Overview and Practical Application of Machine Learning in Pricing 2017 CAS Spring Meeting

May 23, 2017 Duncan Anderson and Claudine Modlin (Willis Towers Watson) Mark Richards (Allstate Insurance Company)



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#### Agenda

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Context of machine learning in pricing

Penalized regression methods

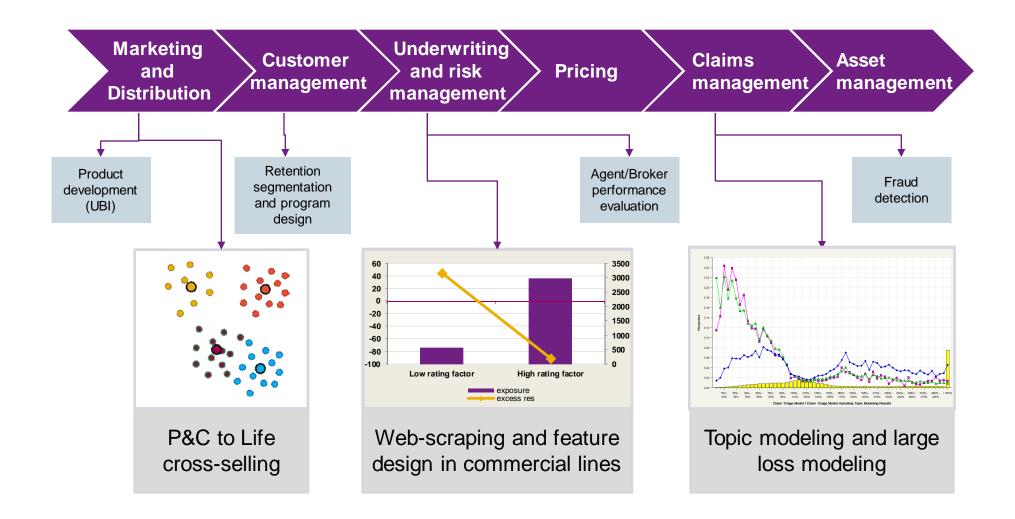
Trees, random forests and GBMs

Conclusions

Q&A

**Objective:** to give you a working knowledge of some machine learning methods that may be used to improve GLM results and/or offer valuable insights in their own right in the field of P&C insurance pricing

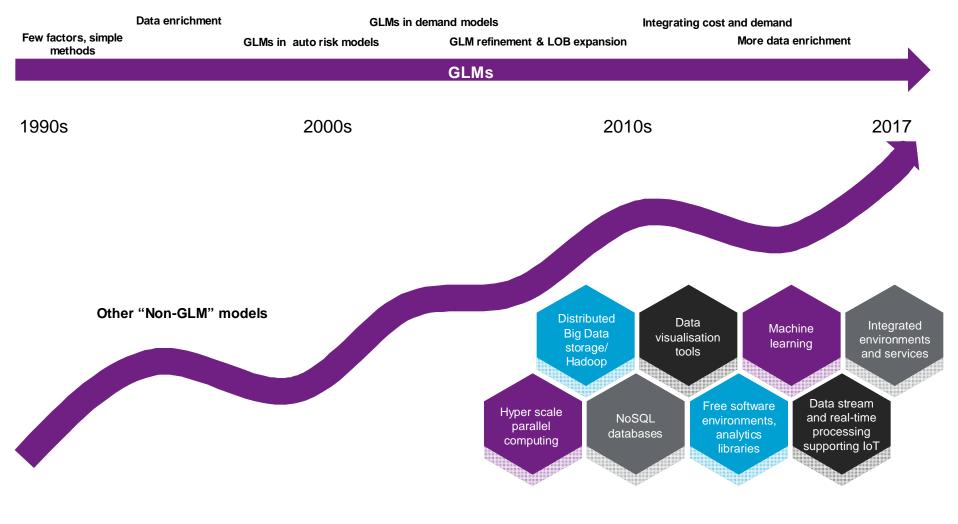
## Applications of machine learning in the insurance sector



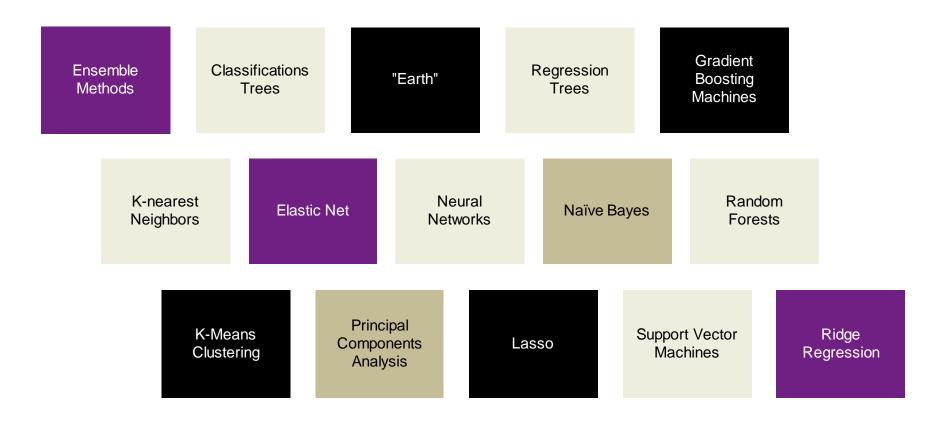
# Focus of today's talk



## This is not new....

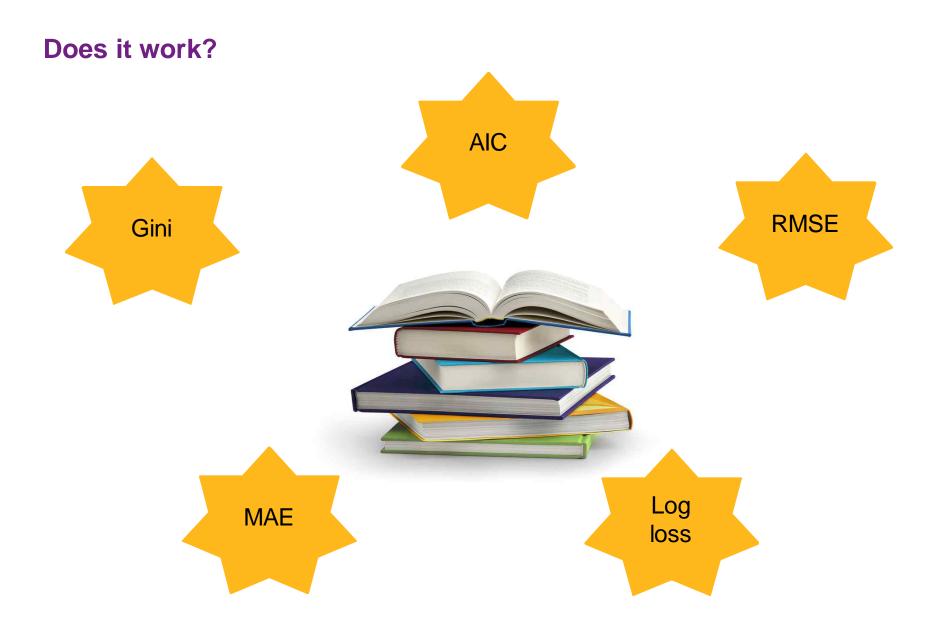


#### What are these methods?



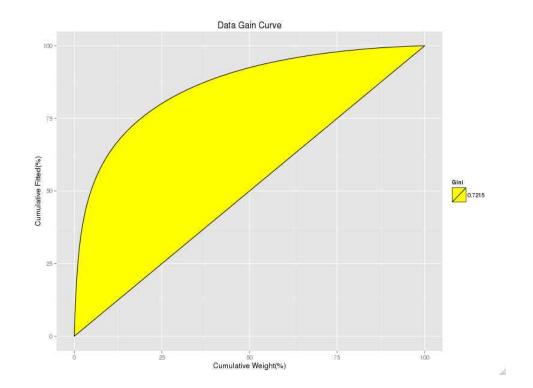
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#### How do you measure value?

Gini



- Rank hold out observations by their fitted values (high to low)
- Plot cumulative response by cumulative exposure
- A better model will explain a higher proportion of the response with a lower proportion of exposure
- ...and will give a higher Gini coefficient (yellow area)

Model	Gini
GLM	0.327

Model	Gini
GLM	0.327
New Model	0.330

Model	Gini	Gini improvement
GLM	0.327	0.0%
New Model	0.330	1.0%

Model	Gini	Gini improvement	Gini rank
GLM (main factor removed)	0.318	-2.6%	4
GLM (minor factor removed)	0.322	-1.3%	3
GLM	0.327	0.0%	2
New Model	0.330	1.0%	1

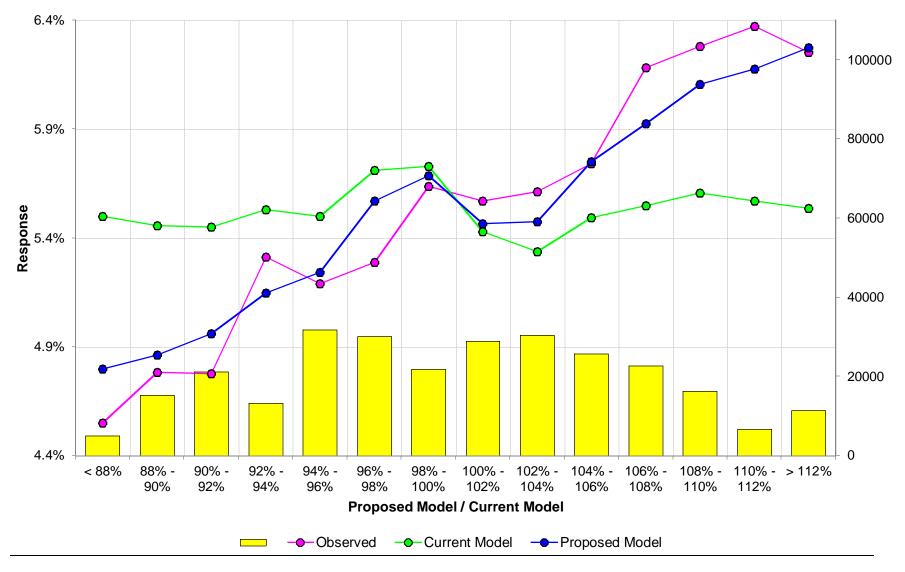
#### But...

- Think of a model...
- Multiply it by 123
- Square it
- Add 74½ billion

 ...and you get the same Gini coefficient!



## **Double lift chart**



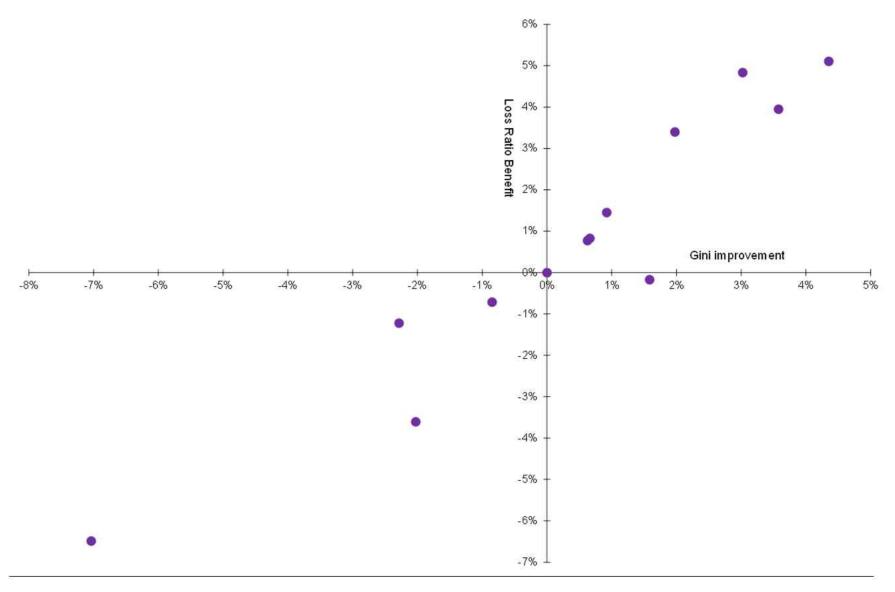
## **Financial value estimate**

- Errors in insurance pricing are not symmetrical
- Financial benefit can be estimated

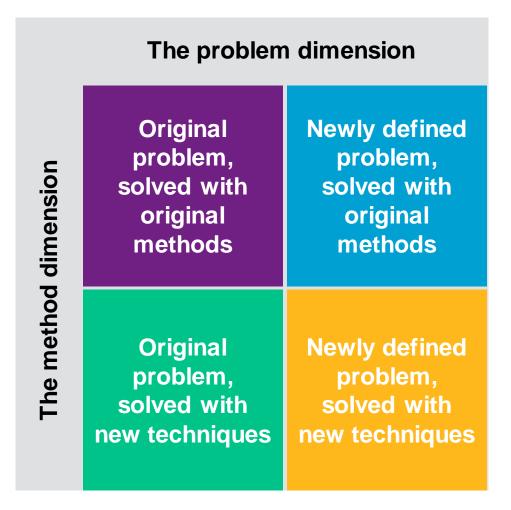


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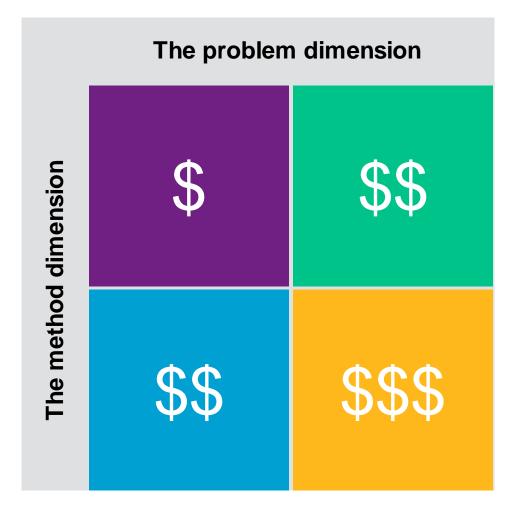
## Financial value vs Gini



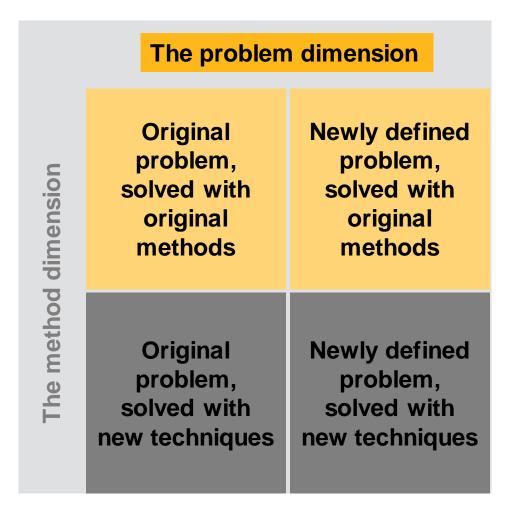
## Is it really all about the method?



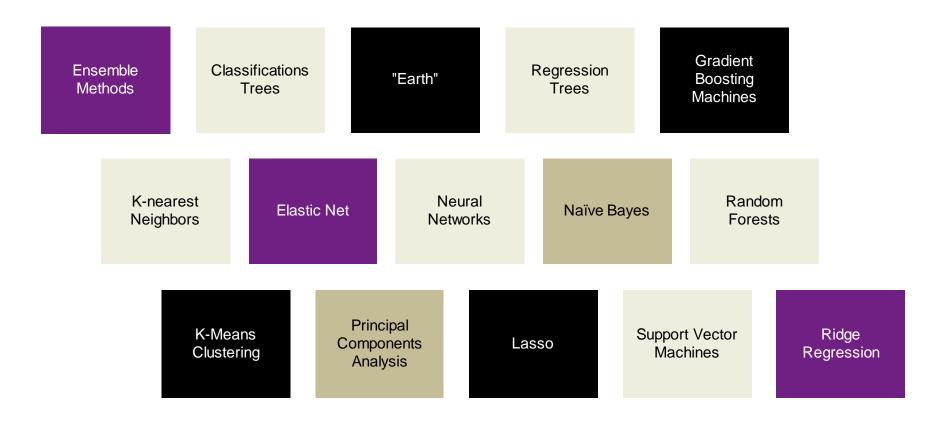
#### Where is the value?



## The problem dimension

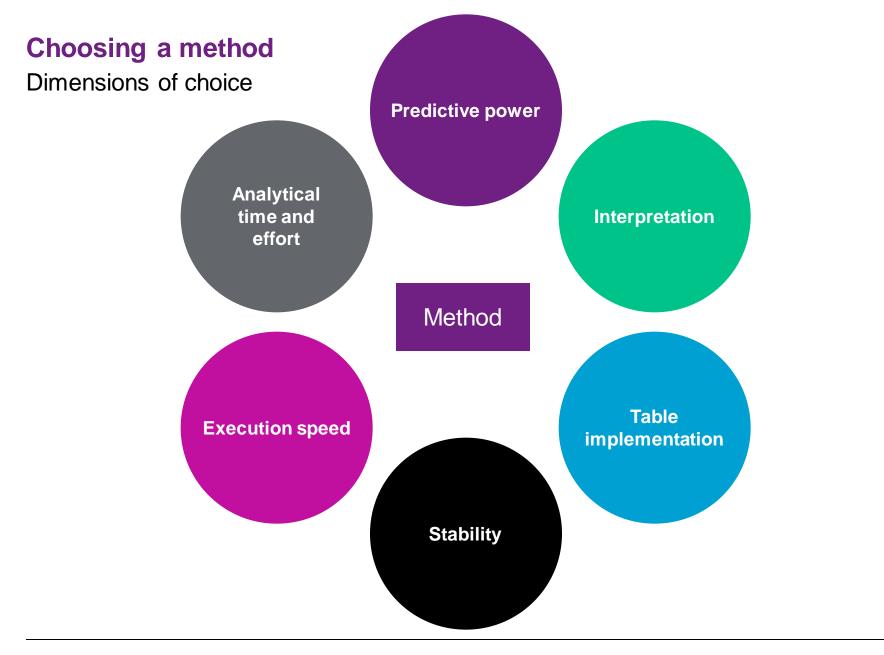


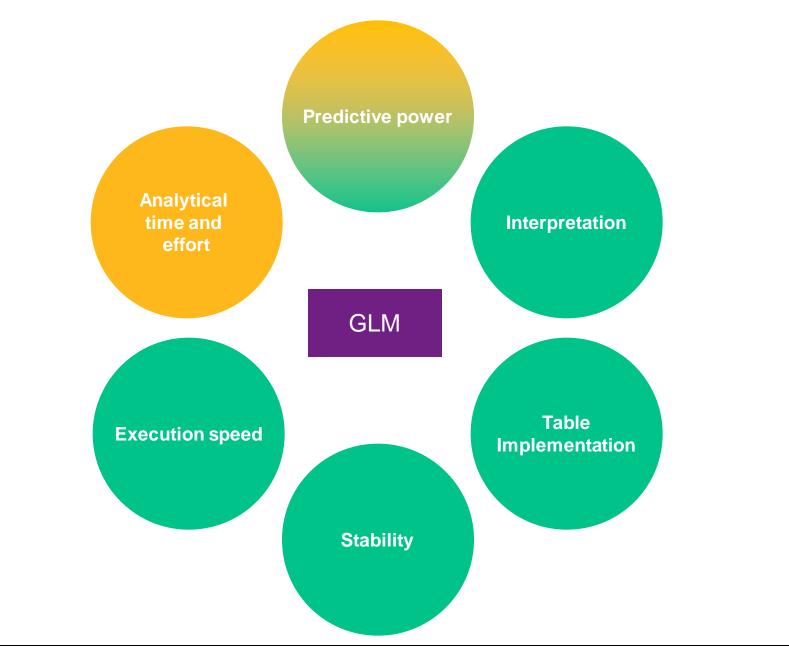
#### What are these methods?



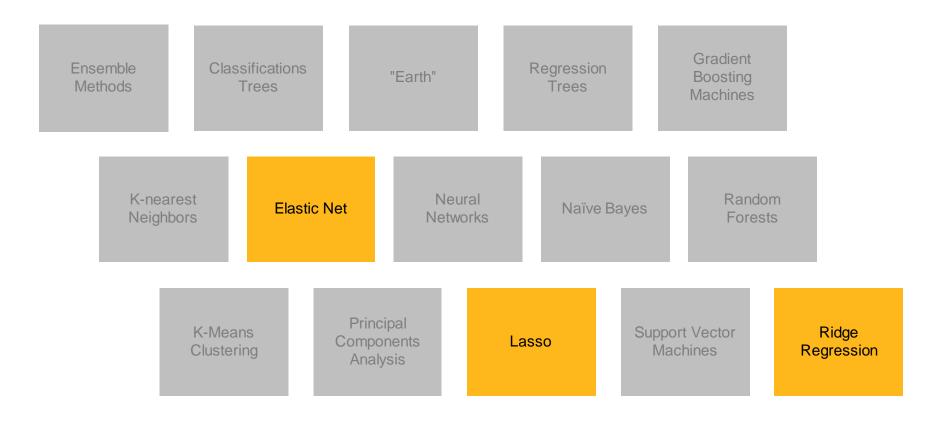
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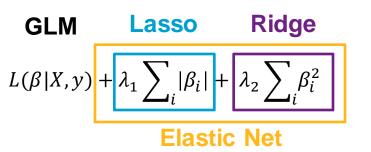


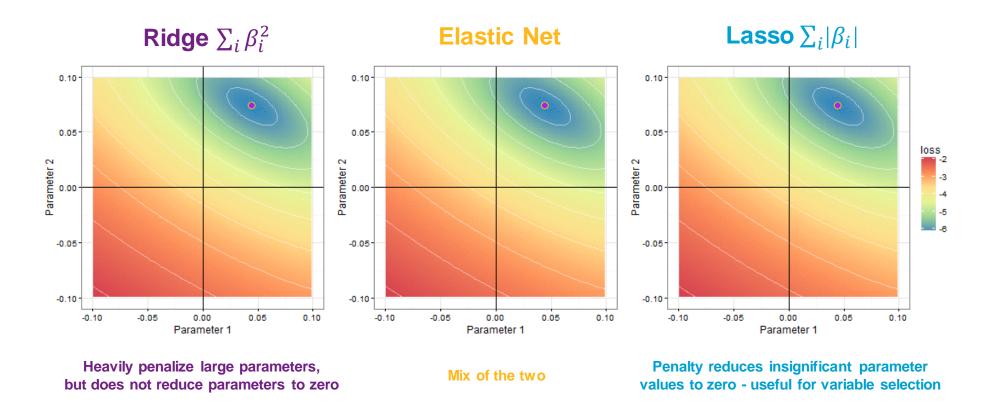


#### What are these methods?



$$f(\underline{x}) = g^{-1}(\mathbf{X},\underline{\beta})$$
 where  $\underline{\beta}$  estimated by minimizing

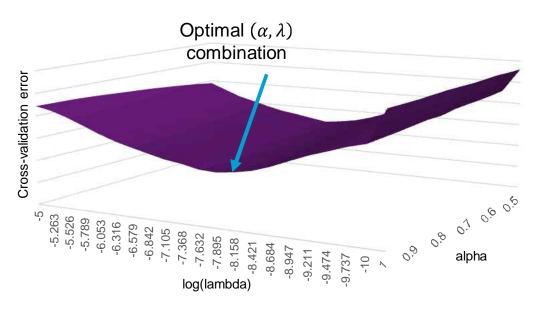




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Parameter selection

- Minimize:  $L(\beta|X, y) + \lambda_1 \sum_i |\beta_i| + \lambda_2 \sum_i \beta_i^2$
- Penalty parameters can be re-written:  $\lambda_1 = \lambda \alpha$ ,  $\lambda_2 = \lambda \left(\frac{1-\alpha}{2}\right)$
- $\alpha$  controls the mixture between Lasso ( $\alpha = 1$ ) and Ridge ( $\alpha = 0$ )
- $\lambda$  controls the overall size of the penalty
- $\lambda$ ,  $\alpha$  selected using cross-validation
- Factors automatically selected from initial set!



Case study - vehicle classification



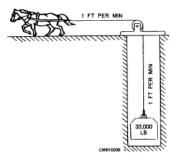
**Physical facticity** E.g., height, length, weight



**Mechanical nature** E.g., engine size, fuel type



**Qualitative descriptors** E.g., body type, model range



# Performance

E.g., maximum speed, torque, BHP

Case study - vehicle classification

**Results redacted** 

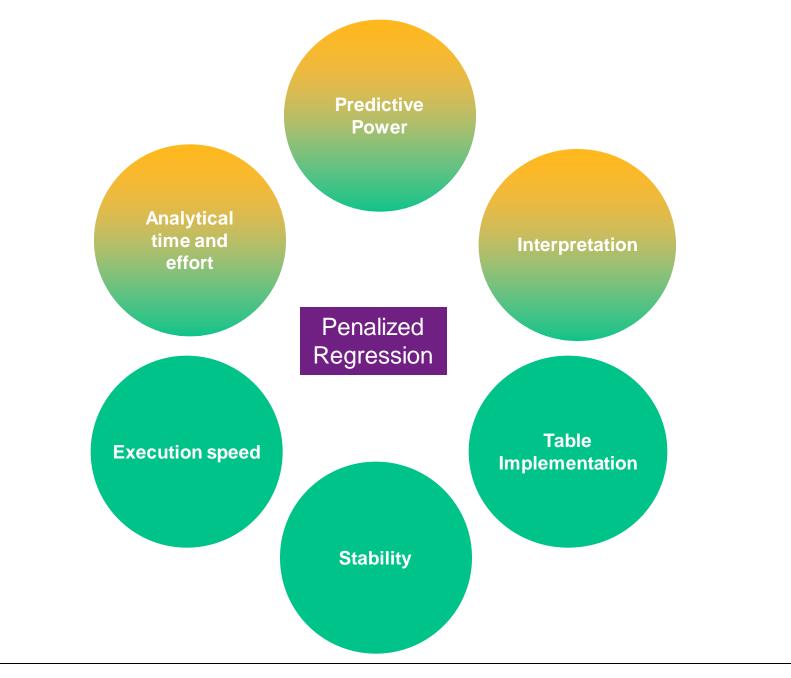
# **Deploying Penalized Regression**

#### Same as GLMs!

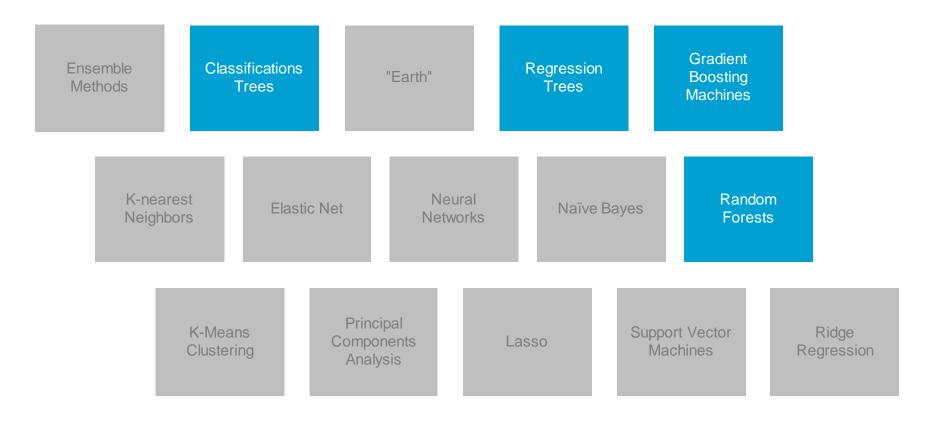
Age	Multiplier
<20	2.12
20-25	1.74
25-30	1.09
30-39	1.00
40-49	0.95
50+	0.06

Multiplier
0.83
0.91
0.96
1.00
1.05
1.17
1.25
1.42
1.89

Gender	Multiplier
Male	1.00
Female	0.97

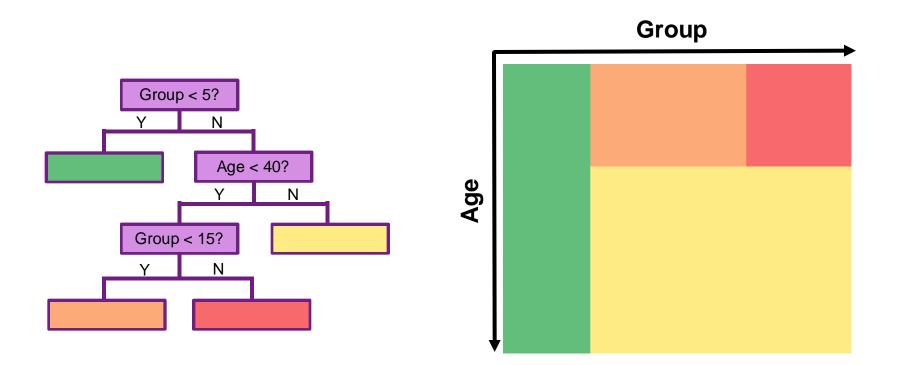


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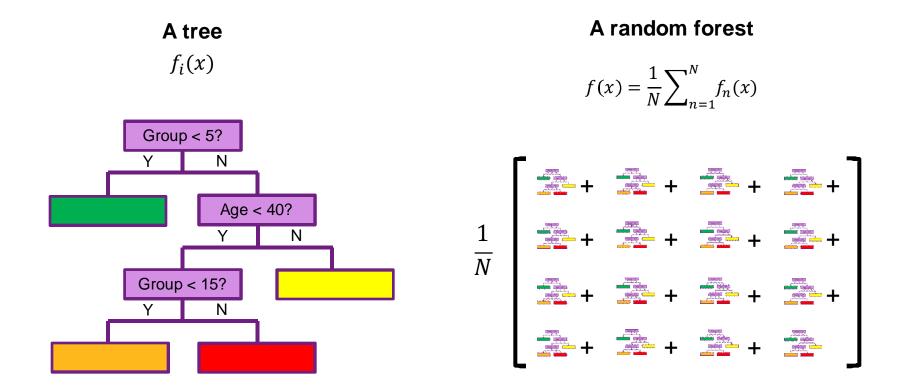


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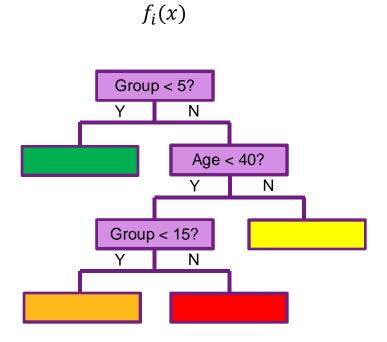
## **Decision Trees**



#### **Random Forests**



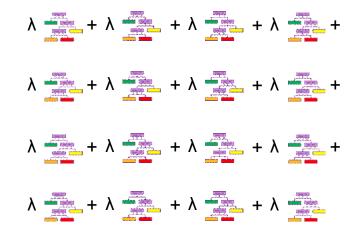
#### **Gradient Boosting Machine or "GBM"**



A tree



$$f(x) = \lambda \sum_{n=1}^{N} f_n(x)$$

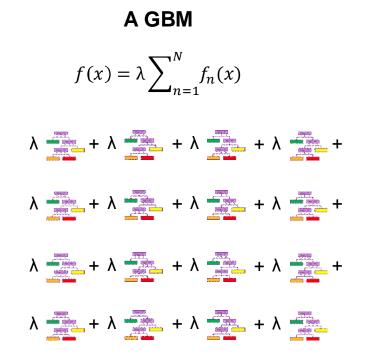


## **Gradient Boosted Machine or "GBM"**

Four main assumptions

#### λ Learning rate / "shrinkage"

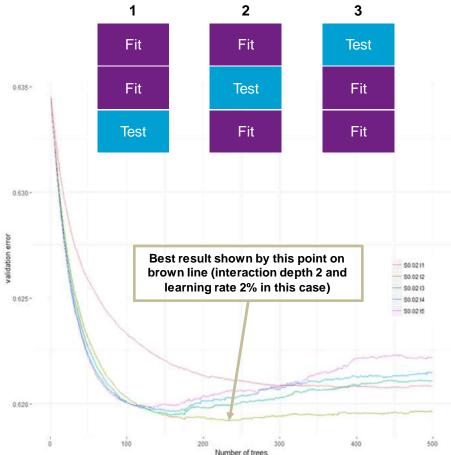
- Amount by which the old model predictions are varied for the next model iteration
- New model =
  Old + (Prediction x Learning rate)
- Interaction depth
  - Number of splits allowed on each tree (or the number of terminal nodes – 1)
- N Number of trees (iterations) allowed
- Bag fraction
  - Trees are fitted to a subset of the data (the bag fraction) on a randomized basis
  - Additional noise-reduction can be achieved by using a random subset of the available factors at each iteration



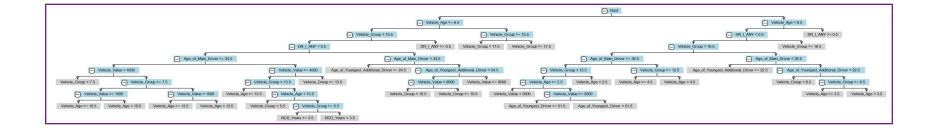
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# What does a GBM look like?



### What does a GBM look like?

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## What are these methods?



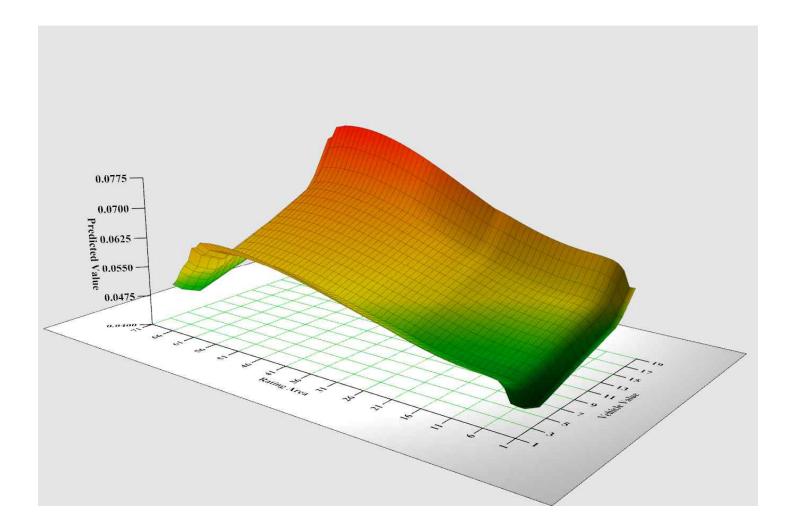
Adding an ensemble

**Results redacted** 

What about a modelled down GBM?

**Results redacted** 

# What about an automated GLM?



What about an automated GLM?

**Results redacted** 

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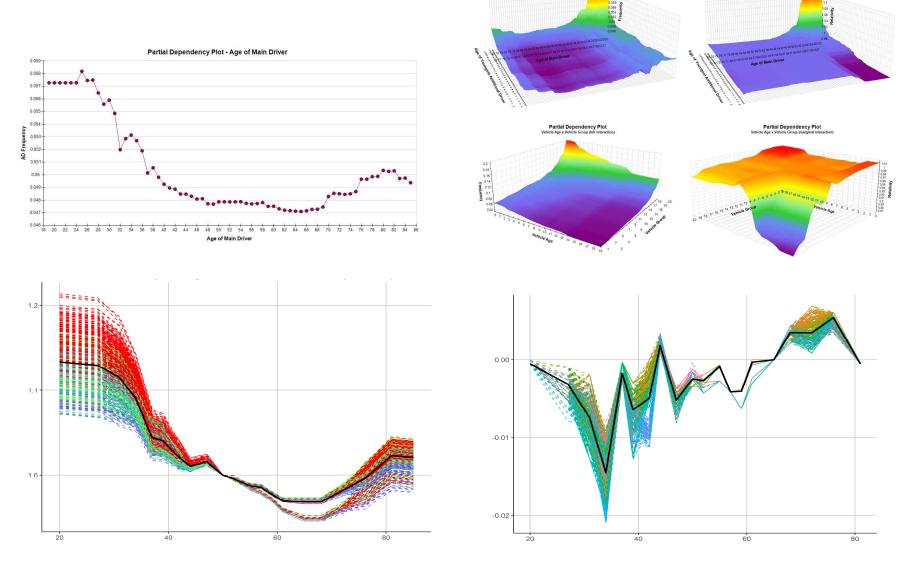
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# Partial dependency plots etc



Partial Dependency Plot

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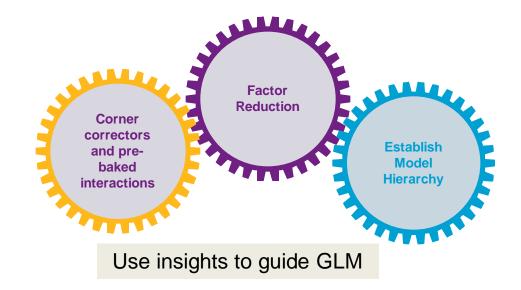
Partial Dependency Plot

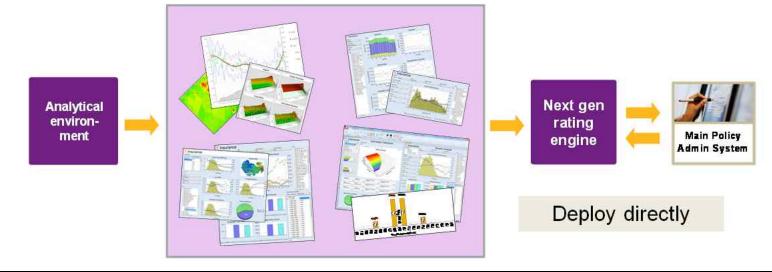
# **Deploying GBMs**

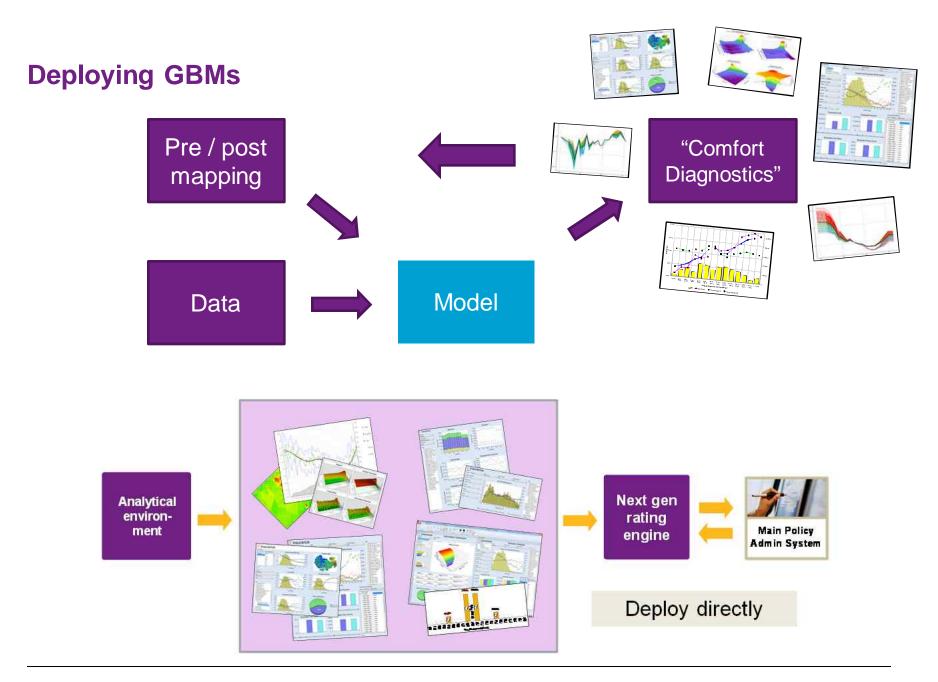
# Model down into multiplicative tables via GLMs

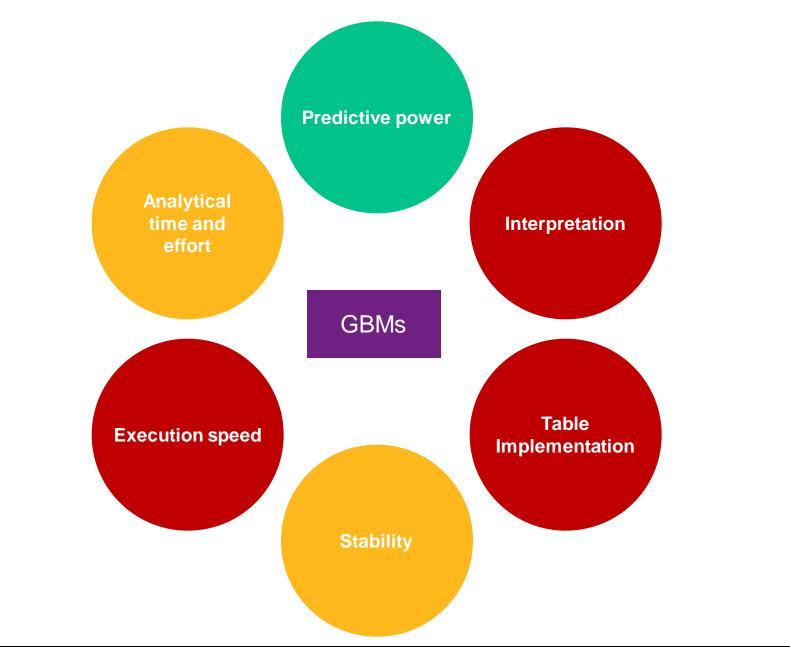
		Age	Exposure	Burning Cost		Vehide Group	Exposure	Burning Cost
	1	<=20	1,720	179	1	1-10	164,107	77
	2	21-30	34,893	122	2	11-14	84,859	101
	3	31-50	118,182	102	3	15-18	28,952	116
	4	51+	127,054	70	4	19-20	3,931	272
1	5	Age Total	281,849	91	5	VG Total	281,849	91
	5	Age Total	281,849	91	5	VG Total	281,849	91

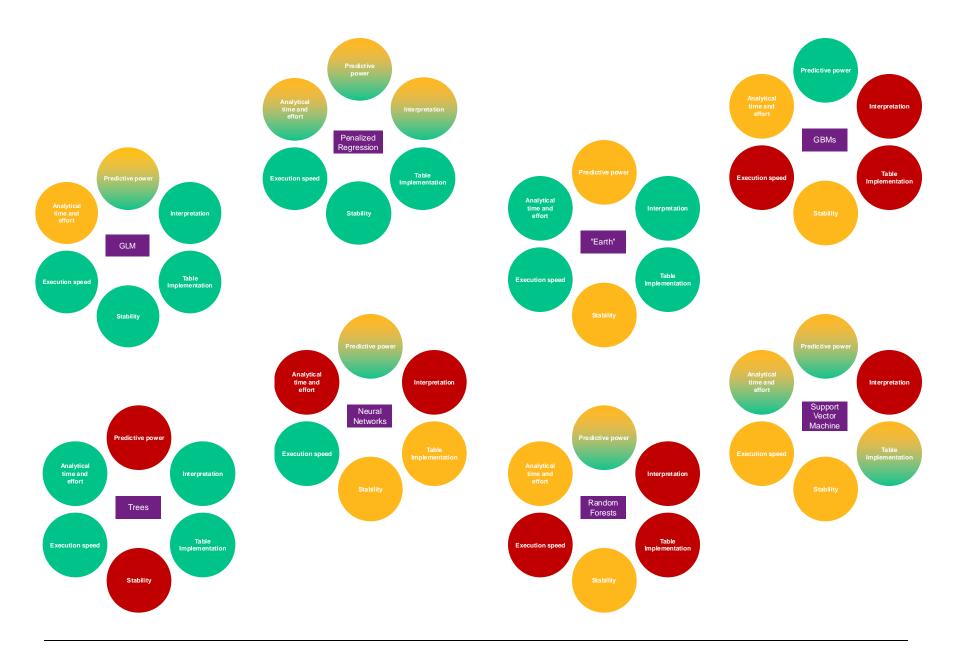
	Gender	Exposure	Burning Cost	
1	Male	197,339	92	
2	Female	84,510	87	
3	Gender Total	281,849	91	







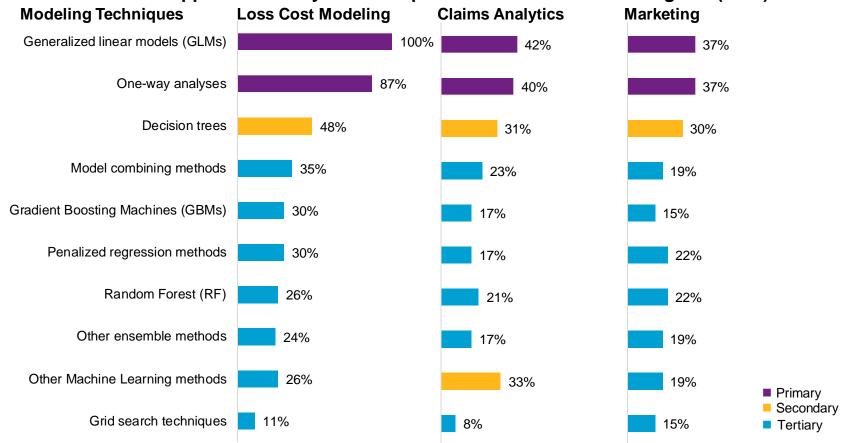




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# How is the North American market doing with machine learning? Methods used

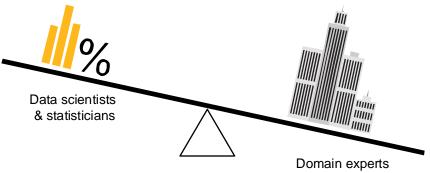
### For which business applications do you use or plan to use these methodologies? (Q.13)



Base: U.S. respondents who use or plan to use the methodology for the application specified (Loss Cost Modeling n = 46, Claims Analytics n = 48, Marketing n = 27).

# Machine learning in personal lines pricing: evolution or revolution? Conclusions

- It's not all about methods
  - Domain expertise in formulating the problem can be more important
  - New (wider) data generally adds more lift than new methods
- There are practical ways to assess model improvement as well as statistical
- Predictions:
  - Many methods can augment the traditional GLM modeling process in particular with growing datasets .
  - Others (e.g., GMBs) can improve prediction in own right but these require different approaches in interpretation and technology/deployment
  - Methods support predictions in new areas
    - Very wide datasets
    - Market rate analysis
    - Cross-selling and other customer behaviors
    - UW, claims, etc
- But it's not all about predictive power
  - Fast investigation of new or "messy" data
  - Quick assessment of emerging experience
  - **Operational efficiency**
  - Industry (and Profession) has work to do in developing machine learning skills integrated with domain expertise



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