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SafePredict: A Machine Learning Meta-Algorithm That Uses Refusals to Guarantee Correctness

David Ramirez (dard@princeton.edu), Mustafa A. Kocak, Elza Erkip, and Dennis E. Shasha



Introduction

Machine learning and prediction algorithms are the building blocks of automation and forecasting.

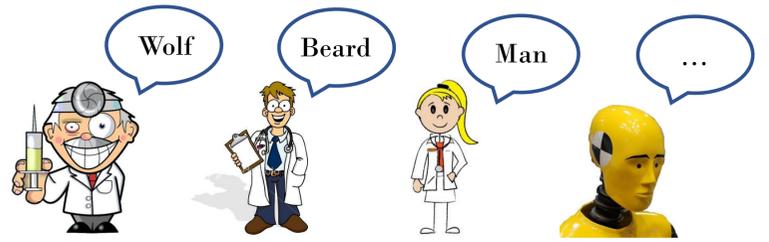
SafePredict, a meta-algorithm, takes predictions from underlying algorithms and decides whether or not to predict with them.



Algorithms benefit from a lower error rate.



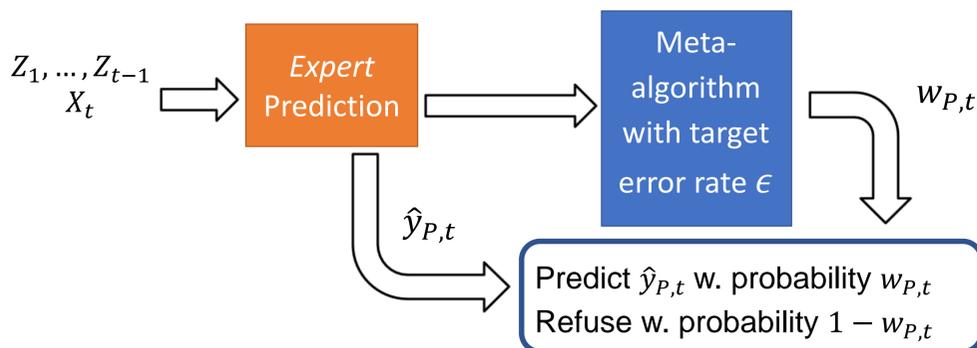
Observation



Crowd of experts (i.e., algorithms) are asked to predict. Dummy expert always *refuses* to predict.

Problem Setup

Online prediction setup with refusal option.



Prediction $\hat{y}_{P,t}$ or refusal \hat{y}_D suffer a loss $l_{P,t}$, $l_D \in [0,1]$. Mistakes are costly, but we learn by observing.

Definitions

t = time index, T = total observations, η = learning rate
 $T^* = \sum_{t=1}^T w_{P,t}$, expected predictions
 $L_T^* = \sum_{t=1}^T l_{P,t} w_{P,t}$, expected cumulative loss
 $V^* = \sum_{t=1}^T w_{P,t} w_{D,t}$, variance for number of predictions
 $w_{P,t+1} = \frac{w_{P,t} e^{-\eta l_{P,t}}}{w_{P,t} e^{-\eta l_{P,t}} + w_{D,t} e^{-\eta \epsilon}}$ weight shift rule

Algorithm Properties

Def. A meta-algorithm is *valid* if, as $T^* \rightarrow \infty$, average expected loss \leq target error rate.

Def. A meta-algorithm is *efficient* if, as $T^* \rightarrow \infty$, refusals occur only a finite number of times.

Main Results

Safe-Predict is valid and efficient!

Guaranteed with no assumptions on data or underlying experts, but asymptotic in the number of non-refused predictions.

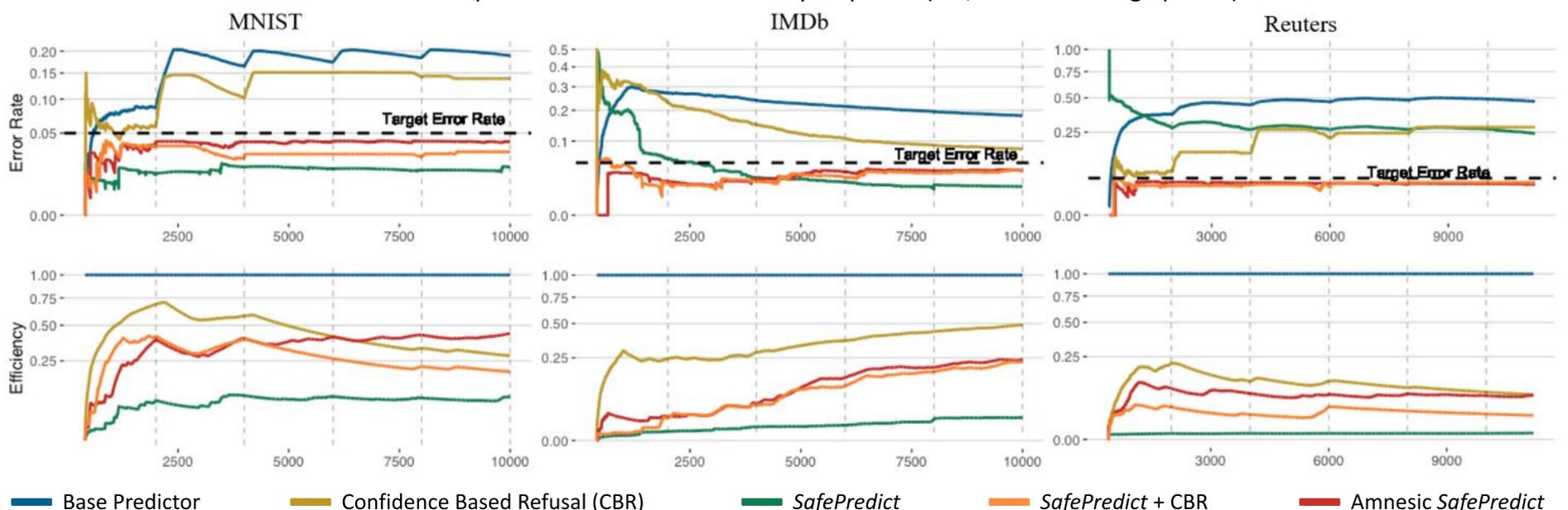
Theorem 1.- With learning rate $\eta = \Theta(\frac{1}{\sqrt{V^*}})$, *SafePredict* is guaranteed *valid* for any P . Particularly $\frac{L_T^*}{T^*} - \epsilon = O\left(\frac{\sqrt{V^*}}{T^*}\right) = O\left(\frac{1}{\sqrt{T^*}}\right)$.

Theorem 2.- If $\limsup_{t \rightarrow \infty} \frac{l_{P,t}}{t} < \epsilon$ and $\eta T \rightarrow \infty$, then *SafePredict* is *efficient*.

Experimental Results

Randomly permute data, choose first 10k points for experiment. Target error rate $\epsilon = 0.05$.

Random label permutation introduced every 2k points (i.e., artificial change points).



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