# Visualization and machine learning

Thomas Torsney-Weir

1



• Born:Allentown, PA





- Born: Allentown, PA
- Undergrad: Georgetown





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- Undergrad: Georgetown
- Finance: NYC





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- Master's: Simon Fraser





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- PhD/Postdoc: University of Vienna





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- Undergrad: Georgetown
- Finance: NYC
- Master's: Simon Fraser
- PhD/Postdoc: University of Vienna
- Next: Swansea University!





Multi-dimensional spaces



Users/tasks



#### Visualization and machine learning



Machine learning

#### Visualization

Morton, Kristi, Ross Bunker, Jock Mackinlay, Robert Morton, and Chris Stolte. "Dynamic workload driven data integration in tableau," Proceedings of the 2012 acm sigmod 11 international conference on management of data. 2012. both!

- Visualization helps machine learning: evaluating models
- Machine learning helps visualization: machine learning for embedded analysis

# <u>Outline</u>

- Visualization helping machine learning
- Machine learning helping visualization
- What does the future hold?

# Visualization helping machine learning

# How do they work together?

- Building models
  - Meta parameters
  - Parameter selection
- Validating models
- Understanding models

#### Meta parameters

# What are meta parameters?

Control how learning takes place

- Learning rate
- Number and size of network layers
- Slack variables
- Stopping conditions

# Why study meta parameters?



# Why study meta parameters?

Meta parameters can have a large influence on performance



### Manual method



20

# Manual method

Manual tuning is time consuming and error prone



# Objective measures



# Visual parameter space exploration

Use a more principled approach



SedImair, Michael, Christoph Heinzl, Stefan Bruckner, Harald Piringer, and Torsten Möller. "Visual parameter space analysis: A conceptual framework," IEEE Transactions on Visualization and Computer Graphics. 2014.



Torsney-Weir, Thomas, Ahmed Saad, Torsten Möller, Britta Weber, Hans-Christian Hege, Jean-Marc Verbavatz, and Steven Bergner. "Tuner: Principled parameter finding for image segmentation algorithms using visual response surface<sup>24</sup> exploration," IEEE Transactions on Visualization and Computer Graphics. 2011.

















https://imagej.nih.gov/ij/plugins/volume-viewer.html



#### <u>Tuner</u>





# Validating and verifying models

### What do we mean?



Committee on Mathematical Foundations of Verification, Validation, and Uncertainty Quantification; Board on Mathematical Sciences and Their Applications, Division on Engineering and Physical Sciences, National Research Council. Assessing the reliability of complex models: Mathematical and statistical foundations of verification 77 validation, and uncertainty quantification 2012.

# Model selection

- What is the best model for my data?
- How well will these models generalize?
- Summary statistics are not always enough
- Balancing multiple objectives is difficult
- Certain training points might be very important

### Example

Boston housing dataset

- 13 factors
  - crime rate
  - number of rooms
  - etc
- want to predict home price
- what regression model to pick?

### **Function inspection**



1D function



2D function

More than this gets hard!

# Slicing



### Sliceplorer views



Torsney-Weir, Thomas, Michael Sedlmair, and Torsten Möller. "Sliceplorer: 1D slices for multi-dimensional continuous functions," Computer Graphics Forum. 2017.

# Summary

- Just an answer is not enough (context)
- Humans have trouble understanding complex models
- Interactivity can bring people into the model

# Machine learning helping visualization





Computers are good at calculating

Sacha, D., A. Stoffel, F. Stoffel, Bum Chul Kwon, G. Ellis, and Daniel A Keim. "Knowledge generation model for visual analytics," Visualization and Computer Graphics, IEEE Transactions on. 2014.

### Book ad!



# Methods

- Clustering
- Classification
- Regression



#### Search for VIS paper keywords

New keyword search:

Submit

#### framework

found in 12 papers cooccured with 40 author keywords in a topic cluster with 41 author keywords



# KeyVis

#### framework found in 12 VIS Papers

Conf.	Year +	Title
VAST	2015	Characterizing Provenance in Visualization and Data Analysis: An Organizational Framework of Provenance Types and Purpose
InfoVis	2014	Design Activity Framework for Visualization Design
VAST	2013	An Extensible Framework for Provenance in Human Terrain Visual Analytics
InfoVis	2012	Design Study Methodology: Reflections from the Trenches and the Stacks
VAST	2012	An AffordanceBased Framework for Human Computation and HumanComputer Collaboration
VAST	2011	Visual analytic roadblocks for novice investigators
InfoVis	2010	behaviorism: a framework for dynamic data visualization
InfoVis	2009	A Nested Model for Visualization Design and Validation
InfoVis	2008	A Framework of Interaction Costs in Information Visualization
Vis	2005	Framework for visualizing higherorder basis functions
InfoVis	2004	A Knowledge TaskBased Framework for Design and Evaluation of Information Visualizations
InfoVis	1998	An operator interaction framework for visualization systems

#### framework cooccurs with 40 other keywords:

Information visualization 4x design 3x evaluation 3x visualization 3x model 2x provenance 2x theory 2x visual analytics 2x analytic gap 1x analytic provenance 1x basis function 1x bookmarks 1x cognitive model 1x conceptual model 1x cybersecurity 1x design study 1x dynamic data 1x extensibility 1x finite elements 1x human complexity 1x human termin analysis 1x information at 1x interaction 1x interaction 1x investigative analysis 1x knowledge tasks 1x methodology 1x narrative 1x nested model 1x operators 1x process 1x qualitative experiment 1x roadblock 1x preadsheets 1x user interaction 1x investigative analysis 1x interaction 1x interaction 1x user interaction 1x interaction 1x interaction 1x user interaction 1x user interaction 1x interaction 1x interaction 1x interaction 1x interaction 1x user interaction 1x interaction 1

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Isenberg, Petra, Tobias Isenberg, Michael SedImair, Jian Chen, and Torsten Möller. "Visualization as seen through its research paper keywords," IEEE Transactions on Visualization and Computer Graphics. 2017. 48



#### goal: find relevant papers for a research project

- What are "key" papers in subject?
- How helpful are keywords?
- Do keywords relate to each other?

<u>KeyVis</u>

#### step 1: cluster the papers based on keywords





#### step 2: build an interface for the clustering

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tookit design 1x treenetviz 1x user interface tookits 1x view space exploration framework 1x visual analytics infrastructures 1x volume visualization framework 1x

# Regression







### The future!

# Interesting projects

- How can humans and machines work together?
- Visualizing regression algorithms
- Understand what "understandability" means

#### Thanks!

#### www.tomtorsneyweir.com thomas.torsney-weir@univie.ac.at @gabysbrain

ask	Task description for discrete data items from [AES05]	Our adaption to continuous scalar functions		QR	l resul	
etrieve value	"Given a set of specific cases, find attributes of those cases"	Given an x, what is the function value?				
lter	"Given some concrete conditions attribute values, find data cases satisfying those conditions."	For what parameter values is the function equal or over x?				
ompute derived value	of those data cases"	Summary statistics: variance, mean, SA				
nd extremum	within the data set" "Given a set of data cases and an attribute of interest, find the soan of	Find local/global min/max				
etermine range	values within the set" "Given a set of data cases and a quantitative attribute of interest,	What is the range of possible outputs?				
haracterize distribution	characterize the distribution of that attribute's values over the set" "Identify any anomalies within a given set of data cases with respect to a	What types of shapes do the manifolds have				
nd anomalies	given relationship or expectation, e.g. statistical outliers"	Do areas of the manifold have shapes unlike any others				
luster	"Given a set of data cases, find clusters of similar attribute values" "Given a set of data cases and two attributes determine useful	Areas of the manifold have similar shapes				
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