

C4: Pricing Workshop – Overview and Practical Applications of Machine Learning Methods in Pricing

Bethan Faultless & Matthew Lambert

25 April 2019

C4: Pricing Workshop

- Overview and Practical Applications of Machine Learning Methods in Pricing

Agenda

Context of machine learning in pricing

- Decision trees
- Random forests
- · Gradient boosting machines

Practical applications of ML techniques

Conclusions

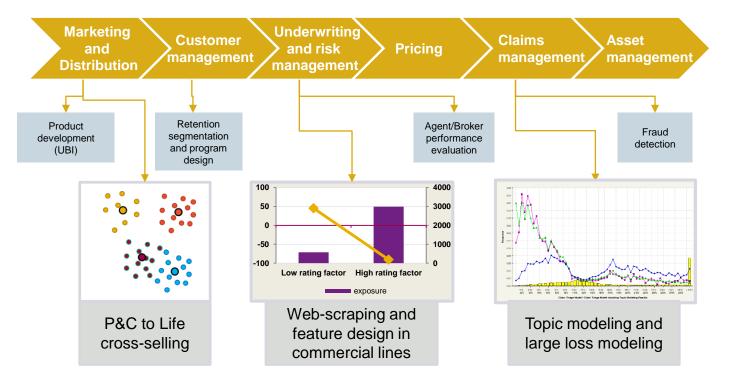
Q&A

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

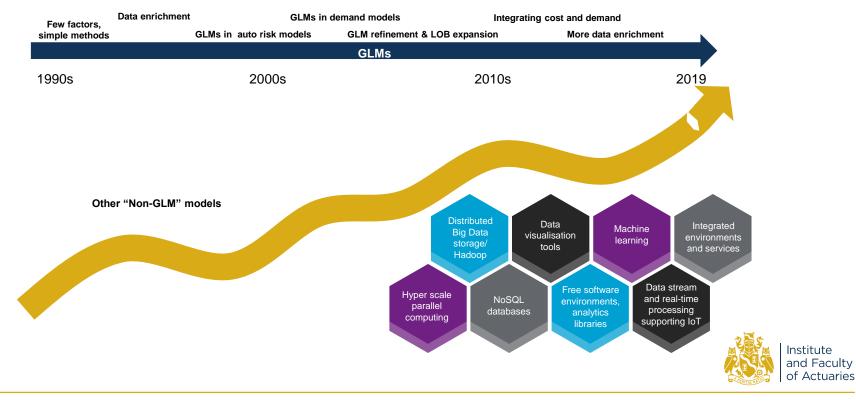


Applications of machine learning in the insurance sector

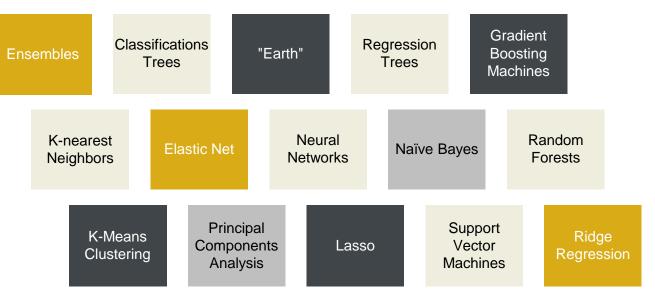




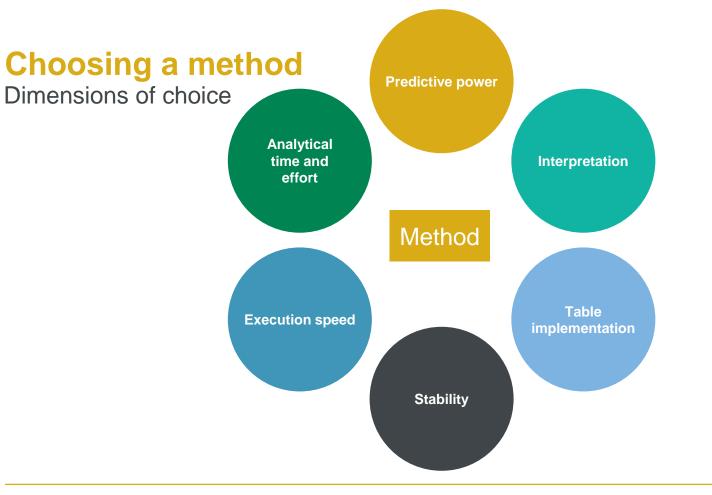
This is not new....



What are these machine learning methods?











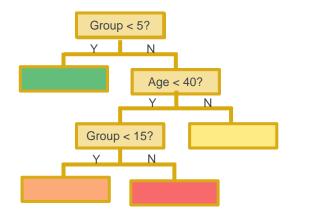


Focus on Trees

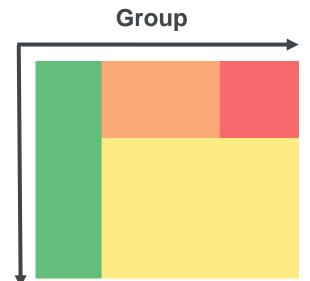




Decision Trees

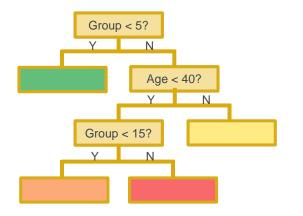


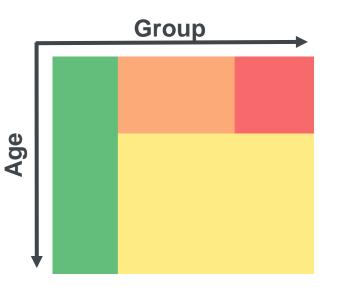






Decision Trees

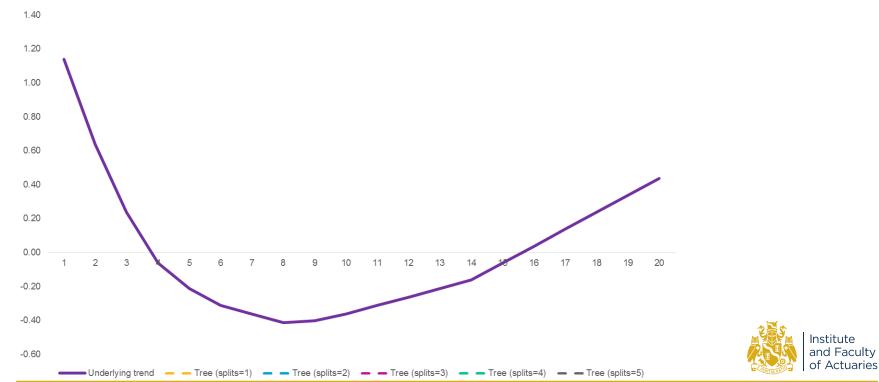






A simple Tree example

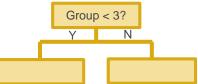
Tree results

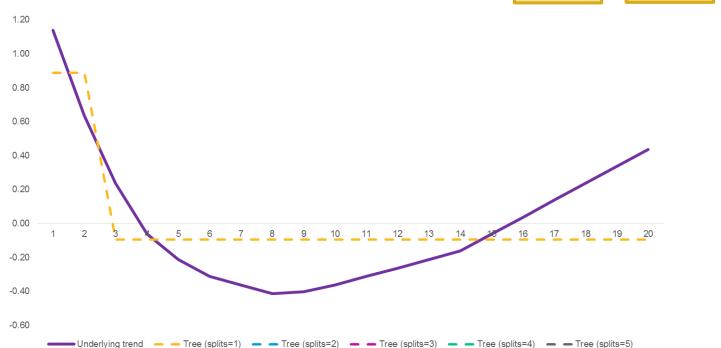


25 April 2019

A simple Tree example

Tree results



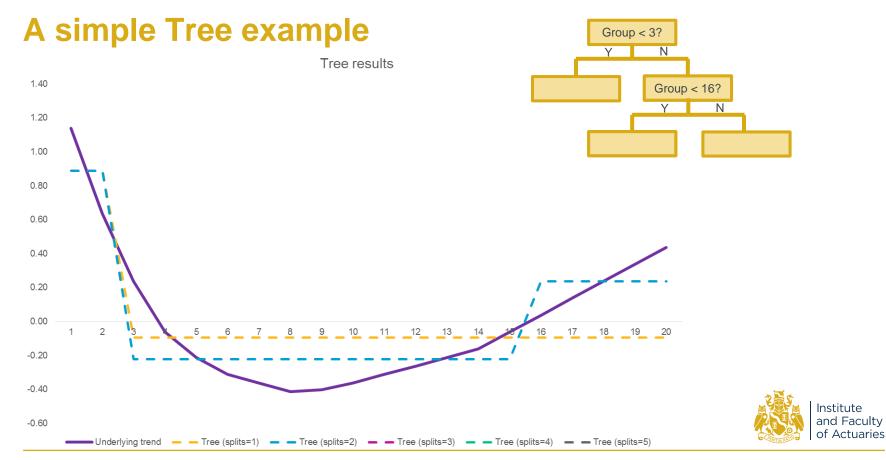




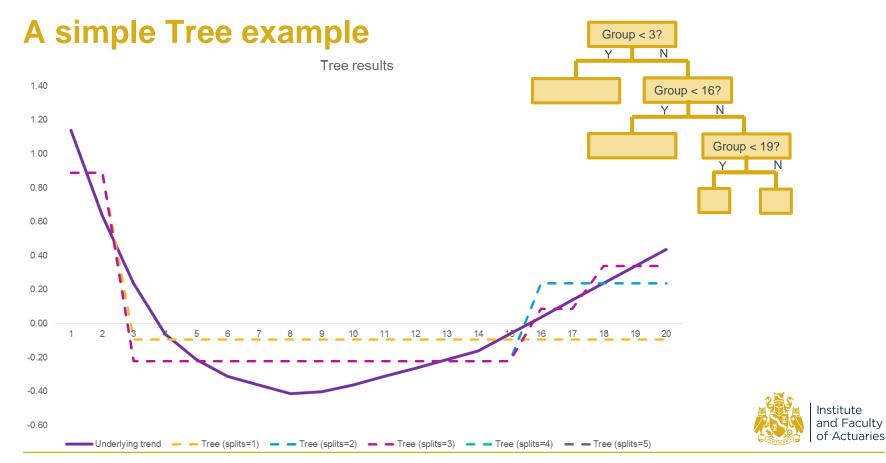
1.40

Institute and Faculty

of Actuaries



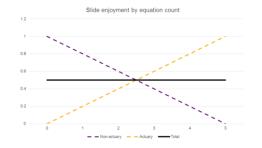
25 April 2019



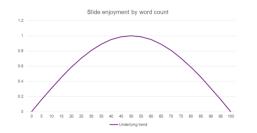
25 April 2019

Shortcomings of using trees

They may miss interactions...



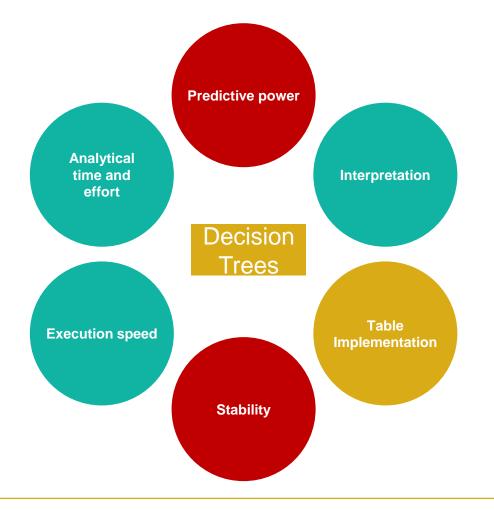
...and they can be bad at turning points



... they may struggle with categorical variables....









Focus on Random Forests





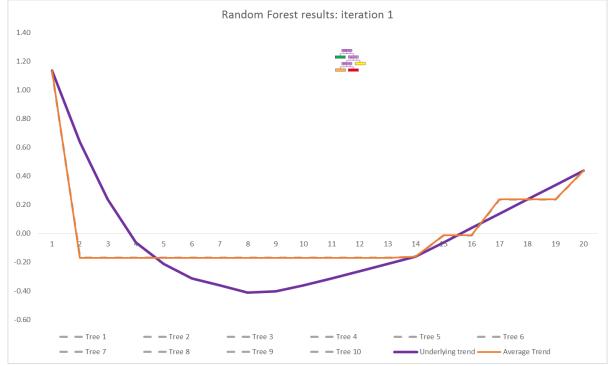
Random Forests

- Tree 1: Prediction 1 = Signal 1 + Noise 1
- Tree 2: Prediction 2 = Signal 2 + Noise 2
- Tree 3: Prediction 3 = Signal 3 + Noise 3
- ...
- Tree 1000: Prediction 1000 = Signal 1000 + Noise 1000
- Random Forest:
- Prediction = AVERAGE(Tree Predictions)

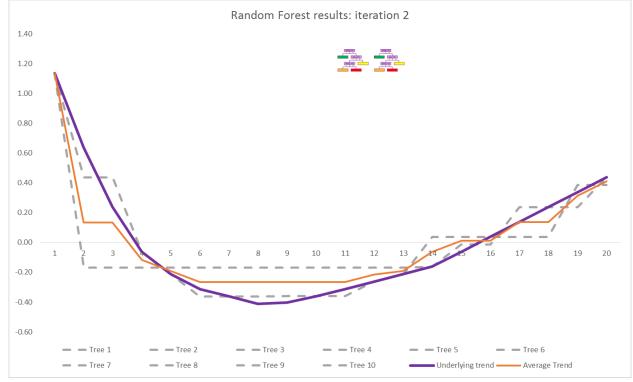
= AVERAGE(Tree Signal) + AVERAGE(Tree Noise)

- Average Noise → 0 if the trees are independent
- Independence of trees achieved by fitting each tree to:
 - Random subset of data (bootstrap sample)
 - Random subset of factors
- Average Signal → Underlying trend, provided trees are complex enough to represent it
- This is bagging (bootstrap aggregation) fit lots of independent models and take an average

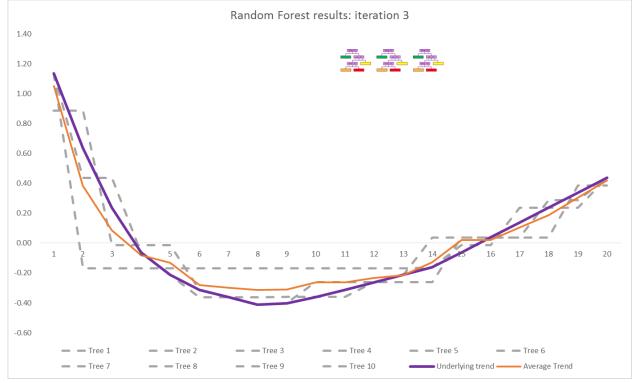




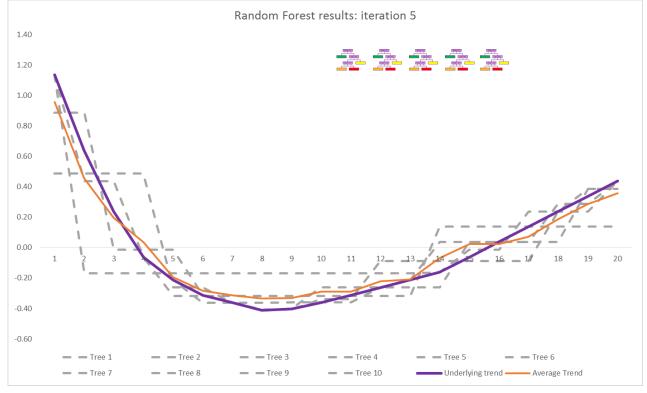




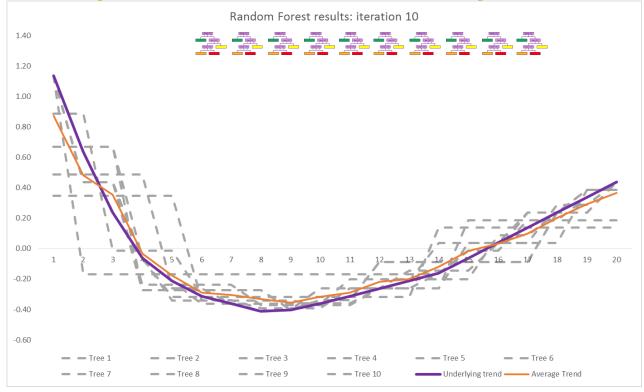




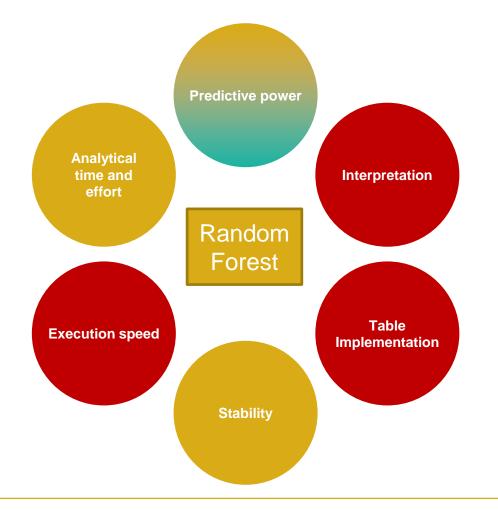






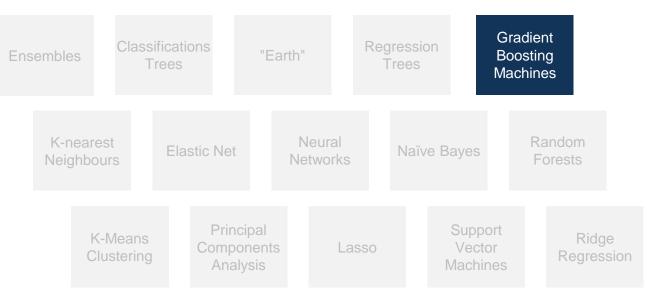






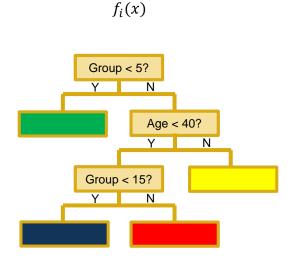


Focus on Gradient Boosting Machines





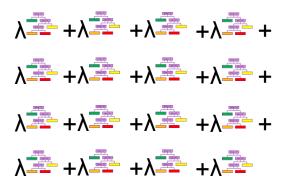
Gradient Boosted Machine or "GBM"



A tree

A GBM

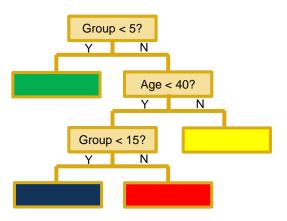
$$f(x) = \lambda \sum_{n=1}^{N} f_n(x)$$



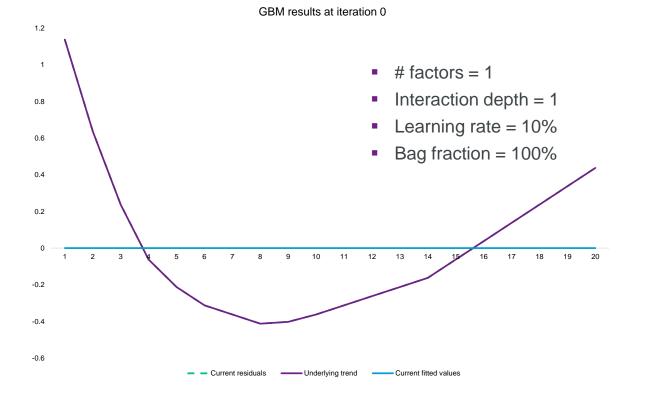


Four main assumptions

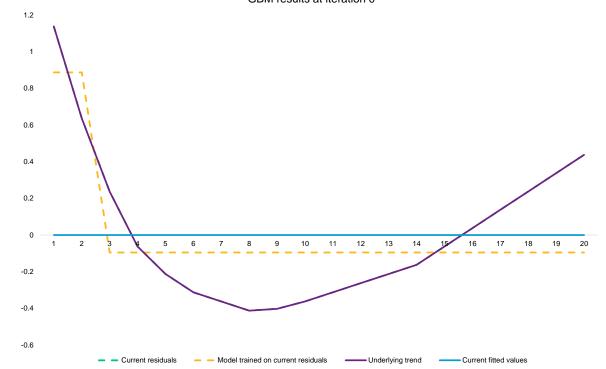
- λ Learning rate / "shrinkage"
 - Amount by which the old model predictions are varied for the next model iteration
 - New model =
 Old + (Prediction x Learning rate)
- Interaction depth
 - Number of splits allowed on each tree (or the number of terminal nodes – 1)
- N Number of trees (iterations) allowed
- 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





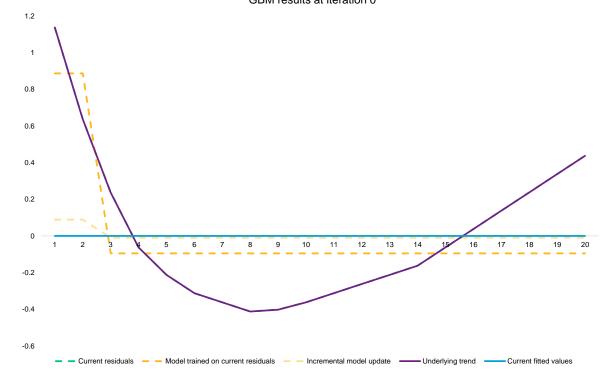


Institute and Faculty of Actuaries



GBM results at iteration 0

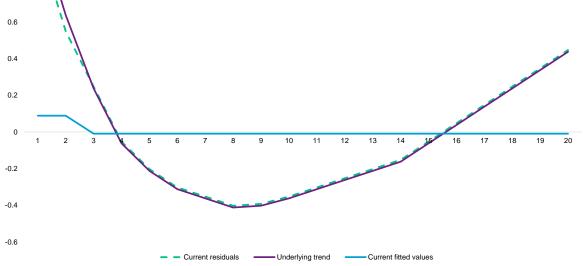




GBM results at iteration 0





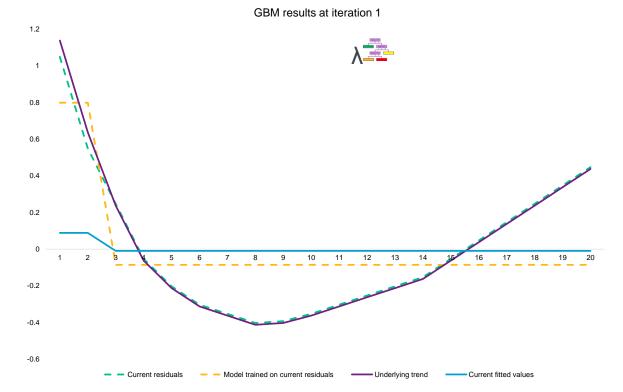




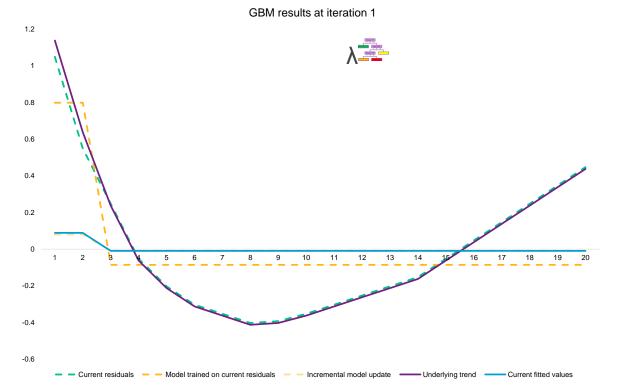
1.2

1

0.8

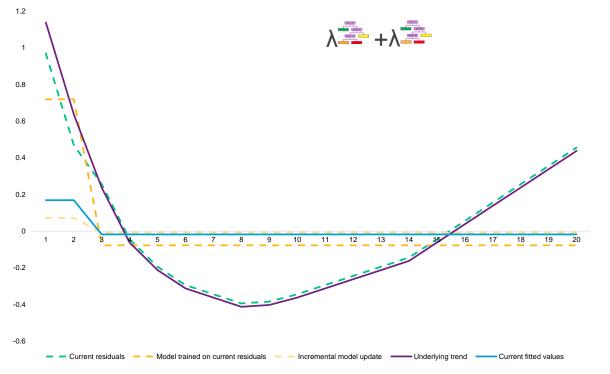


Institute and Faculty of Actuaries

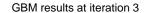


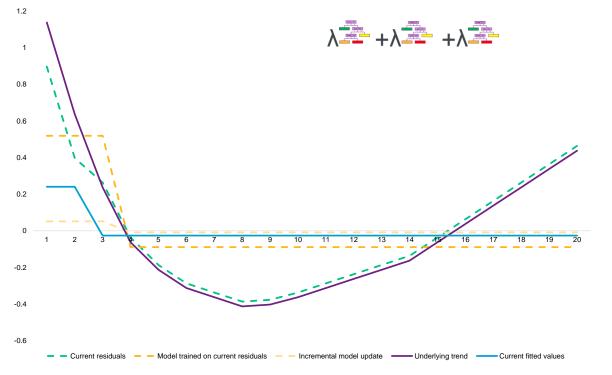
Institute and Faculty of Actuaries

GBM results at iteration 2



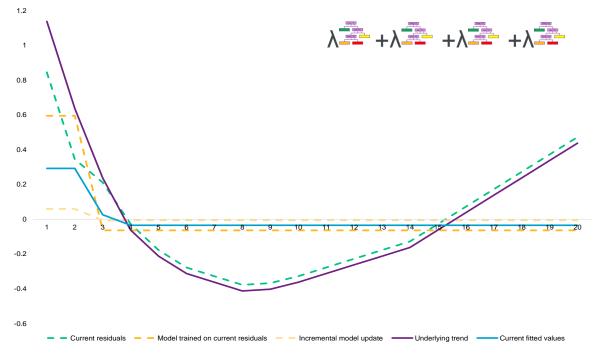




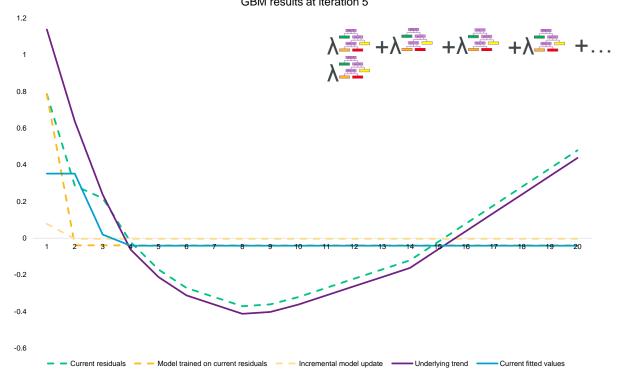




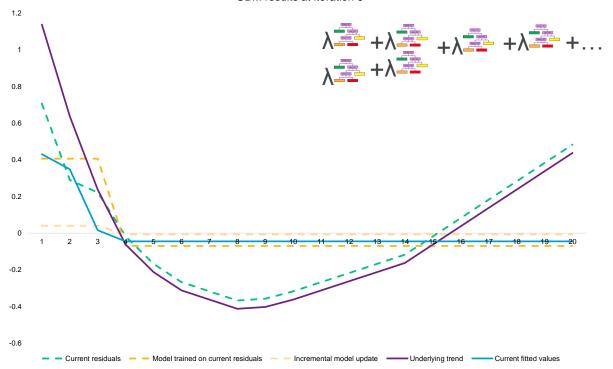




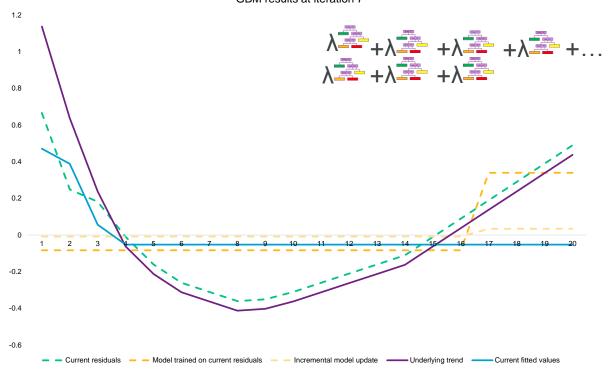




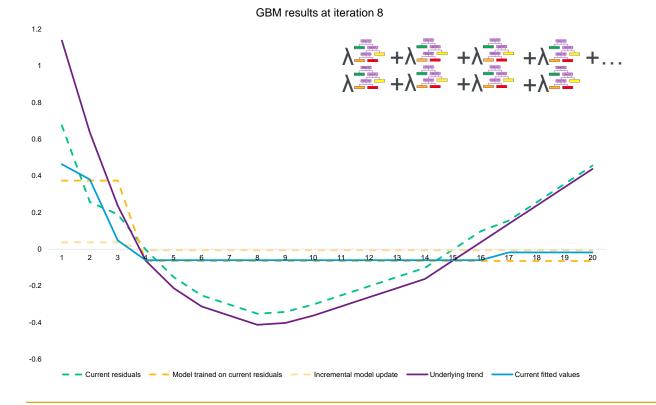




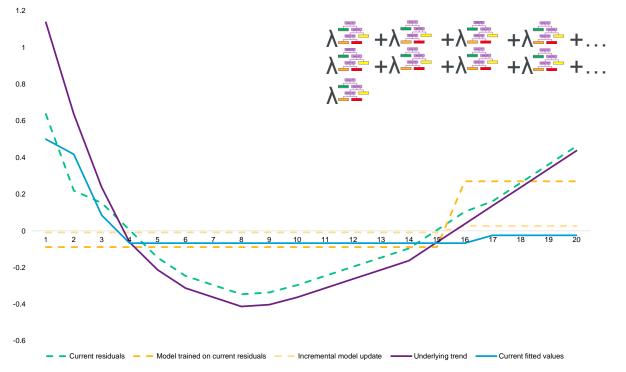




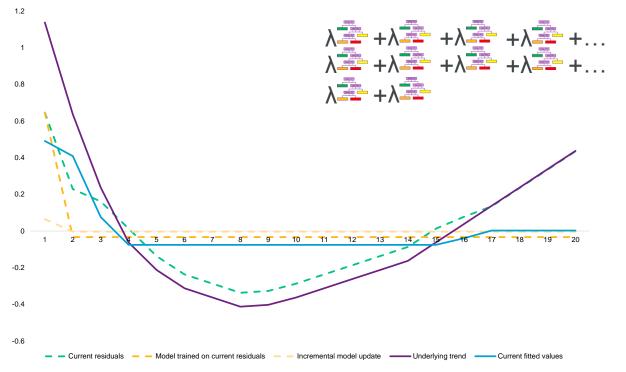




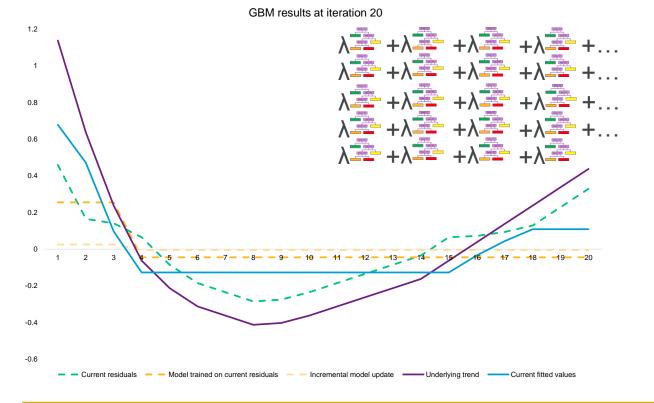
Institute and Faculty of Actuaries



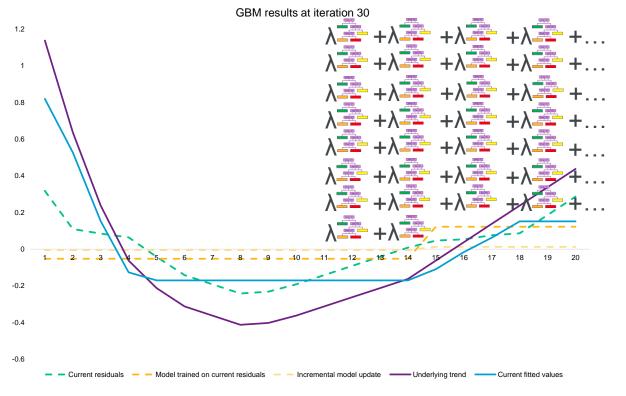




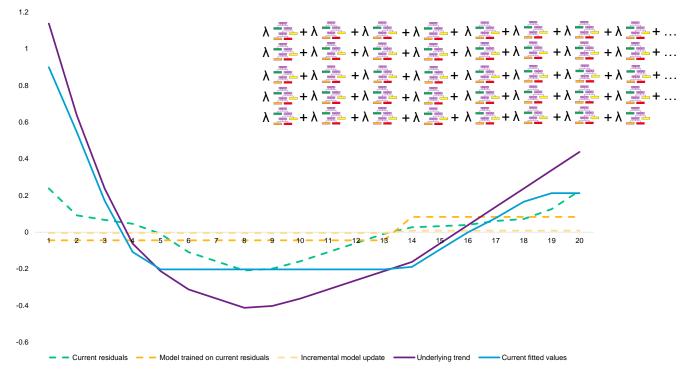




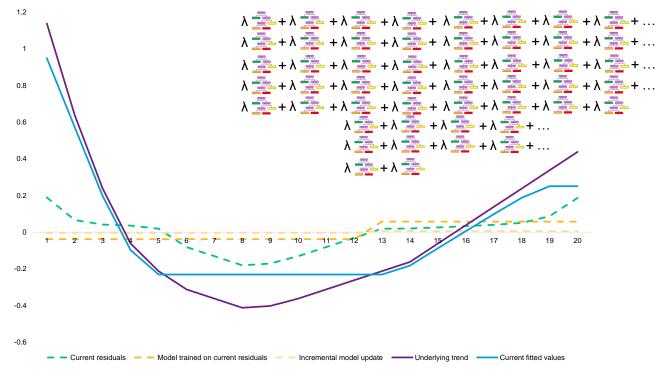
Institute and Faculty of Actuaries





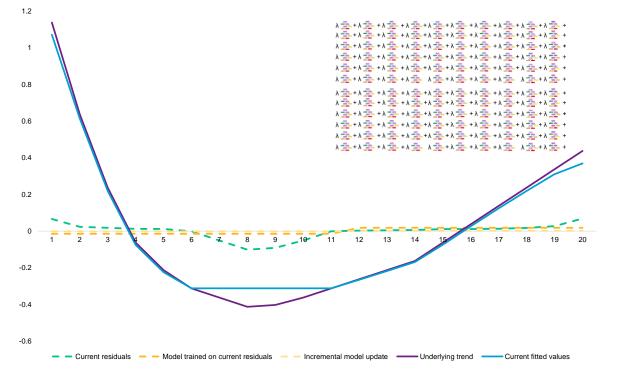






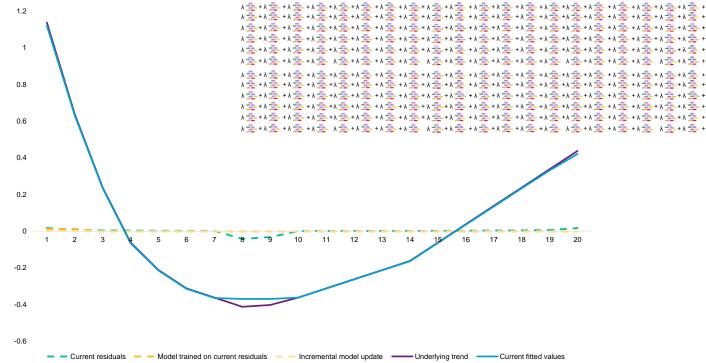


GBM results at iteration 100

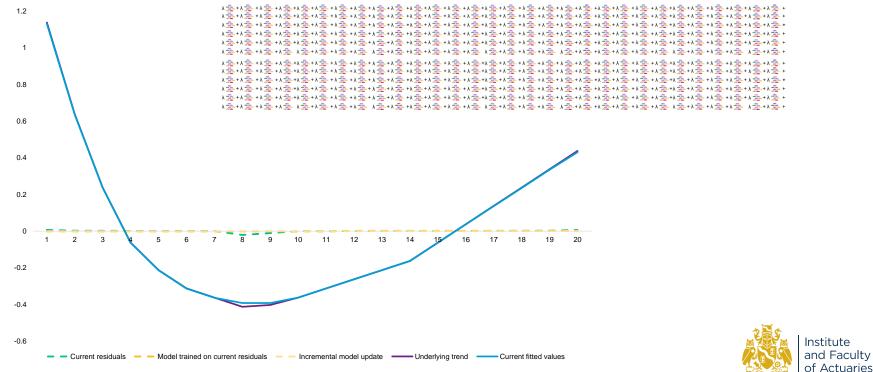


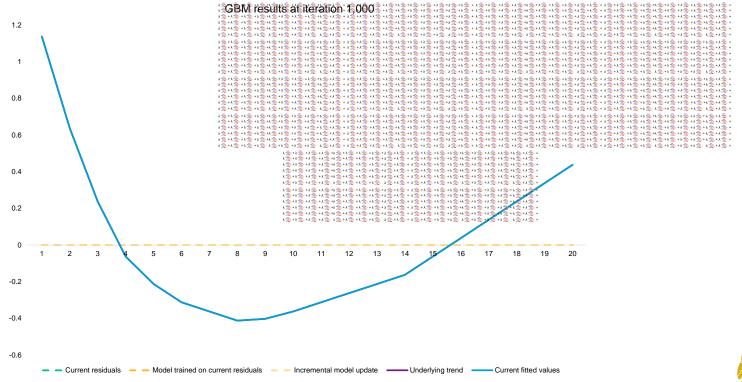














Calibrating the assumptions

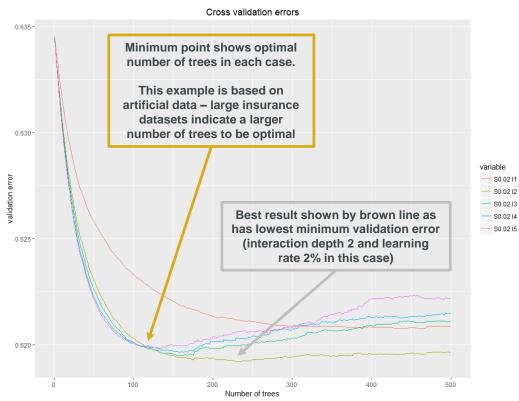
- *n*-fold cross validation used to develop the interaction depth and learning rate assumptions
 - Eg for 3-fold validation, split into 3, fit on gold, test on blue parts, take average



- Resulting plots can be used to determine the optimal assumption choice
 - Including how many trees to run



Example 5-fold cross validation





What does a GBM look like?





What does a GBM look like?





What does a GBM look like?

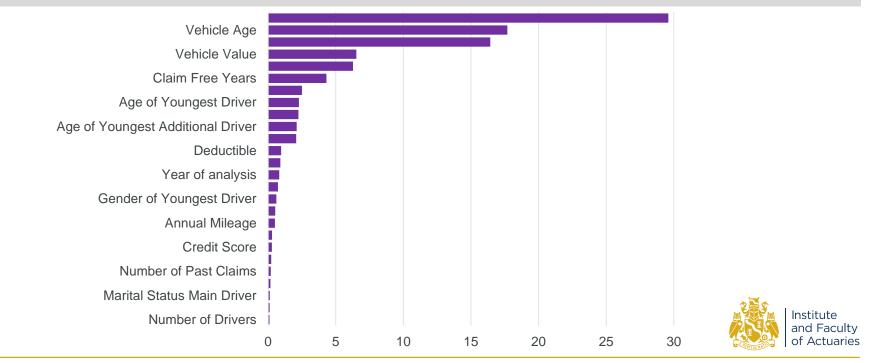


and the second s														Sanda - Sanda - Sanda
		Server and the server of the s	Streets - algorithment and a street of the			and the second s					Streets Mary Street Street Street	The second secon		All and the second seco
											And the second s			Same and
													Alterative with the second sec	
		Contraction of the Contraction of the		And the second s		And the second s		Statis - South Statis			Contraction of the Contraction o	Strate Contraction	State - State - State - State - State	Same - Same - Same
and the second s				And the second s										States - San States
	Alternation of the second seco	Alterative and a second	Manada - Martin - Mar	Strates with a strategy of the	Alterative and the second seco	States and the second s	Martin Martin	Wheather will be a straight of the	Martin allow	Alternative and the second sec	Strate and Strate	Martin Martin Contraction State	Although a state of the state o	West's Mary
and the second s				And the second s										States - San States
and the second s				And the second s										States - San States
	Alternation of the second seco	Alterative and a second	Manada - Martin - Mar	Strates with a strategy of the	Alterative and the second seco	States and the second s	Martin Martin	Wheather will be a straight of the	Martin allow	Alternative and the second sec	Strate and Strate	Martin Martin Contraction State	Although a state of the state o	West's Mary
No. of Street of Street	Manada - Martin Carlos and Carlos	Alternative - Margin and Str. No	Streets - Street Bridge Street Street Street Street	Alterative "market and a second	Second State of State	Warding - weight - the second se	and the second s	Warding - weight the second se	Streets - Street Street Street Street	and a second	Subsection - March 10, 10, 10, 10, 10, 10, 10, 10, 10, 10,	And an alter a second s	Maratha - water and a state of the state of	alles - Society
and the second s				And the second s										States - San States
		Server and the server of the s	Streets - algorithment and a street of the			and the second s					Streets Mary Street Street Street	The second secon		All and the second seco
											And the second s			Same and
State of the second states	Same and the second sec	Wandley Walter Barris	When the " which the	Second States		Second a second se	Window Wi	Wandlin - Malin - Mali	Stratin - ship a	And the state of t	Streets with the second s	Alternative - marging and the state of the s	Alternative - March 199	Manadita - Marchae
No. of Concession, Name	Same and the second	Martin - Mar	Manada - Malan	Strates - Solar Strates - Strates - Strates	Market and the second s	Strate - State	Marine Contraction of the second seco	Wanths - Males	Mandala - Malan	Alternative - Marchine	Streets - Martin	Manda - Marca	Markets - Market	Marilla - Marill
	All and the second seco	Alternative and the second sec	Martin allow	Whether William Contraction of the	Shares and the second s	Stanta - March	allocation with the second sec	Westly all to	Statts Streets	All softs - Martin -	Strate and Strate and Strate	Strate Strate Strate	All hand the " all of the second seco	State - State
	Alternation of the second seco	Alterative and a second	Manada - Martin - Mar	Strates with a strategy of the	Alterative and the second seco	States and the second s	Martin Martin	Wheather will be a starting of the second sta	Martin allow	Alternative and the second sec	Strate and Strate	Martin Martin Contraction State	Although a state of the state o	West's Mary
No. of Concession, Name	Same and the second	Martin - Mar	Manada - Malan	Strates - Solar Strates - Strates - Strates	Market and the second s	Strate - State	Marine Contraction of the second seco	Wanths - Males	Mandala - Malan	Alternative - Marchine	Streets - Martin	Manda - Marca	Markets - Market	Marilla - Marill
		Alasta and a state of the state	Statte and the state of the sta	Contraction of the second second	And the second s	Contraction of the second second	allocation and the second seco	State and a state of the state	Statis and a statistical statistics	Alternative and a second secon	States and the second s	Shadha - allow - and a shadha - allow	Standing of the second se	Same Service
	Alternation of the second seco	Alterative and a second	Manada - Martin - Mar	Strates with a strategy of the	Alterative and the second seco	States and the second s	Martin Martin	Wheather will be a starting of the second sta	Martin allow	Alternative and the second sec	Strate and Strate	Martin Martin Contraction State	Although a state of the state o	West's Mary
No. of Concession, Name	Same and the second	Martin - Mar	Manada - Malan	Strates - Solar Strates - Strates - Strates	Market and the second s	Strate - State	Marine Contraction of the second seco	Wanths - Males	Mandala - Malan	Alternative - Marchine	Streets - Martin	Manda - Marca	Markets - Market	Marilla - Marill
	Same and the second	Maralla - Marall	Manada - Malan	Second and the second s	Mandola - Martin Carlos - State of State	Second a second se	Maratha - Marath	Wandles- will be a straight the	Maratha - Maratha - Maratha	and a second	Second to "Martin Control of the Second Seco	Manadia - Martin Martin - Martin Martin	Wandda - Market Market and State	Marine - Marine - Marine
	Strate - Str	Constant of the first of the second s		Alternation - Al		Same and the second sec				Strategy and Strat	Street and Street Stree	Manada - Salar and a salar	Station - Station - Station - Station	Same - Same - Same
			Strate - Str	And the second sec		States - Sta				Same and the second	and the second second		Contraction of the second s	Strates - States
and the second s		Strating water and the state of	Same and the second sec		Manufactor and the second s	Stratter water and the second se			Strate - State	Streets - Street Streets	and the second sec		Manufactor and a second s	
		Strating water and the state of	Same and the second sec		Manufactor and the second s	Stratter water and the second se			Strate - State	Streets - Street Streets	and the second sec		Manufactor and a second s	
and the second s			Streets - Cally and the Call of the Call o	Strate - Str		Strate Contraction	The second se	ALL	Strate - Str		Street and Street and Street and Street	Same and the second	Streets - Streets - Streets	alteration with the
and the second s				And the second s									Strending - Strength and Strending - Stren	Salar Section
and the second s		Strating water and the state of	Same and the second sec		Manufactor and the second s	Stratter water and the second se			Strate - State	Streets - Street Streets	and the second sec		Manufactor and a second s	
		Alternative - al		Alternation - Martin			States - States - States - States	Contraction of the Contraction of the		Stratter and the second s	States and a state of the state	The set of		Streets Streets
		Schending of the second s	Same - Top of the second s		Manufactor and the second seco	Statistic Contraction			Strate - State	Streets - Street Streets	States - Sta		Martin - Martin - Constant - Constant	Station - State State
and the second sec	Second State of State	and the second s		Second	Sector and the sector of the s			and a set of the set o			And the second s	Sector of the se	Manager - March - Constraints	Manadita - Martin Con
All the second second second second					Alternative - Alternative Alte							Contraction of the Contraction of the		Station - Sales and the
	Want to "with the second	When differ a management of the second		Mandra Walter	Monthly " March 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997	Mandala - Martin - Martin - Martin - Martin - Martin		When which the second s	When white a white provide the state of the	Stratter all the	Streets Street Street Street Street	Martin Color	When the state of	Street Street
All the second line and					Alternative - Alternative Alte									Station - Salar
AND THE OWNER WATER		And the second s		Constant of the other state of t	Standard - State									Mandala - Malan
and the second s		Stranding of the strand of the	Stratte Stratte					Street and Street and Street and Street			Street and Street and Street and Street			Alterative and the second
		Streetly - Street y	Stratter with the second secon	Constant of the second se		Street, and street		Streets - Street - Street - Street			Streets - Street St			although the second sec
			Strate - State				States - Sta						T the second second	
		Stranding of the state of the s	States - States - States - States	Contraction of the Contraction o		Contraction of the other states of the other s	Strate Contraction	Standing -	Strate Contraction		Constant of the		Same and the second	allocation - all grant
	25 April 201	9		Wandthe Vallation State of the	Mandala - Martin Caller - Martin Caller	Street of Street of Street of Street		When white the second s		Stratte all the second se	Streets Street Street Street Street Street Street	Martin College	56	
				Strates - algorithm	Alterative and the second seco	Strate - Str		Streets - Street - Street - Street		Stratter values and strategies	Street and Street and Street and Street		and a second sec	
		Second State of State	Alterative - and the life of the second seco	Alterative Constraints of the second se	Section - March 1997 Barrier St.	Stratte Street Street Street Street	Statistic Statistics	Martin water and the second se	Stratter and the strategy of the	Strate St	Streams - white the second sec	and the second s	States - Sta	and the second sec

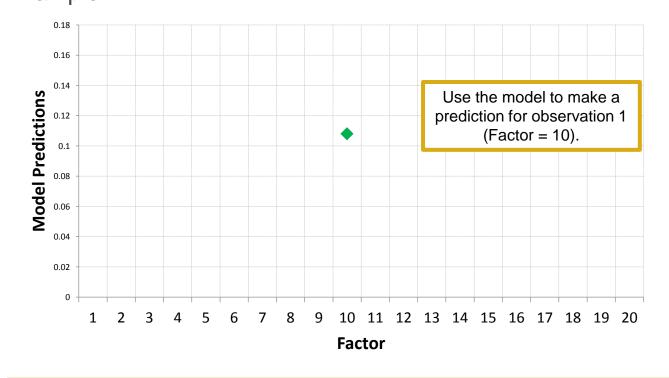
ATRA STREET													Standing of the second se	
												Streets - Street		Stanta Barra
and the second s	And the second s	Contraction of the second seco	Alternative and the second sec	States - Sta		And the second s	And the second s	Alternation of the second seco	Manada - Martin Contraction of State	Streets and street	Alternative and a second secon	State of the state		States - Salar
and the second s				Statistic Statistics				And the second distance of the second distanc	Contraction of the local division of the loc			Strate - Strate - Strate - Strate - Strate	Statistic Statistics	1000 - 100 -
No	Street - The second sec	Contraction of the second seco		States - Sta	Contraction of the second seco				Street, Street			Contraction of the Contraction o	State - State - State - State - State	
				Stratig - State - Stat				and the second s					Manufactor and a second s	1000 - 20 - 10 - 10 - 10 - 10 - 10 - 10
	All and the second seco	Strate Contraction of the Strate						Street, Street	Street and					Stratte digts
													All and the way of the second	
				Stratig - State - Stat				and the second s					Manufactor and a second s	1000 - 20 - 10 - 10 - 10 - 10 - 10 - 10
	All and the second seco	Strate Contraction of the Strate						Street, Street	Street and					Stratte digts
and the second s	The second secon												and a state of the	
													All and the way of the second	
	All and the second seco	Strate Contraction of the Strate						Street, Street	Street and					Stratte digts
								Street and the second s			and the second s	and the second s		Stream and the second
ALA STRUCTURE	And the second s				Alternation - March 1997 Biology and Alternation							Alternative - Marchine	Same - Sa	
AND STRUCTURES.	And the second s			Alternative - March 1997 (Street of the street of the stre	Alternation - March 1997 Biology and State State					Streets - will be a street with the street of the street o		Alternative - Marchine	Same - Sa	
	All and the second seco	All and the second seco	allowing with the second secon	All and the second seco		all and the second seco	all and the second seco	All solar and the solar and th	Allowing and the second	Alternative and the second sec	Alternative with the second se	Strate Strate		and the second second
and the second s	Market and State and State	Martin Martin Contraction State	When the " will be	When the " with the	Wanter William				a contraction of the	Mandala - Martin - Ma	Alternative with the second se	Stratte Street	Martin and Street and Street	Streets March
No. Same	Second State of State	Standing - State of the State of the State of the State	Warding	and a set of the set o	Contraction - March		es it w	ork?	State of the local division of the local div	And and the second seco	Sector and the sector	and a second	Martin - State - State - State - State	Same and the
and the second s	Market and State and State	Martin Martin Contraction State	When the " will be	When the " with the	attenders with the	- D0		UIK (Mandala - Martin - Ma	Alternative with the second se	Stratte Street	Martin and Street and Street	Streets March
and the second s	Market and State and State	Martin Martin Contraction State	When the " will be	When the " with the	attenders with the					Mandala - Martin - Ma	Alternative with the second se	Stratte Street	Martin and Street and Street	Streets March
No. Same	Second State of State	Standing - State of the State of the State of the State	Warding	and a set of the set o	Same and		does it	· w∩rk′	State of the second	And and the second seco	And and the second seco	and a second	Martin - State - State - State - State	Same and the
and the second s	The second secon				Contract of the second s	11010								
	Strate - Destration of the second sec	Same - Same	And the second s	Strate view of the local state of the	State - State				Strate - Strate - Strate - Strate - Strate	And the second s		Strate - State	State - State - State - State - State	
	Strate - Str	Contraction of the second s	Alternative and the second sec	Strate St		Strates - Strates - Strates - Strates	Strates - Strates - Strates - Strates	Strate Contraction of the second seco	Strate - Str	Stratter and strategies	Stratter and Strategies	Same and the second sec	Contraction of the second s	States - States
and the second s			Alternative water and the second seco	Stratter water and the second se		Streets - Street Streets	Streets - Street Streets	Street and a street of the str	Same and the second	Strating of the local sector of the	States - Sta	Same and the second	Martin Contraction of the State	
	Strate - Destration of the second sec	Same - Same	And the second s	Strate view of the local state of the	Strate - Str	Stratter view of the local strategy of the l	Stratter view of the local strategy of the l		Street, Street	And the second s		Street, or other the street of the	State - State - State - State - State	
and the second s	All and the second seco		Alternation - March and Alternation of State	Stratter and the second	And the second s	Alternative and the second sec	Alternative and the second sec	Stratter - Stratter - Stratter - Stratter	All and the second diversion of the second diversion o	Constant of the other state of t	All and the owner of the second	Same and the second		Streets - March
and the second s			Alternative water and the second seco	Stratter water and the second se		Streets - Street Streets	Streets - Street Streets	Street and a street of the str	Same and the second	Strating of the local sector of the	States - Sta	Same and the second	Martin Contraction of the State	
and the second s			Alternative water and the second s	Stratter water and the second se		Streets - Street Streets	Streets - Street Streets	Street and a street of the str	Same and the second	Strating of the local sector of the	States - Sta	Same and the second	Martin Contraction of the State	
And the second s	The second secon	Same and the second		Stratter and the second s				Street and Street and Street and Street	Street and Street and Street and Street			Street Stre		Streets dign
		States - Sta		Same - Same						Same and the second		Same and the second		
and the second sec	And the second s											And the second s	Alterative - March 1997	
and the second sec	And the second s											And the second s	Alterative - March 1997	
			and the second s		Alternative and the second	Streets - algorithm	Streets - all the second	Alterative and the second seco		Alternative and the second sec	And the second s	All states of the second state		Same and the second
and the second sec	Second to - Second Seco	And the second s			And the second sec	Sector and the sector	Sector and the sector		The second	Stratte - action and a second se	And the second line of the secon	And the second sec	Second Contraction of the Second Seco	
State of the state	Alterative - Alter										Section of the sectio			
			and the second s		and the second s	Although a second	Alternative and the second sec	Alterative and the second seco		Alternative and the second sec	And the second s			Same and the second
and the second s			Streets and streets and streets and streets and streets			Streets and the second se	Streets and the second se	Streets and the second se		Streets - along the second sec	Schwartzen werten er einen e		L	and the second
and the second sec	And the second s	and the second s			Second					And the second s		A DE LA DE L	Manager - Manager - State - St	and a second second
and the second s			Stratte della d			Stratter all the	Stratter all the	Streets and the second se		Streets - algorithment and a street of the	Second Se	Wender - March		and the second
	25 April 201	9	Streets - States - States	Street, Street	And the second s	Streets - algorithments - and the second sec	Streets - algorithments - and the second sec	Street, Street		Stratta - Stratta	Schutzer - Martin - M	And the other state of the stat	57	Streets digts
		States and the second sec	Streets - Street and S	Street, St			Stratter and the second s		Mandala - Martin - Ma	Mandala - Malana				
and the second second second second	Strate - State - State - State - State	and an and a second sec	Maralla - Marall	Stratter water and the second se		Manager and State of		Maratha - walter	Same and the second	Stratin - Strate - St		Strate - Str	State - Sec. State - State - State	Maratha - Martin - Martin

Factor importance – relative influence

The relative influence of a factor can be measured as the total reduction in error attributable to splits by that factor, across all trees in the GBM

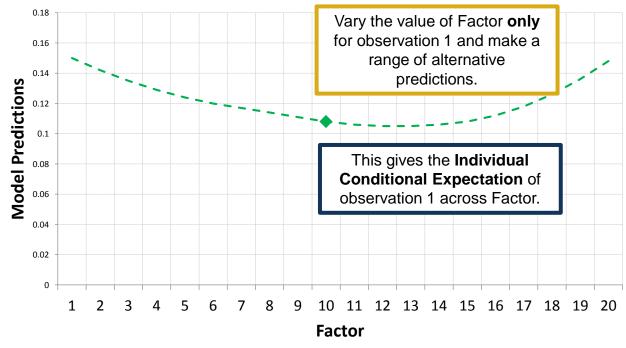


Partial dependency plots Example



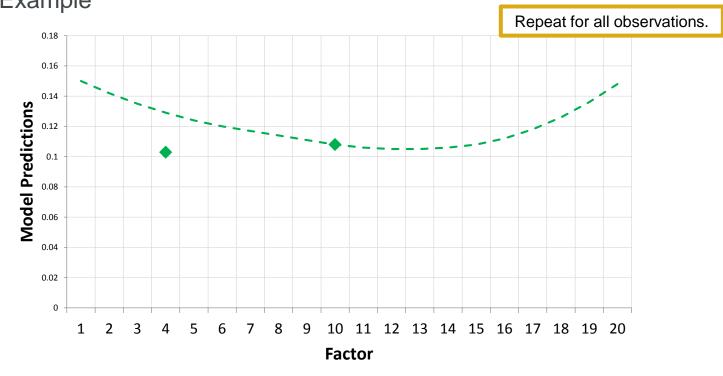


Example



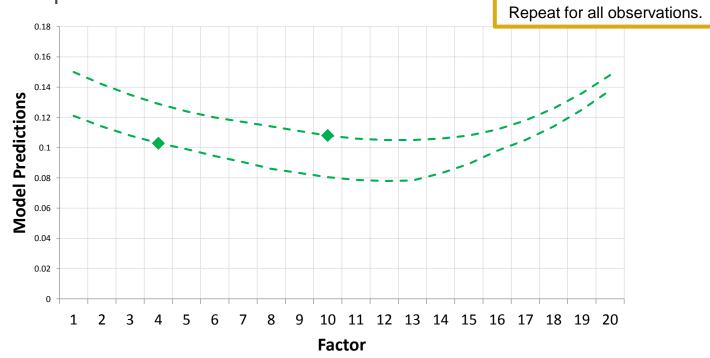


Partial dependency plots Example



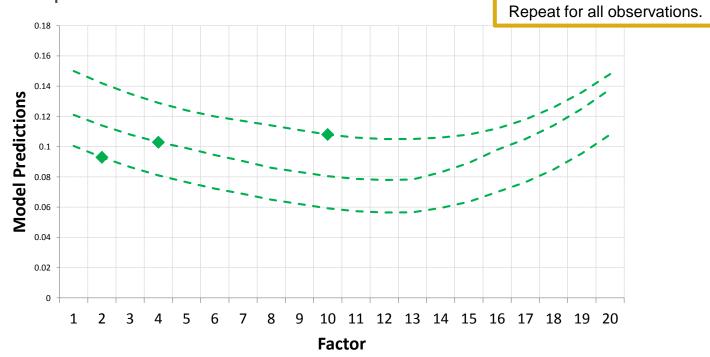


Example





Example

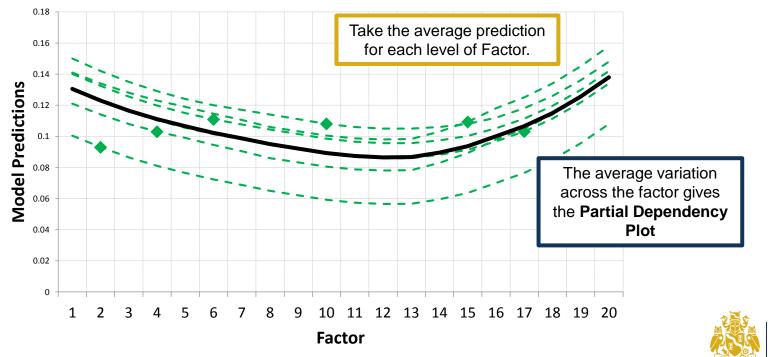




Partial dependency plots Example

Repeat for all observations. 0.18 0.16 0.14 **Model Predictions** 0.12 0.1 The full picture of the 0.08 variation in predictions for all observations is the 0.06 Individual Conditional 0.04 **Expectation** (or ICE) plot. 0.02 0 2 3 5 7 8 10 11 12 13 14 15 16 17 18 19 20 1 4 6 9 Institute Factor and Faculty of Actuaries

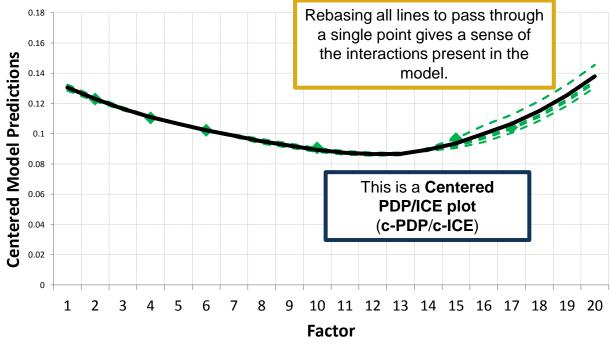
Example



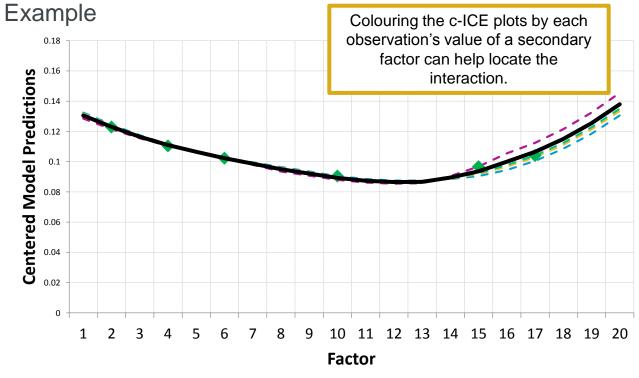
Institute

and Faculty of Actuaries

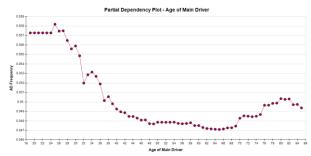
Example











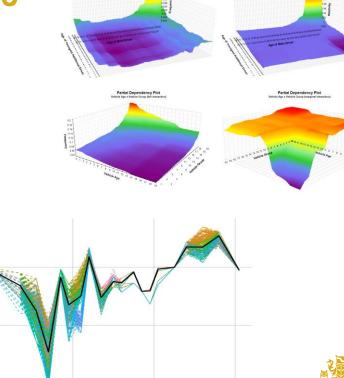
0.00

-0.01

-0.02

20

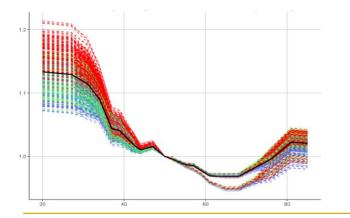
40



60

80

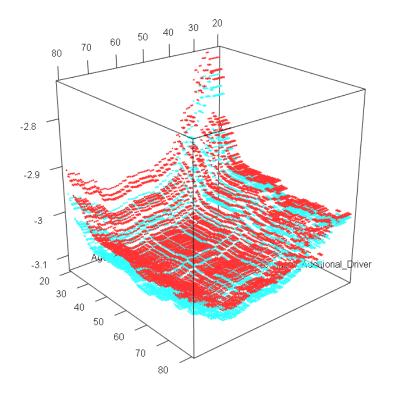
Partial Dependency Plot



Institute and Faculty of Actuaries

Partial Dependency Plot

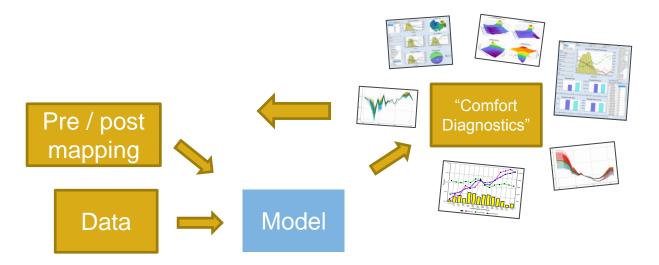
25 April 2019



- Advantages
 - Qualitative description of properties of relationships
 - Most revealing of additive and multiplicative relationships
- Disadvantages
 - "GLM view of a non-GLM thing"
 - Interaction effects outside of the chosen subset may be obfuscated
 - eg if X1X2 is important and X2 is averaged out in the partial dependence plot, X1 may show as being heterogeneous, thus obfuscating the complexity of the modelled relationships



Model build process



Deploy directly



Deploying GBMs

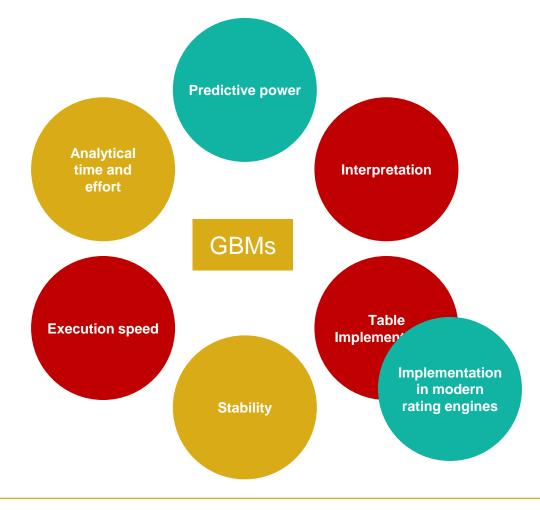
Model down into multiplicative tables via GLMs

	Age	Exposure	Burning Cost		Vehicle 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
5	Age Total	281,849	91	5	VG Total	281,849	91
	Gender	Exposure	Burning				

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











Predictive powe

Stability

Interpretation

Table Implementation



Interpretation

Table Implementation

Random Forests



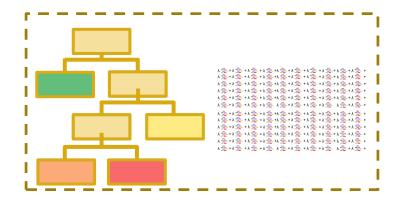
Machine Learning in Pricing

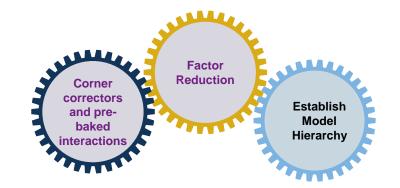
Conclusions

- There are many forms of ML models
- New data and feature/response engineering generally add more value than new methods BUT we need to continuously explore which methods work on which problems
- Traditional measures of prediction value may not reflect applications in insurance
- And it's not all about predictive power anyway other criteria are important
- GBMs can provide predictive lift benefits by capturing higher order effects ... BUT
 - Can you cope with not seeing the model and instead use broad diagnostics
 - Effort is required to expose/understand higher order effects in an expeditious manner
 - How will business leaders and regulators respond to this method?
 - Do you have the software and hardware to fit to large dataset
 - Do you have a rating engine that can implement a GBM



Practical applications of tree based methods in pricing







Questions







and Faculty of Actuaries

Thank you