

# Deep Imbalanced Regression

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# Overview

## Deep Imbalanced Regression

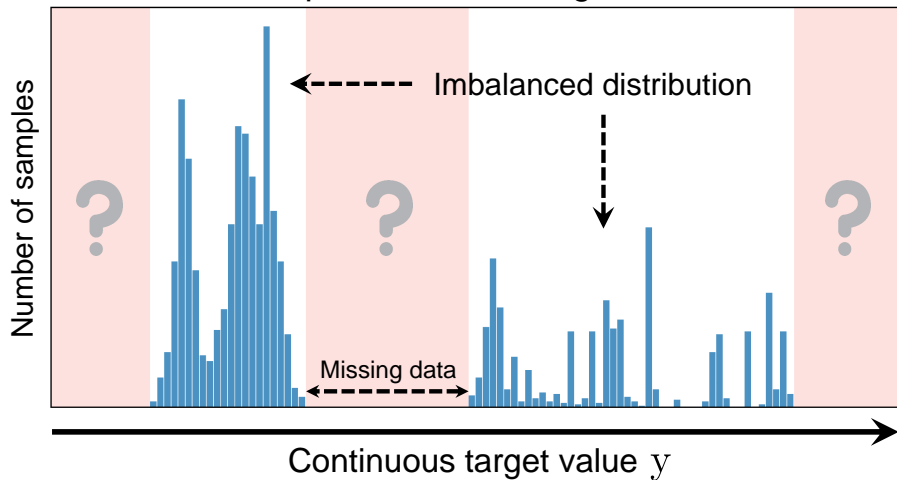


Image credit: [Yang et al. \(2021\)](#)

# Datasets - Overview

Dataset	Target type	Target range	Bin size	Max bin density	Min bin density	# Training set	# Val. set	# Test set
IMDB-WIKI-DIR	Age	0 - 186	1	7,149	1	191,509	11,022	11,022
AgeDB-DIR	Age	0 - 101	1	353	1	12,208	2,140	2,140
STS-B-DIR	Text similarity score	0 - 5	0.1	428	1	5,249	1,000	1,000
NYUD2-DIR	Depth	0.7 - 10	0.1	$1.46 \times 10^8$	$1.13 \times 10^6$	50,688 ( $3.51 \times 10^9$ )	—	654 ( $8.70 \times 10^5$ )
SHHS-DIR	Health condition score	0 - 100	1	275	0	1,892	369	369

# (Training) Datasets - Label Distributions

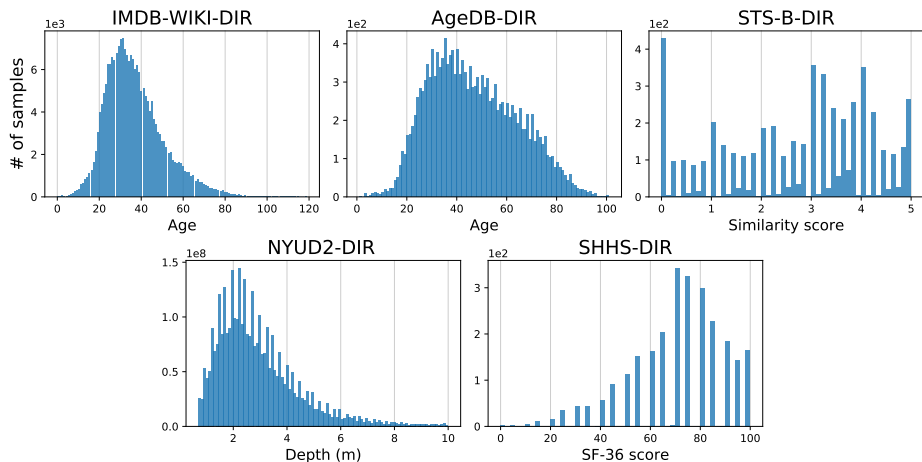
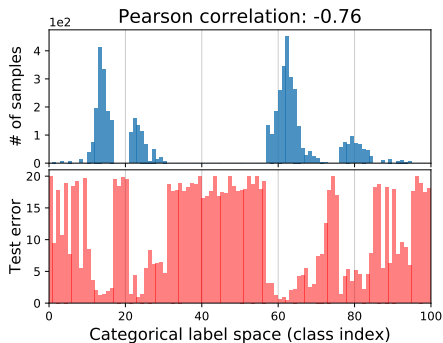
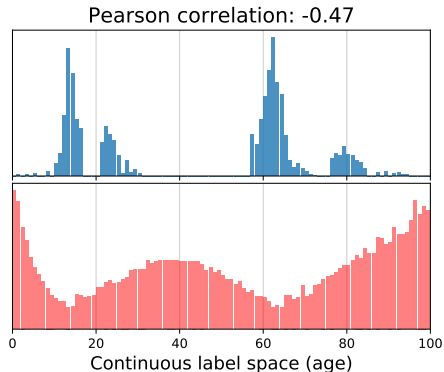


Image credit: [Yang et al. \(2021\)](#)

# 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
- $\theta$ : trainable model parameters

# Label Distribution Smoothing

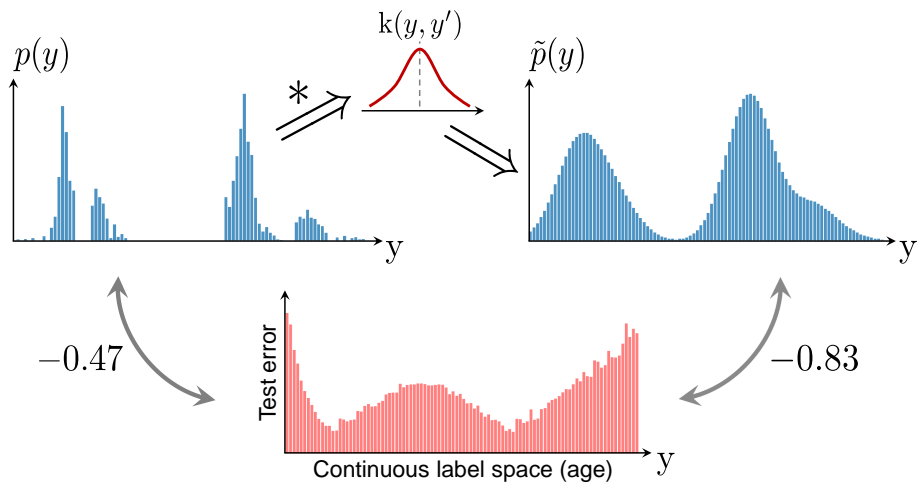


Image credit: [Yang et al. \(2021\)](#)

# Feature Distribution Smoothing

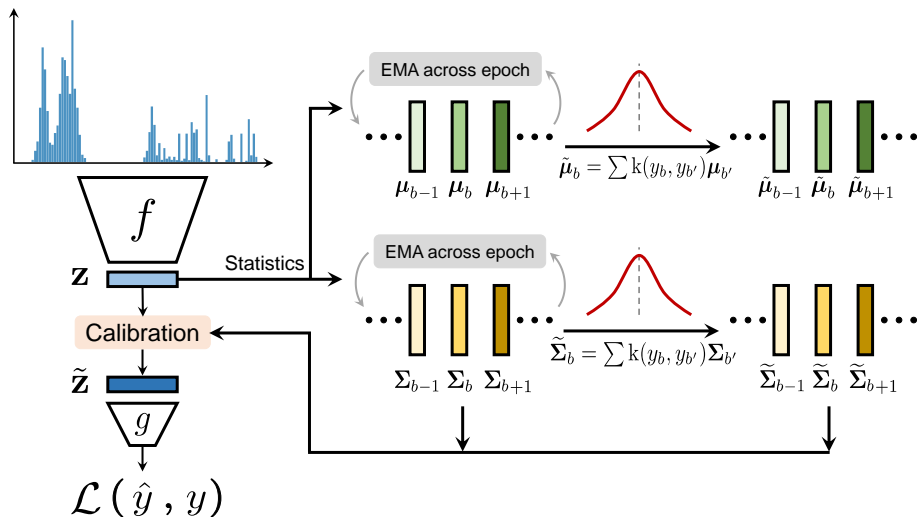


Image credit: [Yang et al. \(2021\)](#)



# 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
- ▶  $\beta, \gamma$ : 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](#)

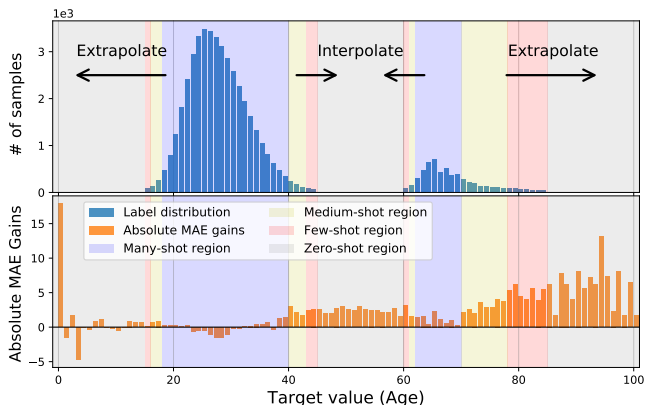
- Metrics

- ▶ 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 + <b>LDS</b>	10.54	8.31	14.14	17.38	6.50	4.67	12.13	15.36
VANILLA + <b>FDS</b>	11.40	8.97	15.83	18.01	7.18	5.12	14.02	16.48
VANILLA + <b>LDS + FDS</b>	<b>10.27</b>	<b>8.11</b>	<b>13.71</b>	<b>17.02</b>	<b>6.33</b>	<b>4.55</b>	<b>11.71</b>	<b>15.13</b>
<b>Ours (best) vs. VANILLA</b>	<b>+1.45</b>	<b>+1.21</b>	<b>+2.42</b>	<b>+1.17</b>	<b>+1.11</b>	<b>+0.78</b>	<b>+2.70</b>	<b>+1.61</b>

**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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