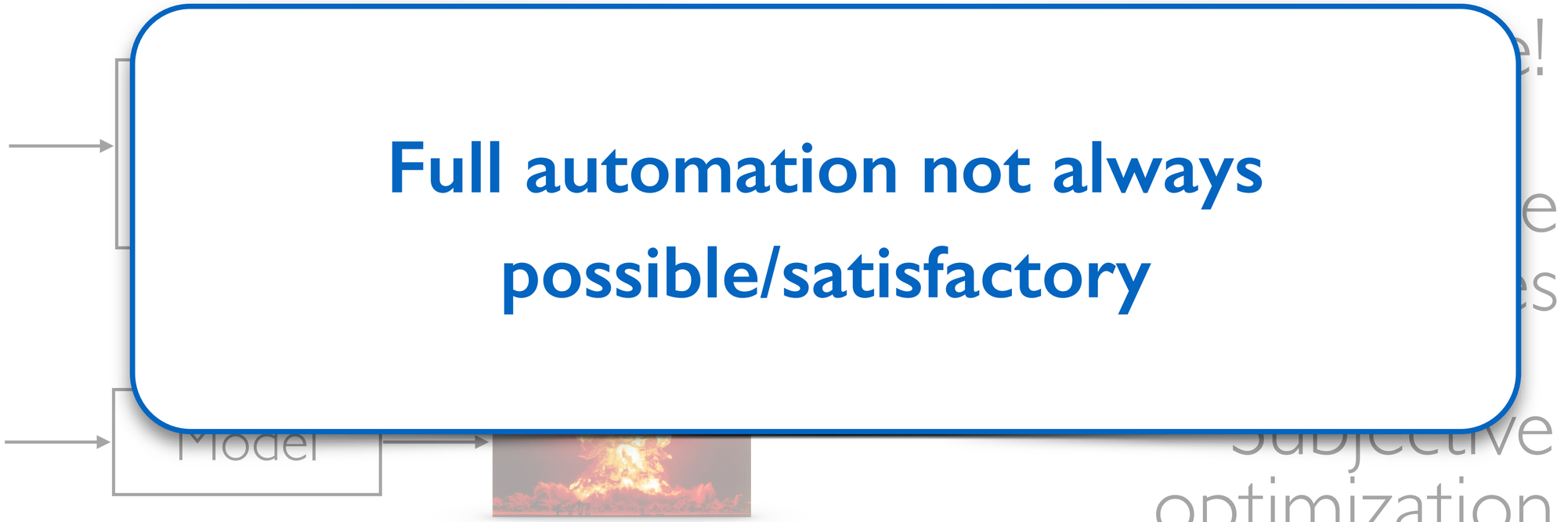
Derive!

Multiple objectives

Subjective optimization

http://vivirmatablog.files.wordpress.com/2014/04/ilovenuclearexplosions-andeverybodyinthetownwhere_23077c829fbfc19e6e96c7c

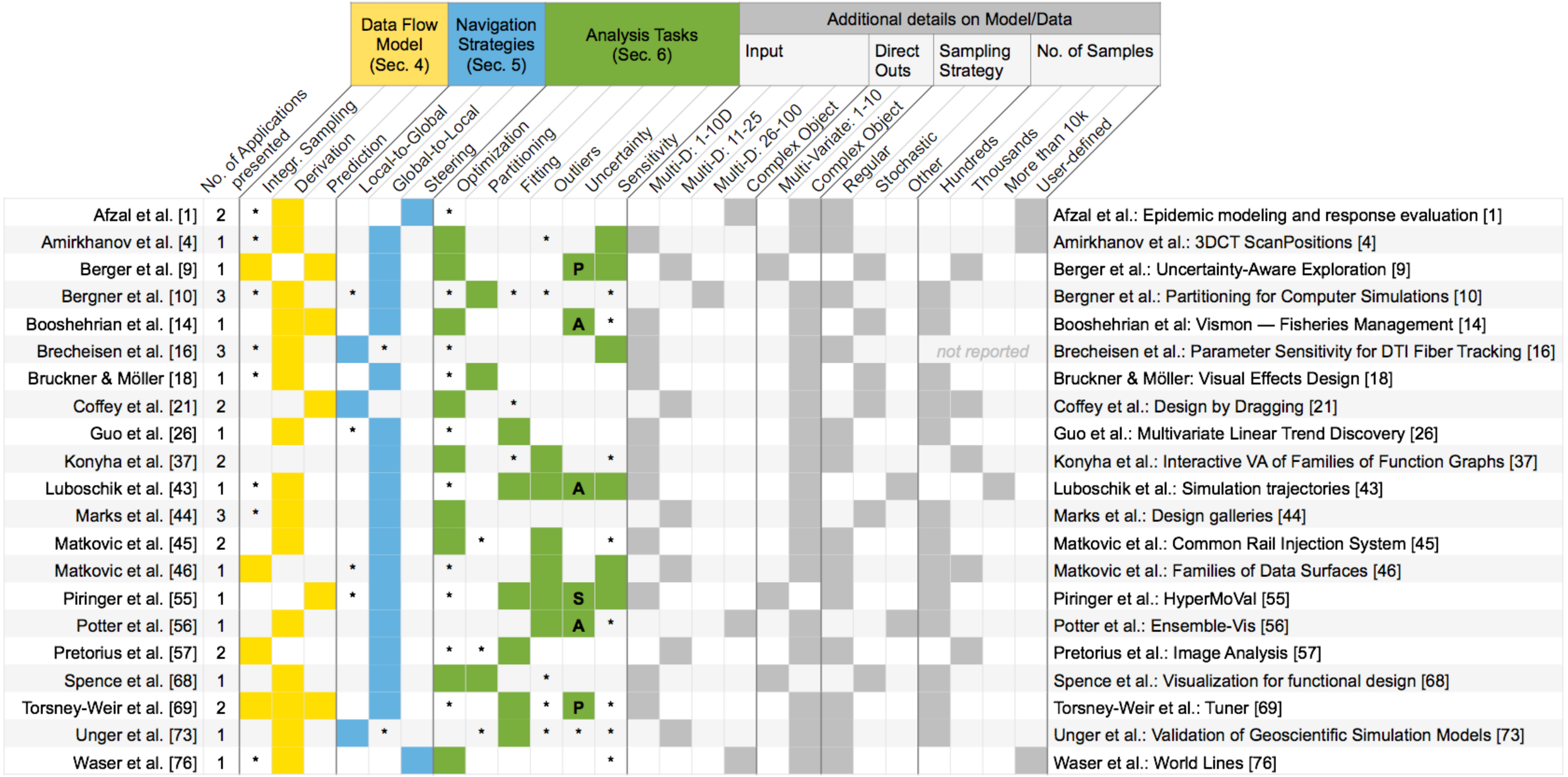
Optimization



Full automation not always possible/satisfactory

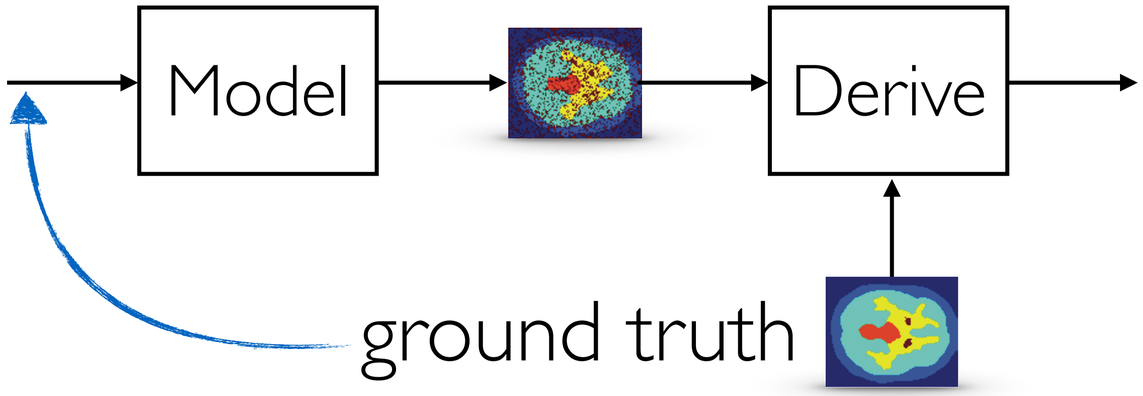
[Bruckner & Möller 2010]

http://vivirmatablog.files.wordpress.com/2014/04/ilovenuclearexplosions-andeverybodyinthetownwhere_23077c829fbfc19e6e96c7c...


Data Flow Model (Sec. 4)
Navigation Strategies (Sec. 5)
Analysis Tasks (Sec. 6)
Additional details on Model/Data
Input
Direct Outs
Sampling Strategy
No. of Samples
No. of Applications presented
Integr. Sampling
Derivation
Prediction
Local-to-Global
Global-to-Local
Steering
Optimization
Partitioning
Fitting
Outliers
Uncertainty
Sensitivity
Multi-D: 1-10D
Multi-D: 11-25
Multi-D: 26-100
Complex Object
Multi-Variate: 1-10
Complex Object
Regular
Stochastic
Other
Hundreds
Thousands
More than 10k
User-defined
Afzal et al. [1] 2
Amirkhanov et al. [4] 1
Berger et al. [9] 1
Bergner et al. [10] 3
Booshehrian et al. [14] 1
Brecheisen et al. [16] 3
Bruckner & Möller [18] 1
Coffey et al. [21] 2
Guo et al. [26] 1
Konyha et al. [37] 2
Luboschik et al. [43] 1
Marks et al. [44] 3
Matkovic et al. [45] 2
Matkovic et al. [46] 1
Piringer et al. [55] 1
Potter et al. [56] 1
Pretorius et al. [57] 2
Spence et al. [68] 1
Torsney-Weir et al. [69] 2
Unger et al. [73] 1
Waser et al. [76] 1
not reported
Afzal et al.: Epidemic modeling and response evaluation [1]
Amirkhanov et al.: 3DCT ScanPositions [4]
Berger et al.: Uncertainty-Aware Exploration [9]
Bergner et al.: Partitioning for Computer Simulations [10]
Booshehrian et al: Vismon — Fisheries Management [14]
Brecheisen et al.: Parameter Sensitivity for DTI Fiber Tracking [16]
Bruckner & Möller: Visual Effects Design [18]
Coffey et al.: Design by Dragging [21]
Guo et al.: Multivariate Linear Trend Discovery [26]
Konyha et al.: Interactive VA of Families of Function Graphs [37]
Luboschik et al.: Simulation trajectories [43]
Marks et al.: Design galleries [44]
Matkovic et al.: Common Rail Injection System [45]
Matkovic et al.: Families of Data Surfaces [46]
Piringer et al.: HyperMoVal [55]
Potter et al.: Ensemble-Vis [56]
Pretorius et al.: Image Analysis [57]
Spence et al.: Visualization for functional design [68]
Torsney-Weir et al.: Tuner [69]
Unger et al.: Validation of Geoscientific Simulation Models [73]
Waser et al.: World Lines [76]

1. Optimization
2. Partitioning
3. **Fitting** aka regression analysis
4. Outliers
5. Uncertainty
6. Sensitivity

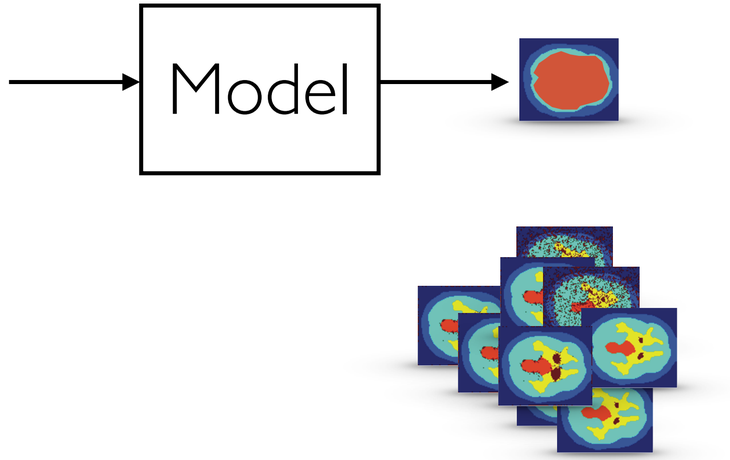
Where in the input parameter space would actual measured data occur?



in 9/21 papers

1. Optimization
2. Partitioning
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

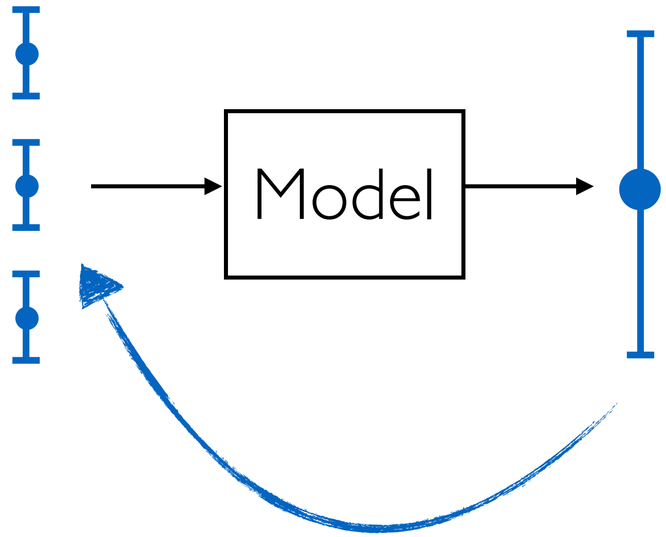
What outputs are special?



in 9/21 papers

1. Optimization
2. Partitioning
3. Fitting
4. Outliers
5. Uncertainty
6. Sensitivity

What ranges/variations of outputs to expect with changes of input?



in 14/21 papers