

Responsible Machine Learning

Lecture 5: Machine Learning Model Debugging

Patrick Hall

The George Washington University

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What is Model Debugging?

- Model debugging is an emergent discipline focused on discovering and remediating errors in the internal mechanisms and outputs of machine learning models.*
- Model debugging attempts to test machine learning models like software (because the models are software).
- Model debugging is similar to regression diagnostics, but for machine learning models.
- Model debugging **promotes trust directly and enhances interpretability as a side-effect**.

* See <https://debug-ml-iclr2019.github.io/> for numerous model debugging approaches.

Why Debug?

Government's Use of Algorithm Serves Up False Fraud Charges

Using a flawed algorithm, Michigan falsely charged thousands with unemployment fraud and took millions from them.

When a Computer Program Keeps You in Jail

By Rebecca Walker

A.C.L.U. Accuses Clearview AI of Privacy 'Nightmare Scenario'

The facial recognition start-up violated the privacy of Illinois residents by collecting their images without their consent, the civil liberties group says in a new lawsuit.

Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam

Access Denied: Faulty Automated Background Checks Freeze Out Renters

Microsoft's robot editor confuses mixed-race Little Mix singers

Fox's plan to replace editors with AI butchers after wrong image of musician is published

Instagram blames GDPR for failure to tackle rampant self-harm and eating-disorder images

Exclusive: Telegraph investigation found Instagram's algorithms push dangerous content almost two years after it promised to crack down

By Lawrence Dedeck, TECHNOLOGY REPORTER, SAN FRANCISCO

4 October 2020 | 08:00

Leaving Cert: Why the Government deserves an F for algorithms

Net Results: Invisible code has a significant – and often negative – impact on all our lives

By Paul, Paul, 2020-09-29 09:00

States Say the Online Bar Exam Was a Success. The Test-Taker Who Peed in His Seat Disagrees

New York, California, and Florida are among the states requiring that nearly all takers of this year's online law exam use a mobile device to take the exam. But examinees complain that percentile scores confuse the test results. Look at these states that declared it a success.

By Karen Depp | October 20, 2019 | 04:44 ET

Lawsuit alleges biometric privacy violations from face recognition algorithm training

Paravision's cloud photo storage roots at issue

Oct 7, 2020 | 08:00

Regulators probe racial bias with UnitedHealth algorithm

Regulators says racial bias in algorithm leads to poorer care for black patients; UnitedHealth defends product.

By Christopher Soundick Star Tribune | OCTOBER 28, 2019 — 6:05PM

Leaving Cert: Why the Government deserves an F for algorithms

Replies to @edward93 @hhd and @AppleCard

I'm a current Apple employee and founder of the company and the same thing happened to us (10x) despite not having any separate assets or accounts. Some say the blame is on Goldman Sachs but the way Apple is attached, they should share responsibility.

2:06 AM - Nov 10, 2019 - Twitter Web App

Tiny Changes Let False Claims About COVID-19, Voting Evade Facebook Fact Checks

October 9, 2020 — 6:01 AM ET

Allstate's Algorithm Sucks List: How Allstate's Secret Auto Insurance Algorithm Squeezes Big Spenders

UK passport photo checker shows bias against dark-skinned women

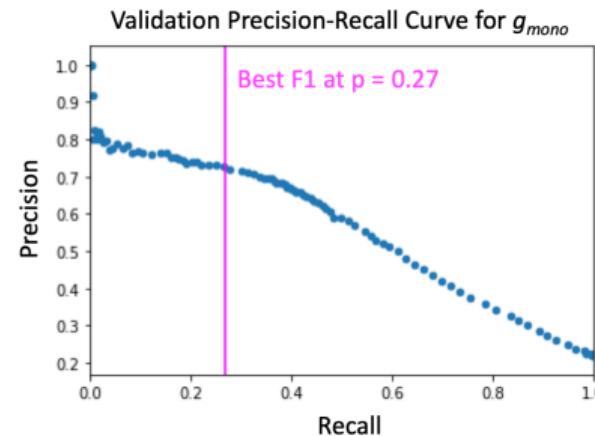
By Maryan Kherlakian | October 2020 — 7:00 AM ET

AI incidents: The Partnership on AI Incident Database contains over 1,200 incident reports.[†]

[†] See <https://incidentdatabase.ai/> to access the database.

Why Debug?

- Constrained, monotonic GBM probability of default (PD) classifier, g_{mono} .
- Grid search over hundreds of models.
- Best model selected by validation-based early stopping.
- Seemingly well-regularized (row and column sampling, explicit specification of L1 and L2 penalties).
- No evidence of over- or under-fitting.
- Better validation logloss than benchmark GLM.
- Decision threshold selected by maximization of F1 statistic.
- BUT traditional assessment can be inadequate!**

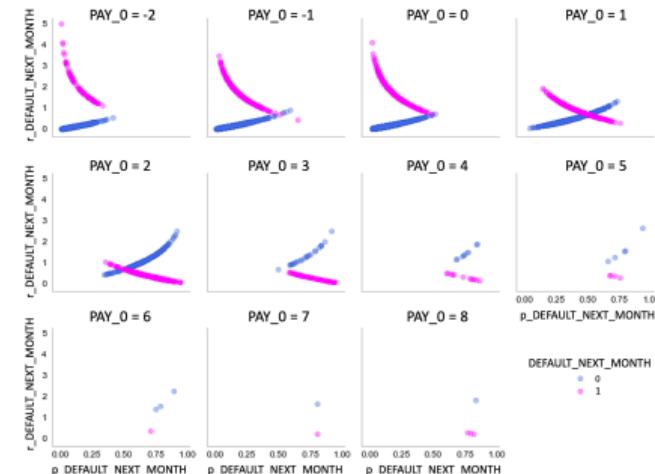
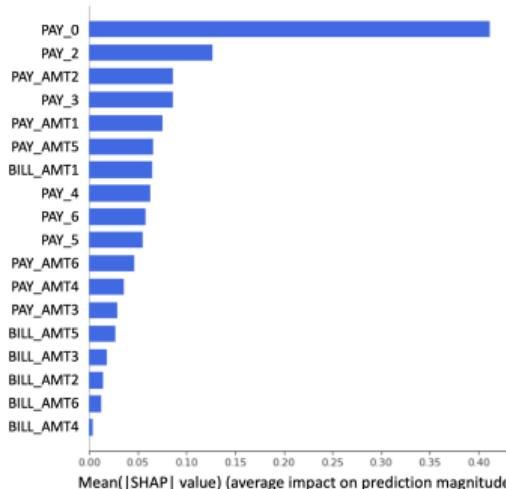


Validation Confusion Matrix at Threshold:

	Actual: 1	Actual: 0
Predicted: 1	1159	827
Predicted: 0	1064	6004

Why Debug?

Machine learning models can be **unnecessary**.



gmono PD classifier over-emphasizes the most important feature, a customer's most recent repayment status, PAY_0.

gmono also struggles to predict default for favorable statuses, $-2 \leq \text{PAY}_0 < 2$, and often cannot predict on-time payment when recent payments are late, $\text{PAY}_0 \geq 2$.

Why Debug?

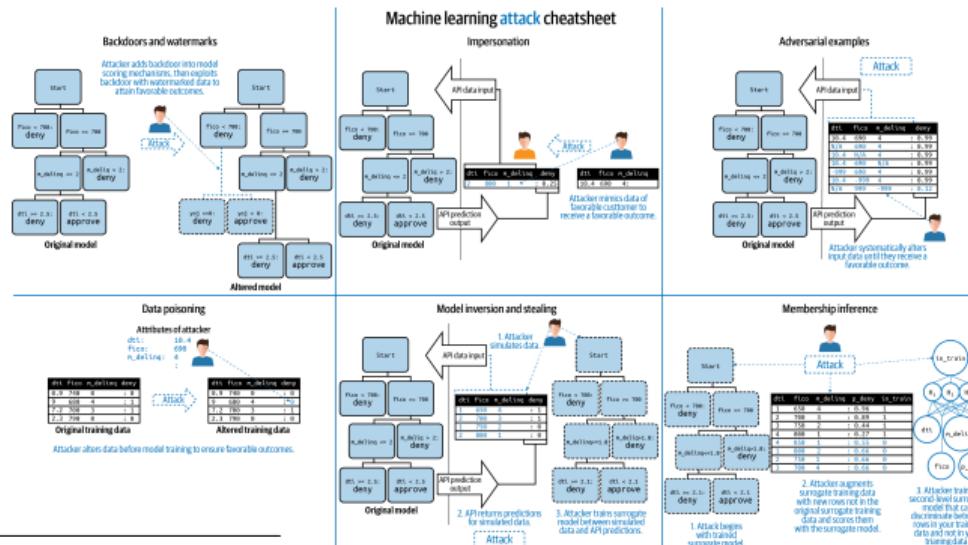
Machine learning models can perpetuate **sociological biases** [1].

	Adverse Impact Disparity	Accuracy Disparity	True Positive Rate Disparity	Precision Disparity	Specificity Disparity
single	0.885	1.029	0.988	1.008	1.025
divorced	1.014	0.932	0.809	0.806	0.958
other	0.262	1.123	0.62	1.854	1.169

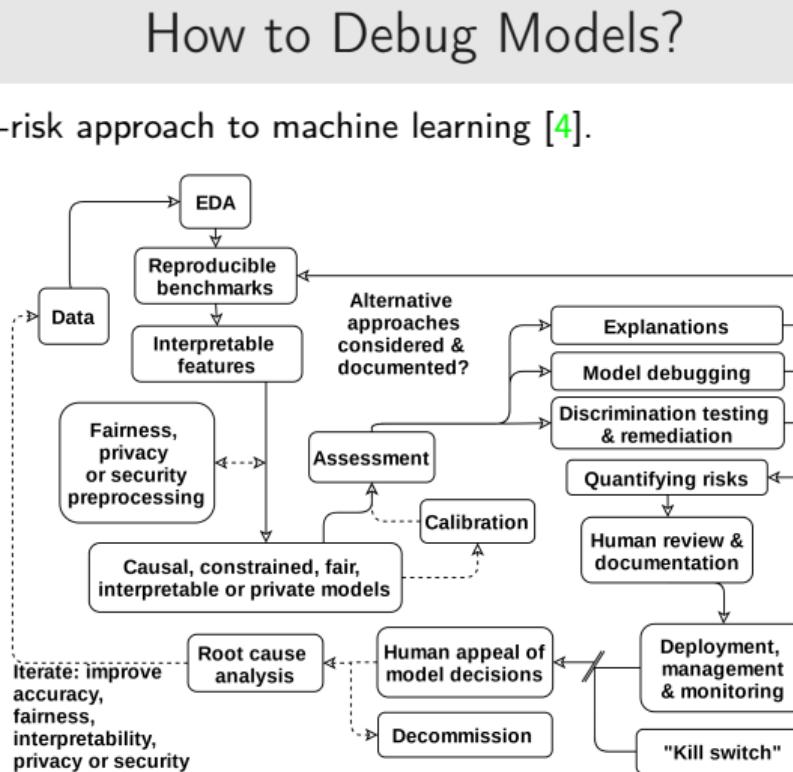
Group disparity metrics are out-of-range for g_{mono} across different marital statuses.

Why Debug?

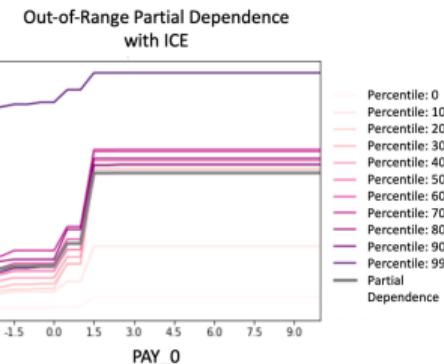
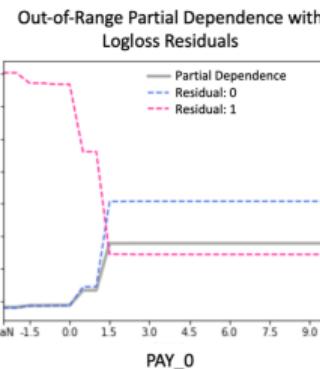
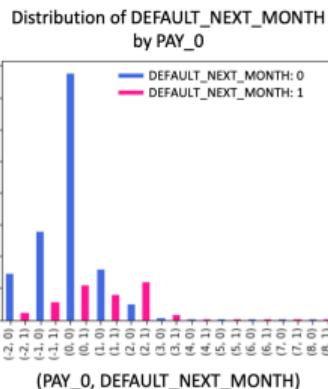
Machine learning models can have **security vulnerabilities** [2], [6], [7].[†]



[†] See <https://bit.ly/3jyYtzi> for full size image.

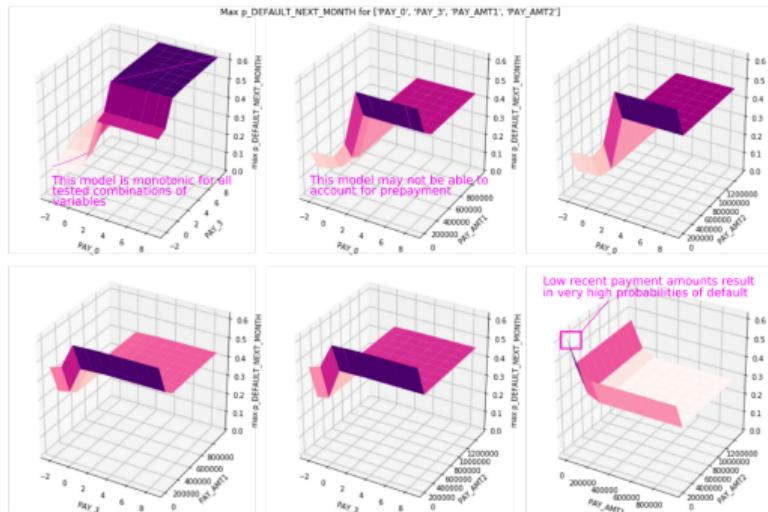


Sensitivity Analysis: Partial Dependence and ICE



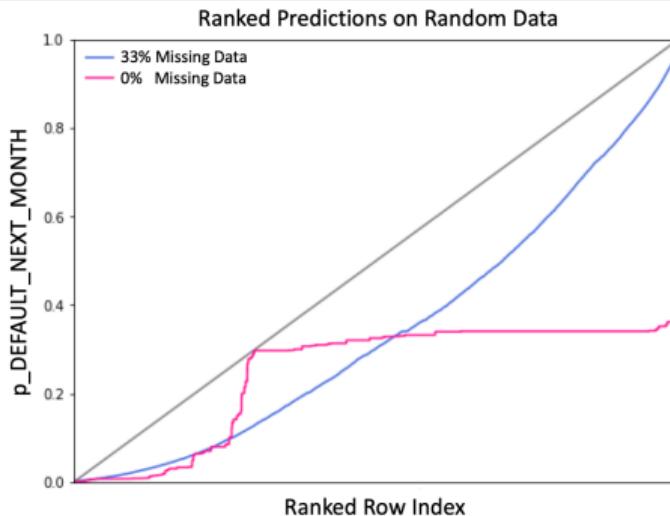
- Training data is very sparse for PAY_0 > 2.
- ICE curves indicate that partial dependence is likely trustworthy and empirically confirm monotonicity, but also expose adversarial attack vulnerabilities.
- Partial dependence and ICE indicate g_{mono} likely learned very little for $\text{PAY}_0 \geq 2$.
- PAY_0 = missing gives lowest probability of default.

Sensitivity Analysis: Search for Adversarial Examples



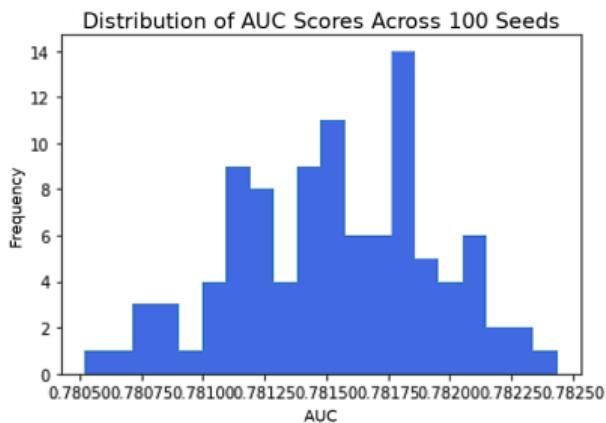
Adversary search confirms multiple avenues of attack and exposes a potential flaw in `gmono` inductive logic: default is predicted for customer's who make payments above their credit limit. (Try heuristics, evolutionary learning or packages like `cleverhans` to generate adversarial examples.)

Sensitivity Analysis: Random Attacks



- In general, random attacks are a viable method to identify software bugs in machine learning pipelines.
(Start here if you don't know where to start.)
- Random data can apparently elicit all probabilities $\in [0, 1]$ from g_{mono} .
- Around the decision threshold, lower probabilities can be attained simply by injecting missing values, yet another vulnerability to adversarial attack.

Sensitivity Analysis: Underspecification



- Without domain-informed constraints ML models suffer from *underspecification* [3].
- Explicit tests for underspecification involve assessing model performance stability across perturbed computational hyperparameters: seeds, threads, number of GPUs, etc.
- Likely due to monotonicity constraints, g_{mono} performance appears stable across random seeds.

Residual Analysis: Disparate Accuracy and Errors

Error Metrics for PAY_0

	Prevalence	Accuracy	True Positive Rate	Precision	Specificity	Negative Predicted Value	False Positive Rate	False Discovery Rate	False Negative Rate	False Omissions Rate
PAY_0										
-2	0.124	0.864	0.099	0.333	0.972	0.884	0.026	0.667	0.901	0.116
-1	0.168	0.816	0.206	0.406	0.939	0.854	0.061	0.594	0.794	0.146
0	0.121	0.867	0.107	0.341	0.972	0.888	0.026	0.659	0.893	0.112
1	0.325	0.491	0.903	0.381	0.292	0.862	0.706	0.619	0.097	0.138
2	0.709	0.709	1	0.709	0	0.5	1	0.291	0	0.5
3	0.748	0.748	1	0.748	0	0.5	1	0.252	0	0.5
4	0.571	0.571	1	0.571	0	0.5	1	0.429	0	0.5
5	0.444	0.444	1	0.444	0	0.5	1	0.556	0	0.5
6	0.25	0.25	1	0.25	0	0.5	1	0.75	0	0.5
7	0.5	0.5	1	0.5	0	0.5	1	0.5	0	0.5
8	0.75	0.75	1	0.75	0	0.5	1	0.25	0	0.5

Error Metrics for SEX

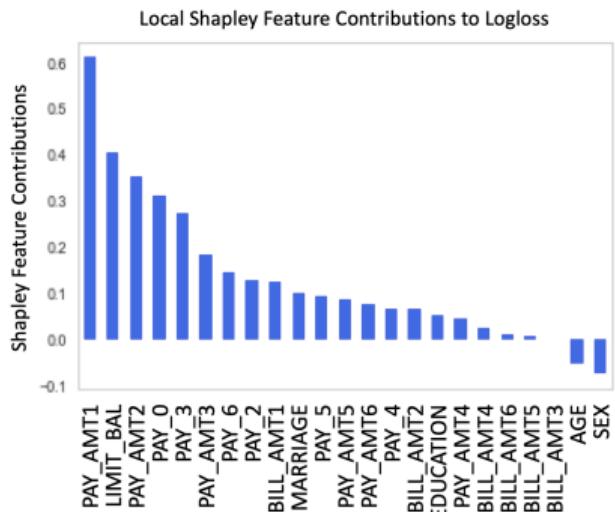
	Prevalence	Accuracy	True Positive Rate	Precision	Specificity	Negative Predicted Value	False Positive Rate	False Discovery Rate	False Negative Rate	False Omissions Rate
SEX										
Male	0.235	0.782	0.626	0.531	0.83	0.879	0.17	0.469	0.374	0.121
Female	0.209	0.797	0.552	0.514	0.862	0.879	0.138	0.486	0.448	0.121

For PAY_0:

- Notable change in accuracy and error characteristics for PAY_0 ≥ 2 .
- Varying performance across segments can be an indication of underspecification.

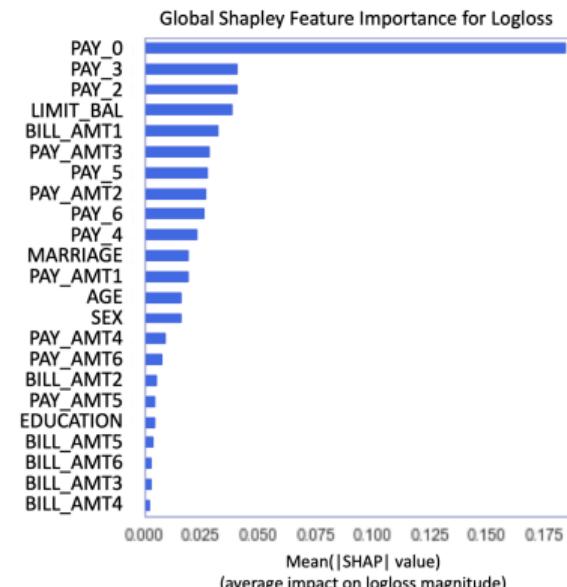
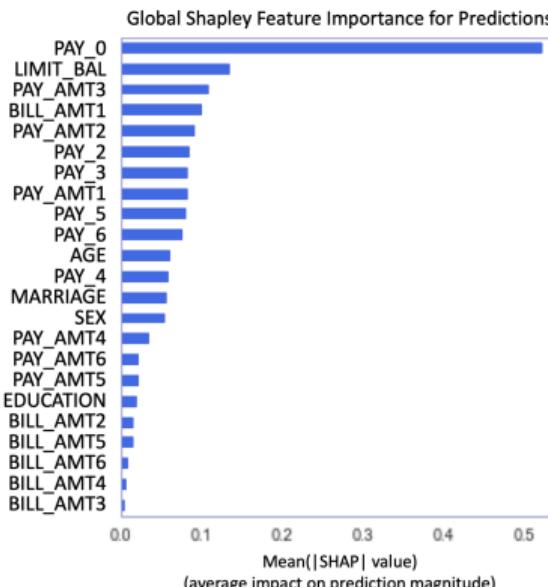
For SEX, accuracy and error characteristics vary little across individuals represented in the training data. Non-discrimination should be confirmed by more involved disparate impact analysis.

Residual Analysis: Local Contributions to Logloss



Exact, local feature contributions to logloss can be calculated, enabling ranking of features contributing to logloss residuals for **each prediction**. Shapley contributions to XGBoost logloss can be calculated using the **shap** package. This is a **time-consuming** calculation.

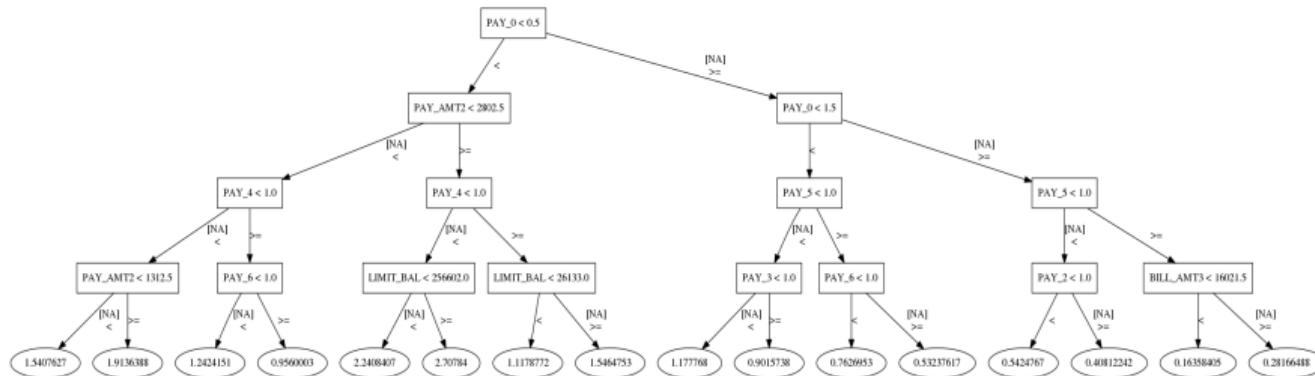
Residual Analysis: Non-Robust Features



Globally important features PAY_3 and PAY_2 are more important, on average, to the loss than to the predictions.

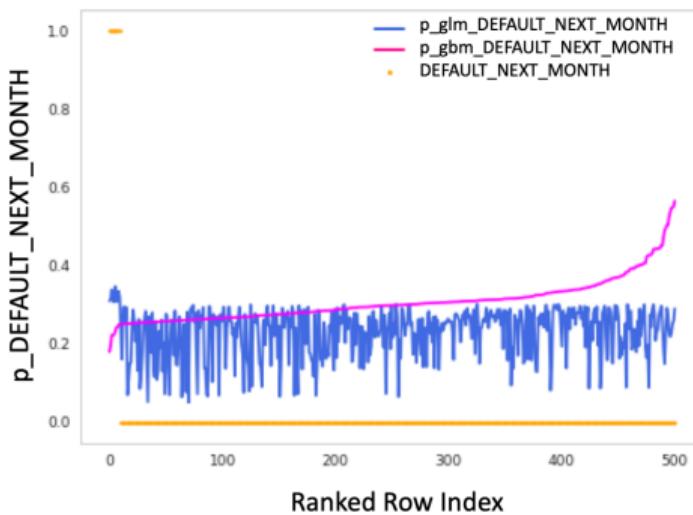
Residual Analysis: Modeling Residuals

Decision tree model of g_{mono} $\text{DEFAULT_NEXT_MONTH} = 1$ logloss residuals with 3-fold CV MSE = 0.0070 and $R^2 = 0.8871$.



This tree encodes rules describing when g_{mono} is probably wrong.

Benchmark Models: Compare to Linear Models



For a range of probabilities $\in (\sim 0.2, \sim 0.6)$, g_{mono} displays exactly incorrect prediction behavior as compared to a benchmark GLM.

Remediation: g_{mono}

- **Over-emphasis of PAY_0:**
 - Engineer features for payment trends or stability.
 - Strong regularization or missing value injection during training or inference.
- **Sparsity of PAY_0 > 2 training data:** Increase observation weights.
- **Payments \geq credit limit:** Inference-time model assertion [5].
- **Disparate impact:** Adversarial de-biasing [8] or model selection by minimal disparate impact.
- **Security vulnerabilities:** API throttling, authentication, real-time model monitoring.
- **Large logloss importance:** Evaluate dropping non-robust features.
- **Poor accuracy vs. benchmark GLM:** Blend g_{mono} and GLM for probabilities $\in (\sim 0.2, \sim 0.6)$.
- **Miscellaneous strategies:**
 - Local feature importance and decision tree rules can indicate additional inference-time model assertions, e.g., alternate treatment for locally non-robust features in known high-residual ranges of the learned response function.
 - Incorporate local feature contributions to logloss into training or inference processes.

Remediation: General Strategies

Technical:

- Calibration to past data
- Data augmentation
- Discrimination remediation
- Experimental design
- Interpretable models
- Model or model artifact editing
- Model assertions
- Model monitoring
- Monotonicity and interaction constraints
- Strong regularization or missing value injection during training or inference

Process:

- Appeal and override
- Bug bounties
- Demographic and professional diversity
- Domain expertise
- Incident response plans
- Model risk management
 - Effective challenge and human review
- Software quality assurance
- Red-teaming

Acknowledgments

Some materials ©Patrick Hall and the H2O.ai team 2017-2020.

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This presentation:

https://www.github.com/jphall1663/jsm_2019

Code examples for this presentation:

https://www.github.com/jphall1663/interpretable_machine_learning_with_python

https://www.github.com/jphall1663/responsible_xai

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