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# Faithful Model Explanations through **E**nergy-**C**onstrained **C**onformal **Co**unterfactuals

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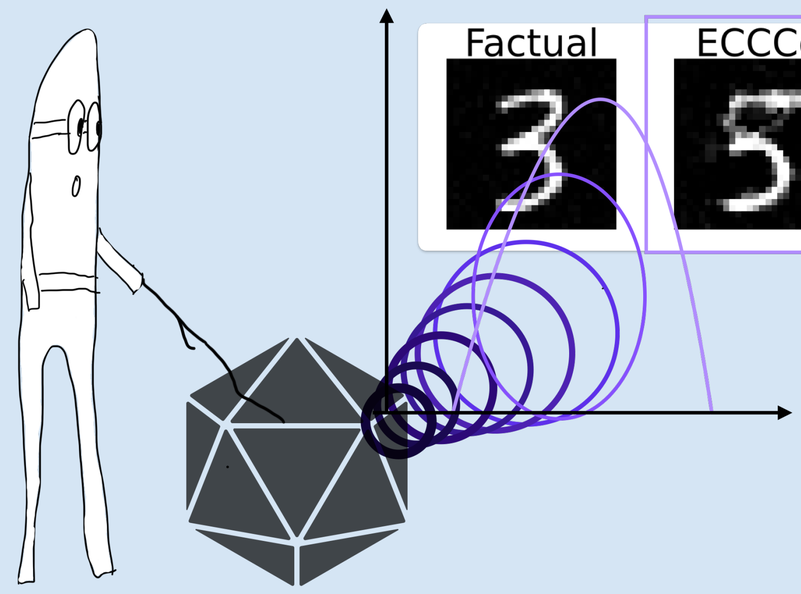

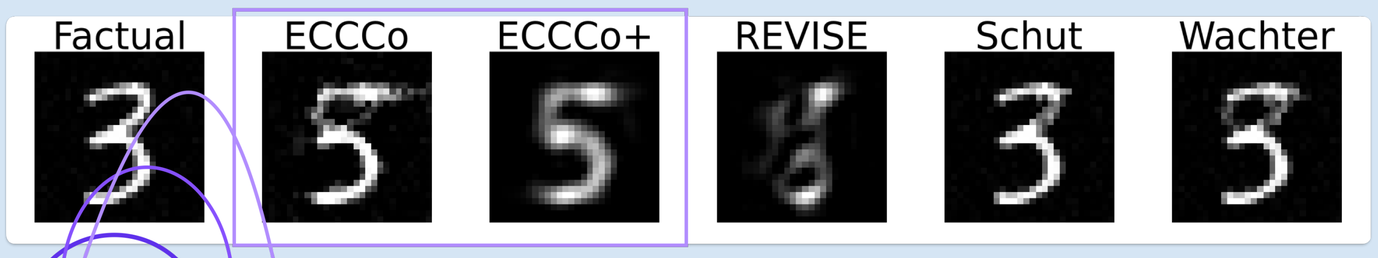


## ECCCos from the Black Box

## BACKGROUND

Counterfactual Explanations (CE) explain

how inputs into a model need to change for it to produce different outputs

$$\min_{\mathbf{Z}' \in \mathcal{Z}^L} \{ \text{yloss}(M_\theta(f(\mathbf{Z}')), \mathbf{y}^+) + \lambda \text{cost}(f(\mathbf{Z}')) \}$$

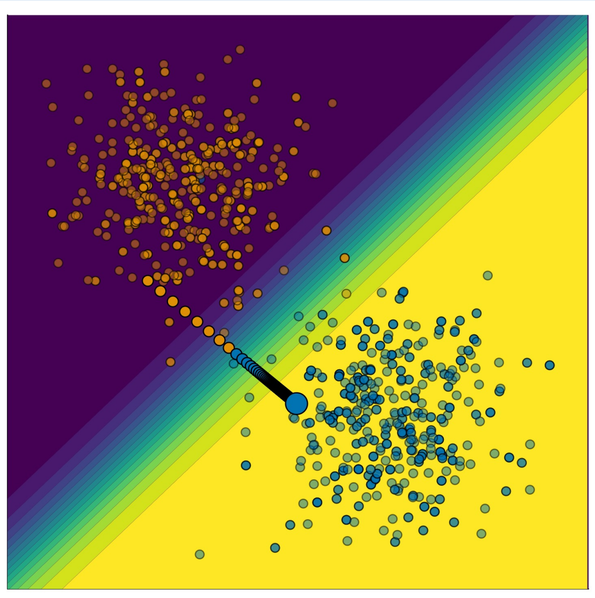

Figure 1: Gradient-based counterfactual search.

## MOTIVATION

We propose *ECCCo*: a new way to generate counterfactuals that are as plausible as the model permits. In Figure 2,

which counterfactual provides the *best* explanation for the classifier?

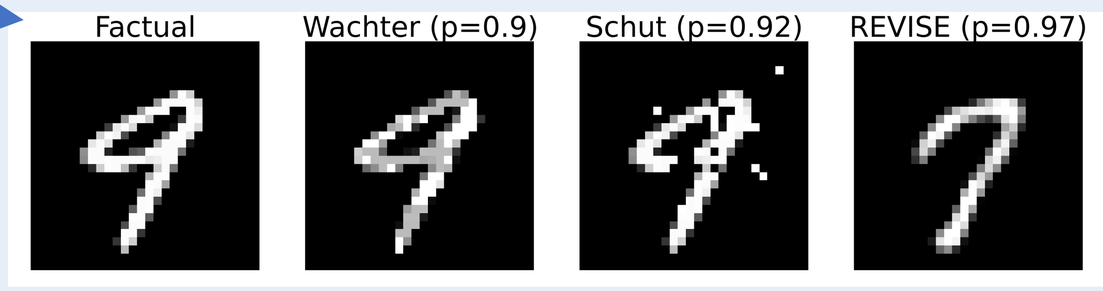


Figure 2: Factual images and counterfactuals for flipping the predicted label of an MLP trained on MNIST from 9 to 7.

## PLAUSIBILITY

We define plausible counterfactuals as:

consistent with the true data generating process

Plausibility is positively associated with actionability, robustness and causal validity.

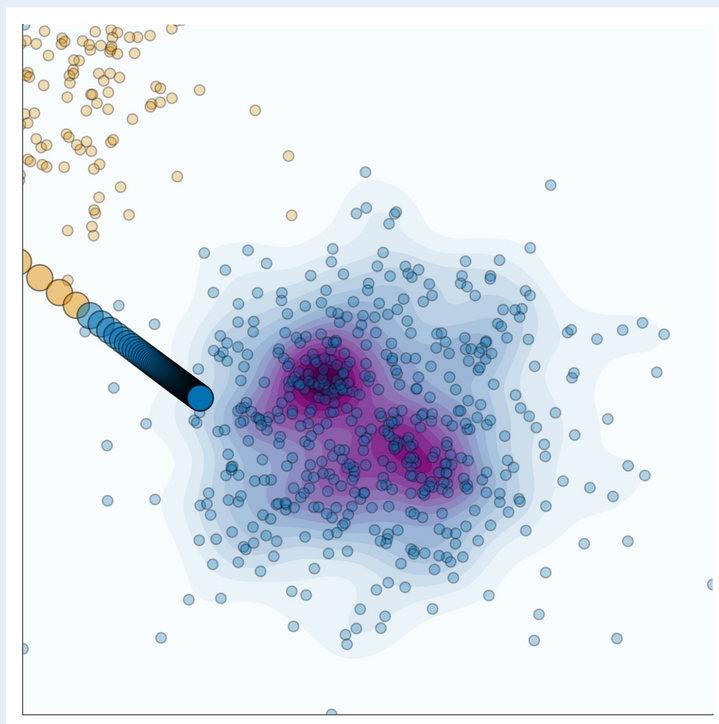

Figure 3: Kernel density estimate (KDE) for the conditional distribution based on observed data.

## FAITHFULNESS

We define faithful counterfactuals as:

consistent with what the model has learned about the data

If the model posterior approximates the true posterior, faithful counterfactuals are also plausible.

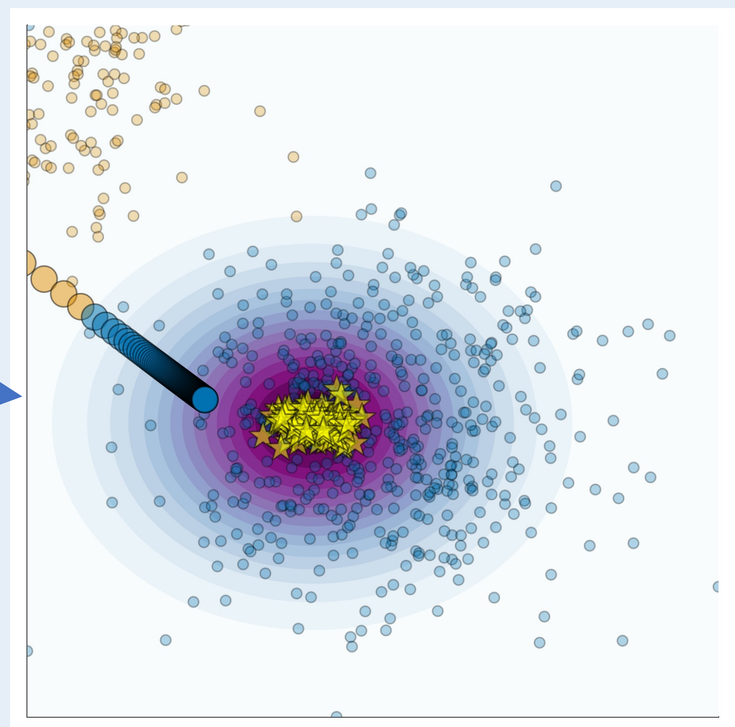

Figure 4: KDE for conditional distribution learned by model. Generated samples in bright yellow.

## METHOD

Use the hybrid objective of joint energy models (JEM) and a model-agnostic penalty for predictive uncertainty:

$$\min_{\mathbf{Z}' \in \mathcal{Z}^L} \{ L_{\text{clf}}(f(\mathbf{Z}'); M_\theta, \mathbf{y}^+) + \lambda_1 \text{cost}(f(\mathbf{Z}')) + \lambda_2 \mathcal{E}_\theta(f(\mathbf{Z}')|\mathbf{y}^+) + \lambda_3 \Omega(C_\theta(f(\mathbf{Z}'); \alpha)) \}$$

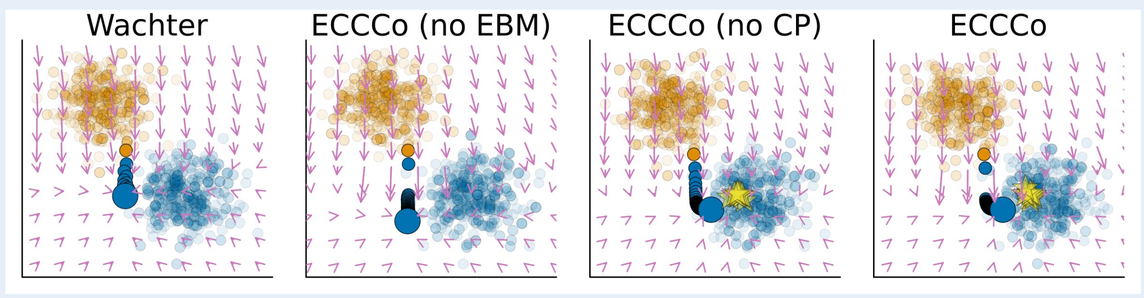


Figure 5: Gradient fields and counterfactual paths for different generators.

## RESULTS

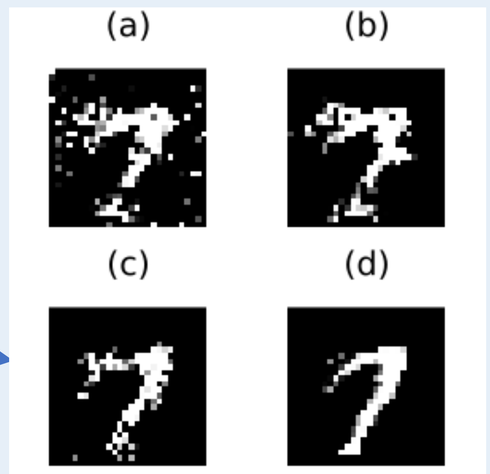


Figure 6: Turning a ‘nine’ into a ‘seven’. ECCCo applied to MLP (a), Ensemble (b), JEM (c), JEM Ensemble (d).

*ECCCo* generates counterfactuals that

faithfully represent model quality
&
achieve state-of-the-art plausibility

Helps us distinguish trustworthy from unreliable models.

| Model | Generator | California Housing | | | GMSC | | |
|---|---|---|---|---|---|---|---|
| | | Unfaithfulness ↓ | Implausibility ↓ | Uncertainty ↓ | Unfaithfulness ↓ | Implausibility ↓ | Uncertainty ↓ |
| MLP Ensemble | ECCCo | **3.69 ± 0.08**** | 1.94 ± 0.13 | **0.09 ± 0.01**** | 3.84 ± 0.07** | 2.13 ± 0.08 | **0.23 ± 0.01**** |
| | ECCCo+ | 3.88 ± 0.07** | 1.20 ± 0.09 | 0.15 ± 0.02 | **3.79 ± 0.05**** | 1.81 ± 0.05 | 0.30 ± 0.01* |
| | ECCCo (no CP) | 3.70 ± 0.08** | 1.94 ± 0.13 | 0.10 ± 0.01** | 3.85 ± 0.07** | 2.13 ± 0.08 | 0.23 ± 0.01** |
| | ECCCo (no EBM) | 4.03 ± 0.07 | 1.12 ± 0.12 | 0.14 ± 0.01** | 4.08 ± 0.06 | 0.97 ± 0.08 | 0.31 ± 0.01* |
| | REVISE | 3.96 ± 0.07* | **0.58 ± 0.03**** | 0.17 ± 0.03 | 4.09 ± 0.07 | **0.63 ± 0.02**** | 0.33 ± 0.06 |
| | Schut | 4.00 ± 0.06 | 1.15 ± 0.12 | 0.10 ± 0.01** | 4.04 ± 0.08 | 1.21 ± 0.08 | 0.30 ± 0.01* |
| | Wachter | 4.04 ± 0.07 | 1.13 ± 0.12 | 0.16 ± 0.01 | 4.10 ± 0.07 | 0.95 ± 0.08 | 0.32 ± 0.01 |
| JEM Ensemble | ECCCo | 1.40 ± 0.08** | 0.69 ± 0.05** | 0.11 ± 0.00** | 1.20 ± 0.06* | 0.78 ± 0.07** | 0.38 ± 0.01 |
| | ECCCo+ | **1.28 ± 0.08**** | 0.60 ± 0.04** | 0.11 ± 0.00** | **1.01 ± 0.07**** | 0.70 ± 0.07** | 0.37 ± 0.01 |
| | ECCCo (no CP) | 1.39 ± 0.08** | 0.69 ± 0.05** | 0.11 ± 0.00** | 1.21 ± 0.07* | 0.77 ± 0.07** | 0.39 ± 0.01 |
| | ECCCo (no EBM) | 1.70 ± 0.09 | 0.99 ± 0.08 | 0.14 ± 0.00* | 1.31 ± 0.07 | 0.97 ± 0.10 | 0.32 ± 0.01** |
| | REVISE | 1.39 ± 0.15** | **0.59 ± 0.04**** | 0.25 ± 0.07 | 1.01 ± 0.07** | **0.63 ± 0.04**** | 0.33 ± 0.07 |
| | Schut | 1.59 ± 0.10* | 1.10 ± 0.06 | **0.09 ± 0.00**** | 1.34 ± 0.07 | 1.21 ± 0.10 | **0.26 ± 0.01**** |
| | Wachter | 1.71 ± 0.09 | 0.99 ± 0.08 | 0.14 ± 0.00 | 1.31 ± 0.08 | 0.95 ± 0.10 | 0.33 ± 0.01 |

Table 1: Subsample of our empirical findings for tabular datasets.

## LEARN MORE

Supplementary Appendix

GitHub Repository

Julia Package

Personal Website