

# Robust Counterfactual Explanations for Tree-Based Ensembles

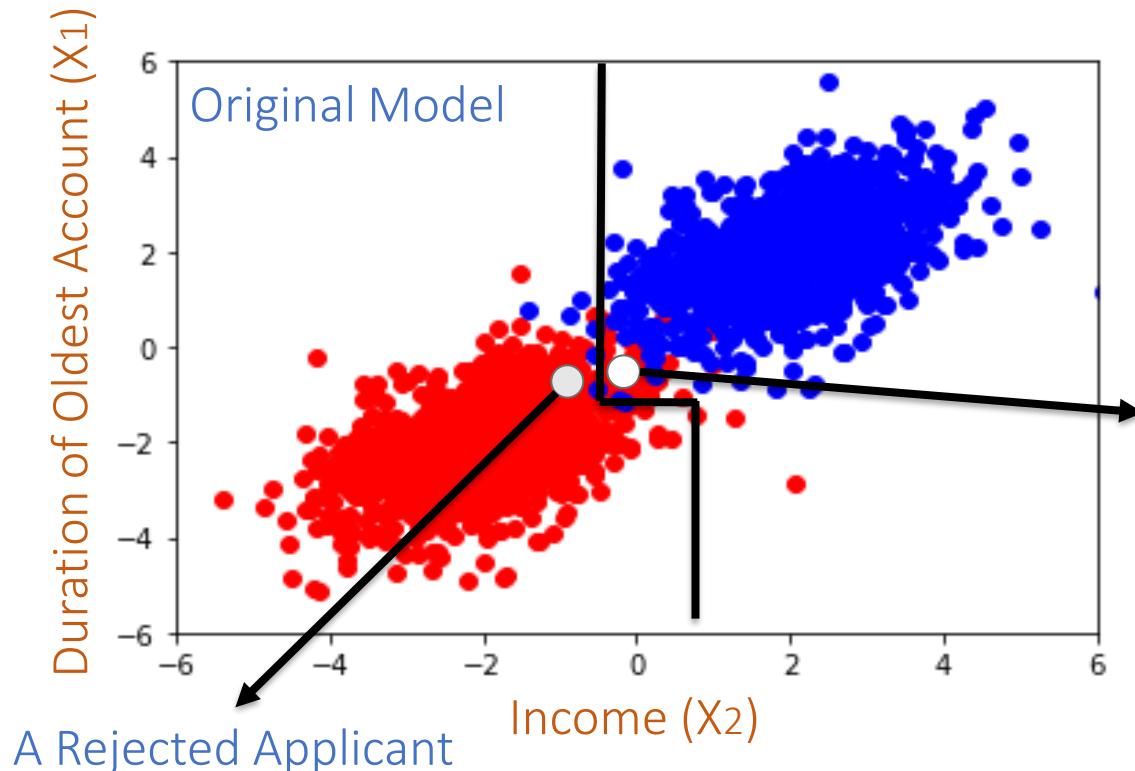
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JP Morgan AI Research

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# Counterfactual Explanations in High-Stakes Applications

**Motivation:** Reliably guide an applicant on how they can change the model outcome

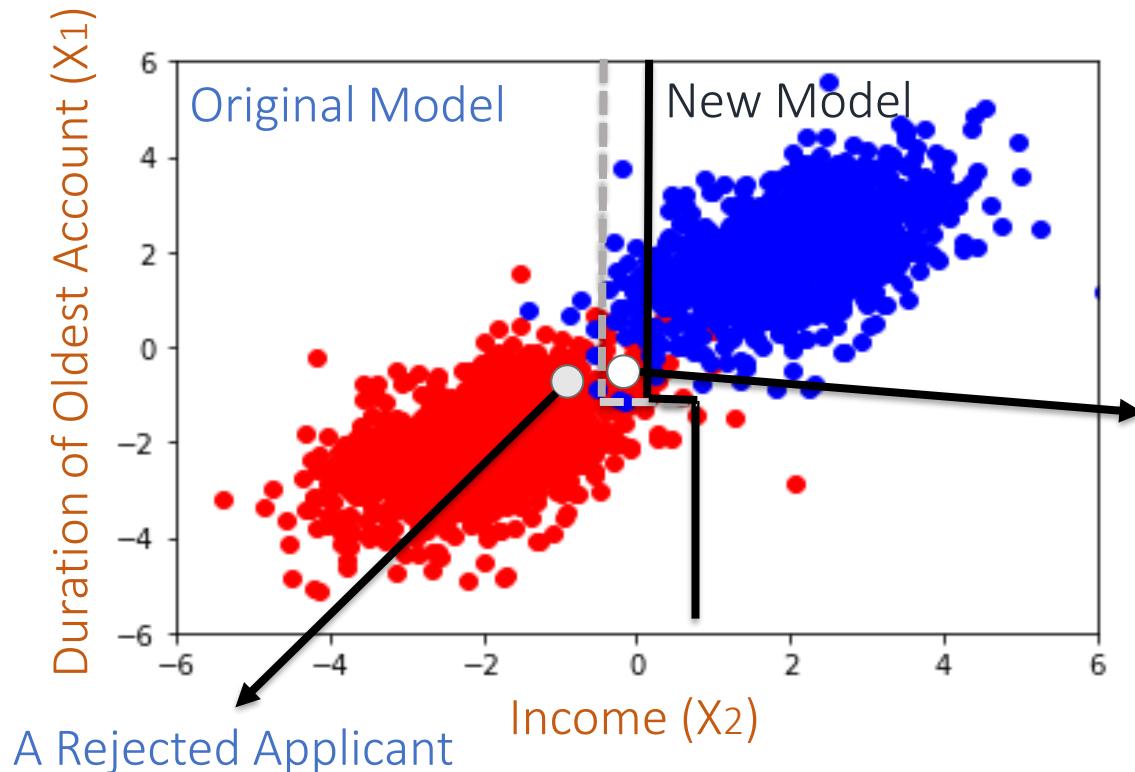


💡 Find the “closest” point on the other side of the decision boundary

Counterfactual Explanation  
(e.g., increase income by 10K)

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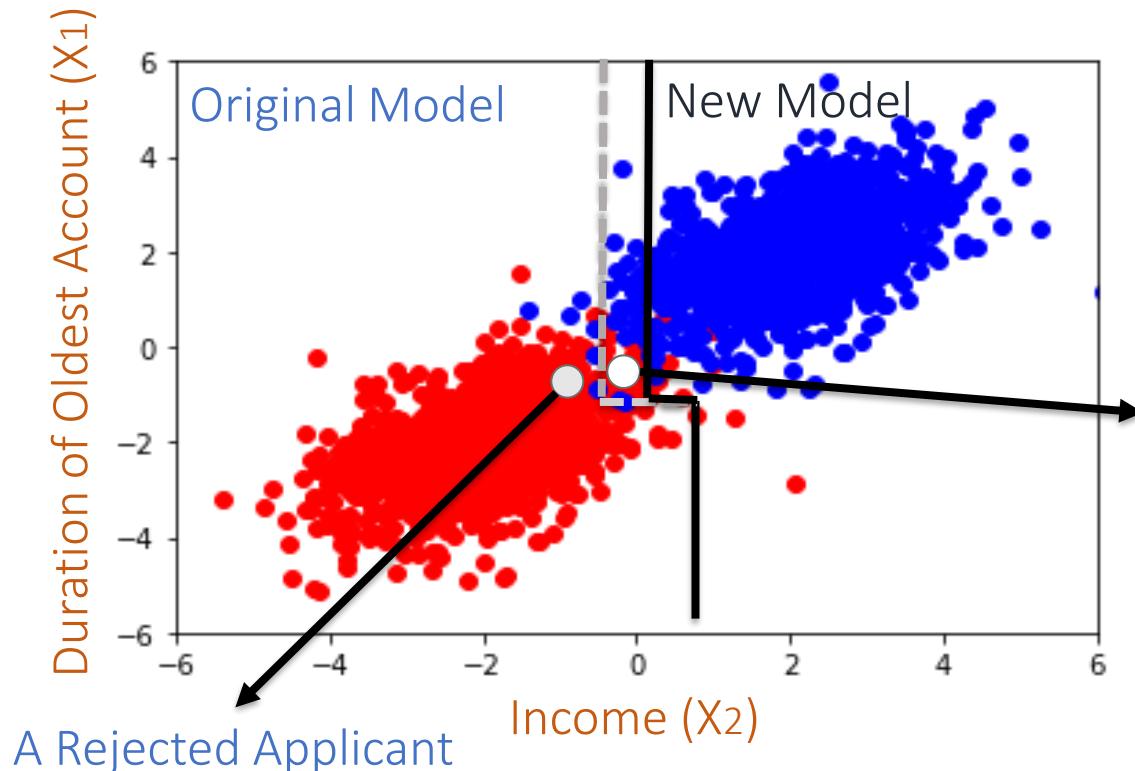


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Counterfactual Explanation  
(e.g., increase income by 10K)

How do we provide counterfactual explanations that are not only “closest” but also **robust** to model changes?

## Problem Statement

Given a data point  $x \in \mathcal{X}$  such that  $M(x) \leq 0.5$ , our **goal** is to find a counterfactual  $x'$  with  $M(x') > 0.5$  that meets our requirements:

- **Close**, i.e.,  $\|x - x'\|_p$  is low
- **Valid** after changes to the model, i.e.,  $M_{new}(x') > 0.5$
- **Realistic** with respect to the data manifold, i.e., has a better LOF

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Related Works:

[Upadhyay et al.'21][Rawal et al.'21][Black et al.'21]

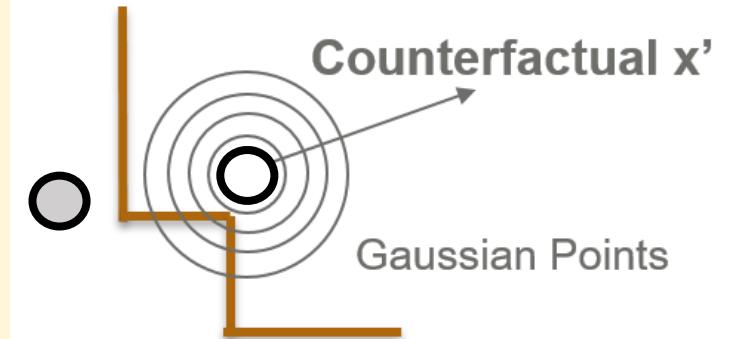
Our focus:  
Tree-based models

# Contribution 1: Counterfactual Stability

A Novel Measure to Quantify Robustness for Tree-Based Ensembles

$$R_{K,\sigma^2}(x, M) = \frac{1}{K} \sum_{x' \in N_x} M(x') - \sqrt{\frac{1}{K} \sum_{x' \in N_x} \left( M(x') - \frac{1}{K} \sum_{x' \in N_x} M(x') \right)^2}$$

where  $N_x$  is a set of  $K$  points from the distribution  $N(x, \sigma^2)$

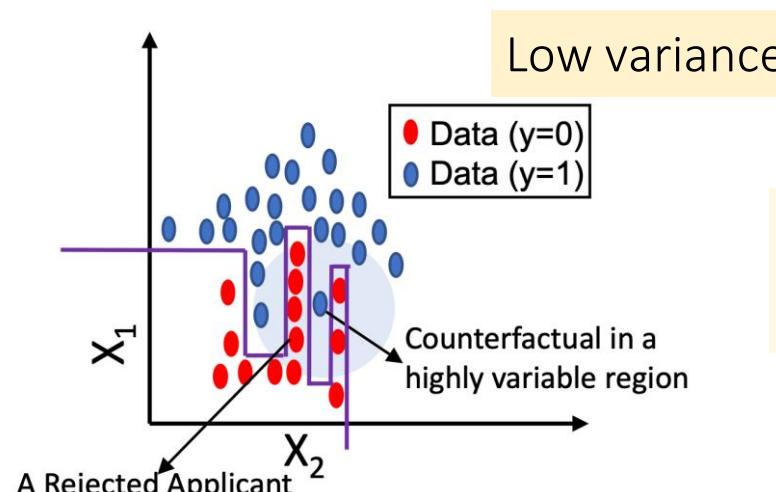
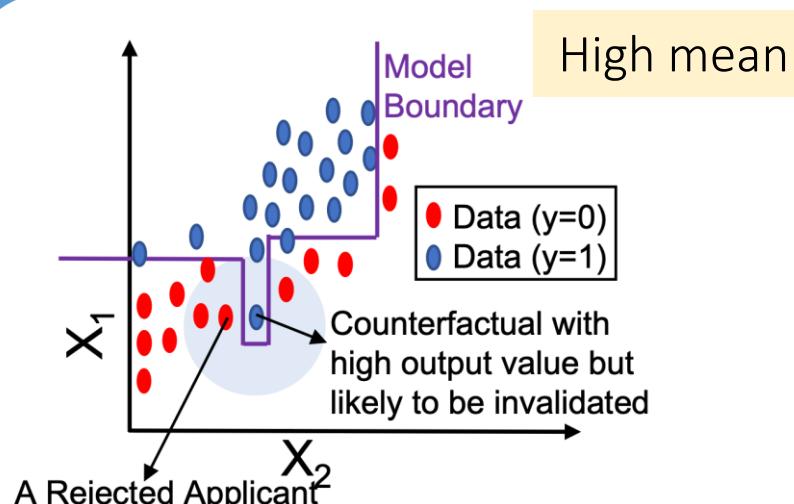
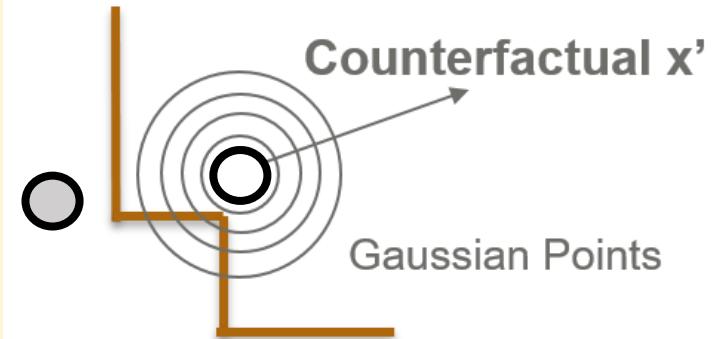


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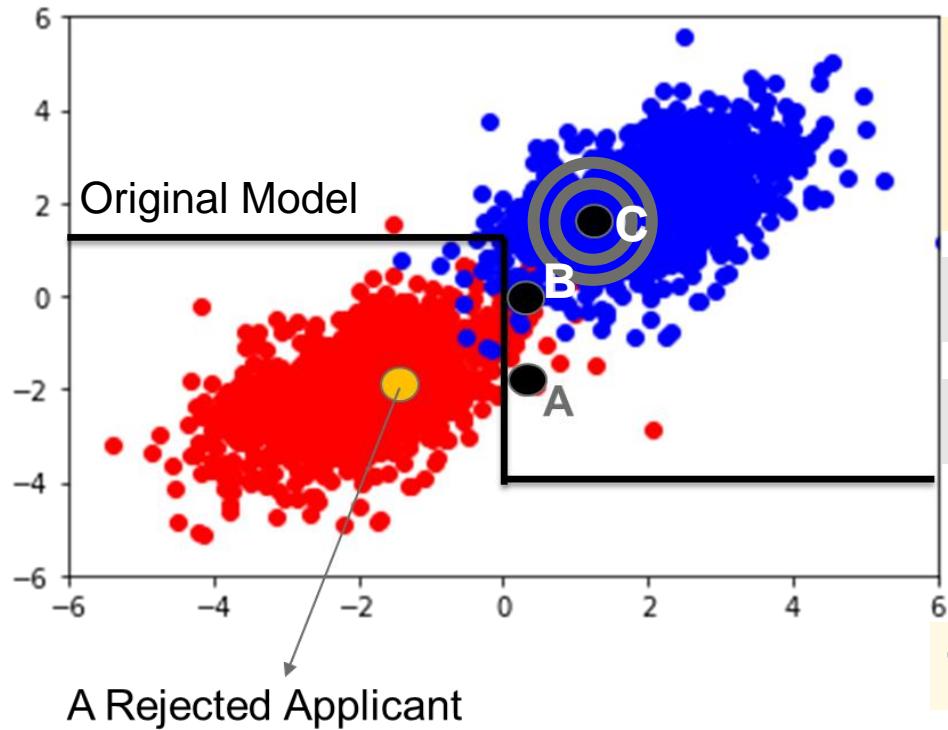
where  $N_x$  is a set of  $K$  points from the distribution  $N(x, \sigma^2)$



 Identify key properties that affect robustness

## Contribution 2: Conservative Counterfactuals

Nearest neighbor in the dataset on the other side of the decision boundary that also has high stability, i.e.,  $R_{K,\sigma^2}(x, M) \geq \tau$  (stability test)



C: Conservative Counterfactual  
(Closest Data-Support Counterfactual  
that is also Well-Within the boundary)

B: Closest Data-Support Counterfactual

A: Closest Counterfactual



Theoretical Robustness Guarantee

## Contribution 3: RobX Algorithm

Finds counterfactuals that are close, robust, and realistic

- Can be applied on top of any base-method of counterfactual generation for tree-based models, e.g., Feature Tweaking, FOCUS, FACE, kNN, etc.
- Iteratively refines the generated counterfactual and keeps moving it towards a conservative counterfactual until  $R_{K,\sigma^2}(x, M) \geq \tau$  (stability test)

Experimental Results on GERMAN CREDIT and HELOC datasets:  
More robust (validity) and realistic (LOF) with slight increase in distance (Lp norm)

Thank You!