**Motivation**

The World is Long-Tailed

- Distribution of images per category in iNaturalist 2017:
  - Long-tailed distribution

**Data Overlap**

- The more data, the better. However, as the number of samples increases, the marginal benefit a model can extract from the data diminishes.

**Overview**

- Effective Number of Samples: $E_n = (1 - \beta^n)/(1 - \beta)$
  - $\beta \in [0, 1)$
  - $n$: number of samples.

- Class-Balanced Loss:
  - Class-Balanced Softmax Loss:
    - $\text{CB}_{\text{softmax}}(p, y) = \frac{1}{E_n} \log \left( \frac{\exp(p_y)}{\sum_{k=1}^{K} \exp(p_k)} \right)$
  - Class-Balanced Sigmoid Loss:
    - $\text{CB}_{\text{sigmoid}}(p, y) = \frac{1}{E_n} \log \left( \frac{1}{1 + \exp(-y)} \right)$
  - Class-Balanced Focal Loss:
    - $\text{CB}_{\text{focal}}(p, y) = \frac{1}{E_n} \left( 1 - \beta^n \right) \log(p_y)$

**Experiments**

- Classification Error Rate of ResNet-32 on CIFAR
  - Dataset Name | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 |
  - Long-Tailed CIFAR-100 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 | 100.00 | 234.00 |
  - iNaturalist 2017 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 |
  - IS-LVC 2012 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 | 5,099 | 435.44 |

- ResNet-50 Training Curves
  - Network | Loss | $\beta$ | $\gamma$ | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 | Top-1 | Top-5 |
  - ResNet-50 Softmax | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-101 Softmax | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-152 Softmax | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-50 CBF Softmax | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-101 CBF Softmax | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-152 CBF Softmax | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-50 CBF Focal | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-101 CBF Focal | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
  - ResNet-152 CBF Focal | 0.999 | 0.5 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

- Imbalance: the number of training samples in the largest class divided by the smallest class.