

Deep Imbalanced Regression

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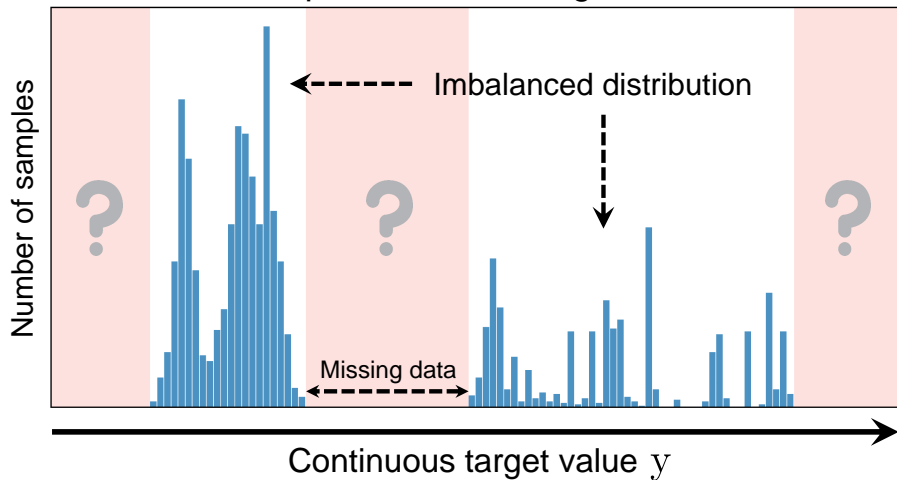
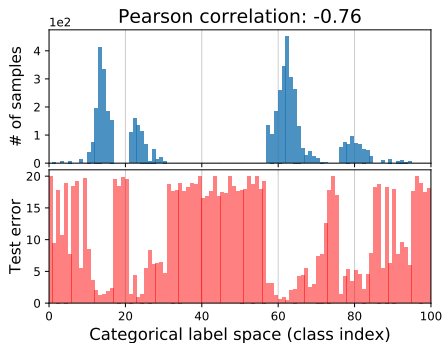
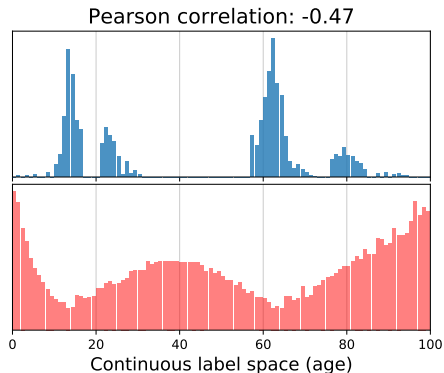


Image credit: [Yang et al. \(2021\)](#)

Test Error on Categorical vs. Continuous Label Space



(a) CIFAR-100 (subsamped)



(b) IMDB-WIKI (subsamped)

Image credit: [Yang et al. \(2021\)](#)

Problem Settings

- $\{(\mathbf{x}_i, y_i)\}_{i=1}^N$: training set
- $\mathbf{x}_i \in \mathbb{R}^d$: input
- $y_i \in \mathcal{Y}$: continuous label or target
- $b_i \in \mathcal{B}$: discrete label or target
- $\mathcal{Y} \subset \mathbb{R}$: continuous label space
- $\mathcal{B} = \{1, \dots, M\} \subset \mathbb{Z}^+$: index space
 - ▶ divides \mathcal{Y} into M groups (bins) with equal intervals $[t_j, t_{j+1})$
 - ▶ $\{[t_0, t_1), \dots, [t_{M-1}, t_M)\}$: discrete label space
 - ▶ $t_k \in \mathcal{Y}$
 - ▶ minimum resolution
 - ★ e.g., $\delta y \triangleq t_{j+1} - t_j = 1$ in age estimation
- $\hat{y}_i = g(\mathbf{z}_i) \in \mathbb{R}$: predicted continuous label
- $\mathbf{z}_i = f(\mathbf{x}_i; \theta) \in \mathbb{R}^{d'}$: learned representation
- θ : trainable model parameters

Label Distribution Smoothing

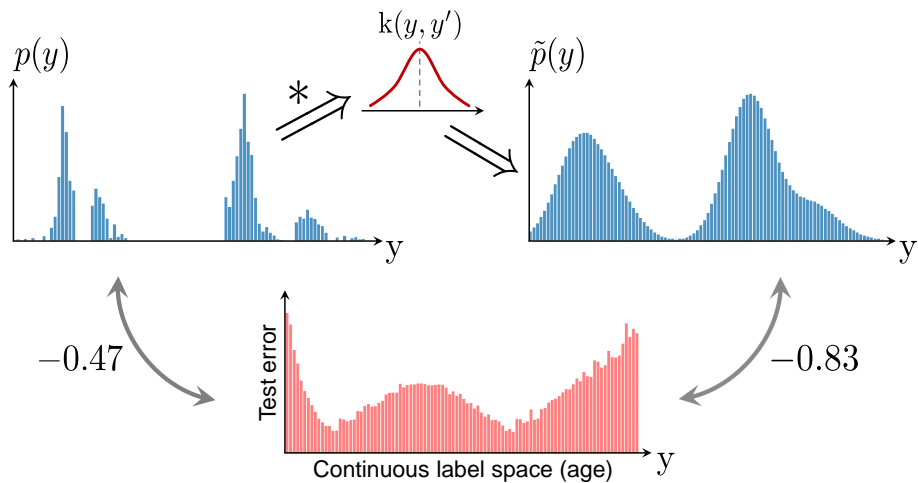


Image credit: [Yang et al. \(2021\)](#)

Feature Distribution Smoothing

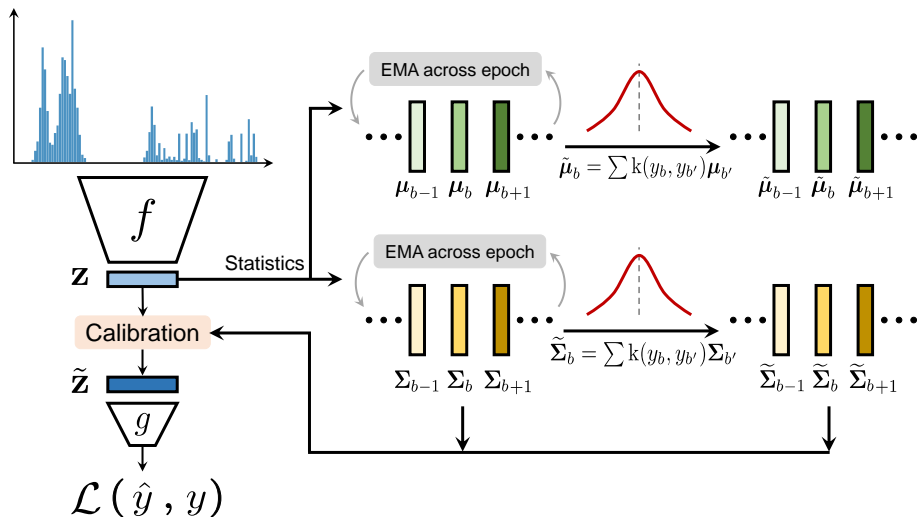


Image credit: [Yang et al. \(2021\)](#)

Baselines (1/2)

- Vanilla: neglects data imbalance
- Synthetic samples
 - ▶ SMOTER ([Torgo et al. 2013](#))
 - ① Defines frequent and rare regions using label density.
 - ② Creates synthetic samples for pre-defined rare regions by linearly interpolating both inputs and labels.
 - ▶ SMOGN ([Branco et al. 2017](#)): augments SMOTER with Gaussian noise
- Focal-R

$$\frac{1}{n} \sum_{i=1}^n \sigma(|\beta e_i|)^{\gamma} e_i$$

- ▶ Error-aware loss
- ▶ Maps the absolute error into $[0, 1]$.
- ▶ e_i : L_1 error for the i -th sample
- ▶ β, γ : hyper-parameters
- ▶ Inspired by Focal Loss ([Lin 2017](#)) for classification

Baselines (2/2)

- Regressor re-training (RRT)
 - ▶ Two-stage training
 - 1 Train encoder
 - 2 Re-train regressor with inverse re-weighting and frozen encoder.
 - ▶ Inspired by [Kang et al. 2019](#)
- Cost-sensitive re-weighting: re-weighting schemes based on label distribution
 - ▶ Inverse-frequency weighting (INV)
 - ▶ Square-root weighting variant (SQINV)

Evaluation

- Divide target space into disjoint regions (bins)

- ▶ *Many-shot*: > 100 training examples
- ▶ *Medium-shot*: 20-100 training examples
- ▶ *Few-shot*: < 20 training examples
- ▶ *Zero-shot*: 0 training examples
- Inspired by [Liu et al. 2019](#)

- Metrics

- ▶ Mean Absolute Error (MAE)
- ▶ Mean Squared Error (MSE)
- ▶ Pearson Correlation (PCC)
- ▶ Geometric Mean Error (GM)

$$GM = \sqrt[n]{\prod_{i=1}^n |y_i - \hat{y}_i|}$$

★ Pros: + fairness (uniformity) in prediction

Results (1/2)

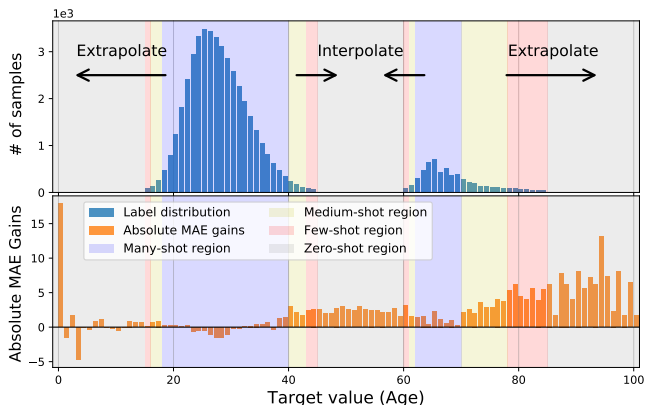


Figure: MAE gains of LDS + FDS over the vanilla model, on a curated subset of IMDB-WIKI-DIR.

- Performance gains esp. for extrapolation & interpolation

Image credit: [Yang et al. \(2021\)](#)

Results (2/2)

Metrics	MAE ↓				GM ↓			
Shot	All	w/ data	Interp.	Extrap.	All	w/ data	Interp.	Extrap.
VANILLA	11.72	9.32	16.13	18.19	7.44	5.33	14.41	16.74
VANILLA + LDS	10.54	8.31	14.14	17.38	6.50	4.67	12.13	15.36
VANILLA + FDS	11.40	8.97	15.83	18.01	7.18	5.12	14.02	16.48
VANILLA + LDS + FDS	10.27	8.11	13.71	17.02	6.33	4.55	11.71	15.13
Ours (best) vs. VANILLA	+1.45	+1.21	+2.42	+1.17	+1.11	+0.78	+2.70	+1.61

Table: Interpolation & extrapolation results on a curated subset of IMDB-WIKI-DIR.

- Best results by smoothing both label & feature distributions

Table credit: [Yang et al. \(2021\)](#)

References

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