# FairAdaBN: Mitigating unfairness with adaptive batch normalization and its application to dermatological disease classification

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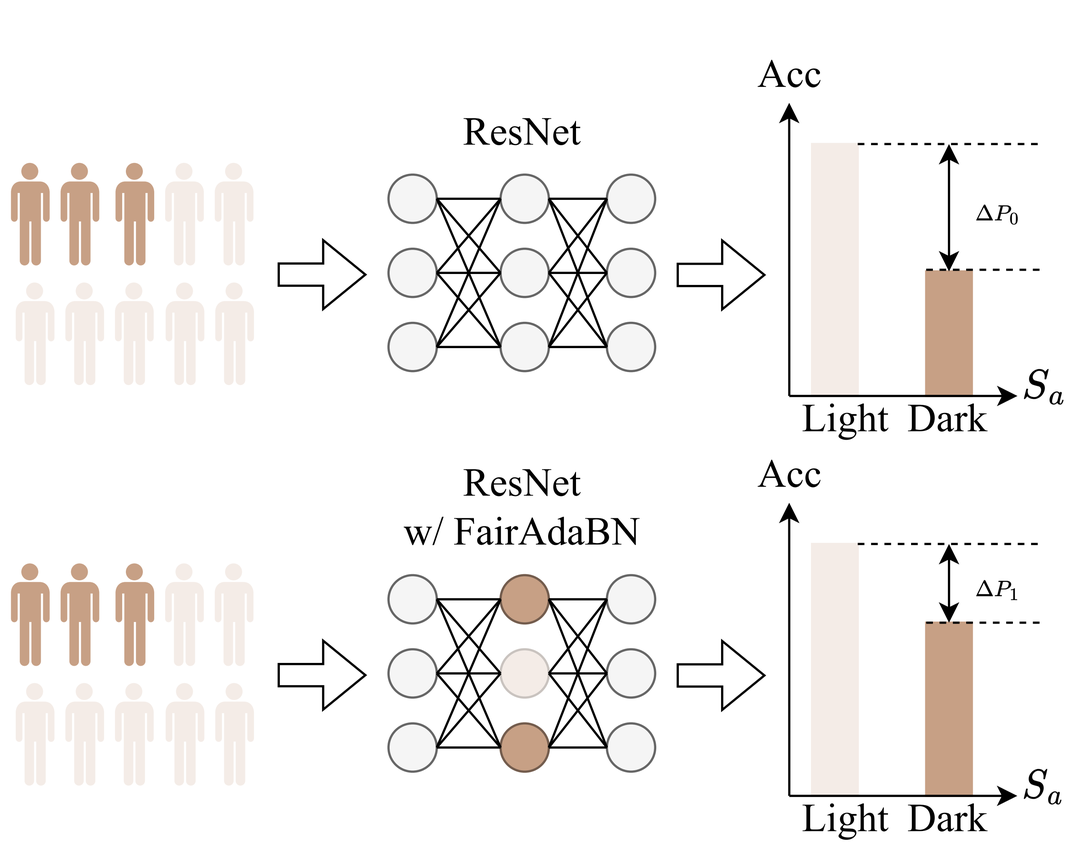
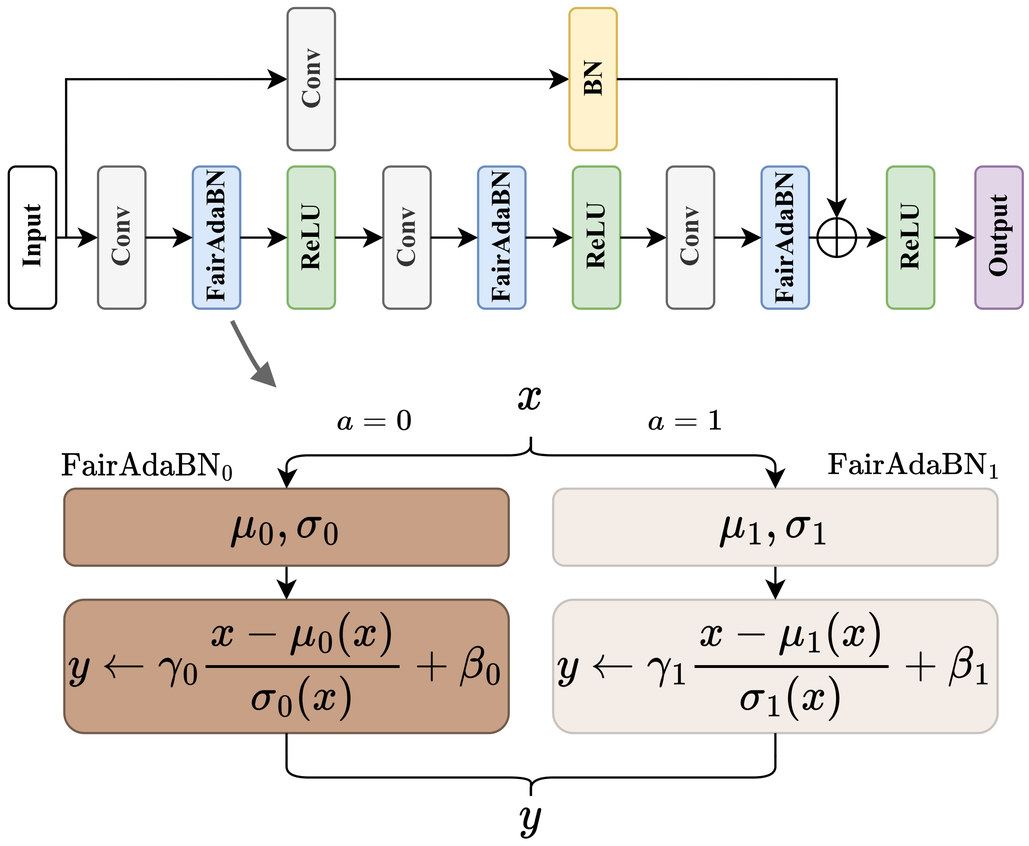



(a) Overview of Our Method




(b) Details of FairAdaBN

## Problem Definition

$$\hat{\theta} = \arg\min_{\theta} \left\| \mathbb{E}_{d_i \epsilon D_{A=1}} \mathbb{I}(Y_i, f_\theta(X_i)) - \mathbb{E}_{d_i \epsilon D_{A=0}} \mathbb{I}(Y_i, f_\theta(X_i)) \right\|$$

$$\text{EOpp0} = |P(\hat{Y} = 0 \mid Y = 0, A = 1) - P(\hat{Y} = 0 \mid Y = 0, A = 0)|$$
$$\text{EOpp1} = |P(\hat{Y} = 1 \mid Y = 1, A = 1) - P(\hat{Y} = 1 \mid Y = 1, A = 0)|$$
$$\text{EOdd} = |P(\hat{Y} = 1 \mid Y = y, A = 1) - P(\hat{Y} = 1 \mid Y = y, A = 0)|, y \in \{0, 1\}$$

## Contributions

## FairAdaBN Formulation

$$\text{FairAdaBN}_a(x) = \gamma_a \cdot \frac{x - \mu_a(x)}{\sigma_a(x)} + \beta_a$$

## Loss Function

$$L = L_{CE} + \alpha \cdot L_{SD}$$
$$= L_{CE} + \sum_{y=1}^{N_{cg}} \left\| \mathbb{E}_{X_i \sim D_{A=0}} \mathbb{I}(f_\theta(X_i) = y) - \mathbb{E}_{X_i \sim D_{A=1}} \mathbb{I}(f_\theta(X_i) = y) \right\|^2$$

## Fairness-Accuracy Trade-off Efficiency

$$\text{FATE}_{FC} = \frac{\text{ACC}_m - \text{ACC}_b}{\text{ACC}_b} - \lambda \frac{\text{FC}_m - \text{FC}_b}{\text{FC}_b}$$

## Result

Table 1: Result on Fitzpatrick-17k and ISIC 2019 Dataset (Mean$^{\text{Std}} \times 10^{-2}$). **Best** and Second-best are highlighted.

| Fitzpartrick-17k Dataset | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Method | Accuracy↑ | Precision↑ | Recall↑ | F1↑ | EOpp0↓ | EOpp1↓ | Eodd↓ | $E_0$ ↑ | $E_1$ ↑ | $E_2$ ↑ |
| Vanilla | $87.53^{0.14}$ | $\mathbf{79.60^{0.33}}$ | $\mathbf{80.22^{0.19}}$ | $\mathbf{78.41^{0.15}}$ | $1.00^{0.30}$ | $10.40^{1.43}$ | $10.54^{0.98}$ | / | / | / |
| Resampling [18]† | $87.73^{0.27}$ | $79.21^{0.40}$ | $80.01^{0.35}$ | $78.27^{0.42}$ | $1.11^{0.26}$ | $10.43^{1.91}$ | $10.78^{2.06}$ | −10.86 | −0.03 | −2.05 |
| Ind [18]† | $86.33^{0.12}$ | $76.11^{0.38}$ | $77.48^{0.18}$ | $75.20^{0.09}$ | $0.78^{0.33}$ | $10.13^{0.51}$ | $9.72^{0.94}$ | 20.63 | 1.23 | 6.41 |
| GroupDRO [19]† | $86.62^{0.19}$ | $77.21^{0.62}$ | $78.29^{0.52}$ | $76.56^{0.56}$ | $0.94^{0.34}$ | $8.04^{0.90}$ | $8.23^{1.25}$ | 5.07 | 21.66 | 20.91 |
| EnD [23]† | $86.80^{0.52}$ | $77.32^{0.60}$ | $78.58^{0.53}$ | $76.90^{0.66}$ | $1.22^{0.31}$ | $9.01^{1.60}$ | $9.20^{1.59}$ | −22.83 | 12.53 | 11.88 |
| CFair [29]† | $\mathbf{87.91^{0.35}}$ | $78.62^{0.49}$ | $79.73^{0.37}$ | $78.12^{0.38}$ | $0.93^{0.28}$ | $9.83^{1.65}$ | $10.17^{1.57}$ | 10.03 | 12.15 | 10.09 |
| FairAdaBN | $84.72^{0.40}$ | $74.43^{0.22}$ | $75.74^{0.33}$ | $73.31^{0.48}$ | $\mathbf{0.48^{0.09}}$ | $\mathbf{7.67^{3.86}}$ | $\mathbf{7.73^{3.95}}$ | **48.79** | **23.04** | **23.45** |
| **ISIC 2019 Dataset** | | | | | | | | | | |
| Method | Accuracy↑ | Precision↑ | Recall↑ | F1↑ | EOpp0↓ | EOpp1↓ | Eodd↓ | $E_0$ ↑ | $E_1$ ↑ | $E_2$ ↑ |
| Vanilla | $92.52^{0.12}$ | $82.64^{0.31}$ | $82.94^{0.36}$ | $82.60^{0.32}$ | $0.85^{0.12}$ | $6.12^{1.83}$ | $6.02^{1.66}$ | / | / | / |
| Resampling [18]† | $\mathbf{92.81^{0.28}}$ | $\mathbf{83.15^{0.50}}$ | $\mathbf{83.42^{0.51}}$ | $\mathbf{83.12^{0.52}}$ | $0.86^{0.15}$ | $5.65^{2.83}$ | $5.76^{2.78}$ | -0.80 | -2.48 | -5.49 |
| Ind [18]† | $92.43^{0.11}$ | $82.16^{0.15}$ | $82.46^{0.12}$ | $82.11^{0.08}$ | $0.85^{0.11}$ | $7.04^{0.96}$ | $7.37^{0.77}$ | −0.10 | −15.13 | −22.52 |
| GroupDRO [19]† | $91.86^{0.22}$ | $81.30^{0.52}$ | $81.44^{0.47}$ | $81.17^{0.50}$ | $0.82^{0.12}$ | $6.78^{3.20}$ | $6.62^{3.21}$ | 2.41 | −22.99 | −22.01 |
| EnD [23]† | $92.13^{0.08}$ | $81.42^{0.48}$ | $81.64^{0.35}$ | $81.36^{0.38}$ | $0.98^{0.09}$ | $5.18^{0.99}$ | $5.10^{1.06}$ | −15.72 | 14.94 | 14.86 |
| CFair [29]† | $87.39^{0.77}$ | $72.39^{2.67}$ | $72.60^{2.22}$ | $71.28^{2.12}$ | $2.83^{1.09}$ | $9.21^{3.53}$ | $10.80^{4.15}$ | −238.49 | −56.03 | −84.95 |
| FairAdaBN | $89.11^{0.09}$ | $74.24^{0.13}$ | $74.79^{0.18}$ | $74.18^{0.14}$ | $\mathbf{0.69^{0.07}}$ | $\mathbf{4.85^{2.50}}$ | $\mathbf{4.76^{2.73}}$ | **15.14** | **17.07** | **17.24** |

* $E_0, E_1, E_2$ denotes $\text{FATE}_{EOpp0}, \text{FATE}_{EOpp1}, \text{FATE}_{EOdd}$, respectively.
† Private implementation.

Table 2: Ablation Study (Mean$^{\text{Std}} \times 10^{-2}$). **Best** in each group are highlighted.

| Method | Accuracy↑ | Precision↑ | Recall↑ | F1↑ | EOpp0↓ | EOpp1↓ | Eodd↓ | $E_0$ ↑ | $E_1$ ↑ | $E_2$ ↑ |
|---|---|---|---|---|---|---|---|---|---|---|
| VGG | $\mathbf{88.11^{0.51}}$ | $\mathbf{79.18^{0.56}}$ | $\mathbf{80.07^{0.49}}$ | $\mathbf{78.55^{0.56}}$ | $1.42^{0.25}$ | $10.64^{2.15}$ | $11.78^{2.34}$ | / | / | / |
| VGG + FairAdaBN | $83.55^{0.24}$ | $69.73^{0.83}$ | $72.09^{0.41}$ | $70.15^{0.69}$ | $\mathbf{1.09^{0.04}}$ | $\mathbf{10.58^{1.80}}$ | $\mathbf{10.48^{1.97}}$ | 18.06 | -4.61 | 5.86 |
| DenseNet | $\mathbf{87.32^{0.06}}$ | $\mathbf{78.12^{0.52}}$ | $\mathbf{79.08^{0.38}}$ | $\mathbf{77.37^{0.24}}$ | $\mathbf{1.18^{0.37}}$ | $10.96^{1.34}$ | $11.47^{1.16}$ | / | / | / |
| DenseNet + FairAdaBN | $80.40^{0.23}$ | $65.32^{0.57}$ | $69.42^{0.40}$ | $65.25^{0.60}$ | $1.43^{0.79}$ | $\mathbf{7.70^{1.06}}$ | $\mathbf{8.30^{1.58}}$ | -29.11 | 21.82 | 19.71 |
| ResNet | $\mathbf{87.53^{0.14}}$ | $\mathbf{79.60^{0.33}}$ | $\mathbf{80.22^{0.19}}$ | $\mathbf{78.41^{0.15}}$ | $1.00^{0.30}$ | $10.40^{1.43}$ | $10.54^{0.98}$ | / | / | / |
| Ours w/o $L_{SD}$ | $87.18^{0.50}$ | $78.50^{0.75}$ | $79.24^{0.68}$ | $77.40^{0.71}$ | $1.07^{0.16}$ | $9.33^{0.23}$ | $9.91^{0.29}$ | -7.87 | 9.88 | 5.55 |
| Ours w/o FairAdaBN | $85.02^{0.03}$ | $73.76^{0.11}$ | $75.67^{0.05}$ | $73.63^{0.16}$ | $1.39^{0.45}$ | $15.30^{1.91}$ | $15.05^{1.37}$ | 42.15 | -49.94 | -45.62 |
| Ours ($\alpha = 0.1$) | $84.82^{0.79}$ | $73.44^{1.11}$ | $75.15^{0.98}$ | $73.17^{0.95}$ | $1.26^{0.18}$ | $13.39^{2.98}$ | $12.76^{3.28}$ | -29.10 | -31.85 | -24.16 |
| Ours ($\alpha = 1.0$) | $84.72^{0.40}$ | $74.43^{0.22}$ | $75.74^{0.33}$ | $73.31^{0.48}$ | $\mathbf{0.48^{0.09}}$ | $\mathbf{7.67^{3.86}}$ | $\mathbf{7.73^{3.95}}$ | **48.79** | **23.04** | **23.45** |
| Ours ($\alpha = 2.0$) | $84.57^{0.38}$ | $74.26^{0.22}$ | $75.40^{0.11}$ | $72.91^{0.87}$ | $1.10^{0.60}$ | $8.53^{2.79}$ | $8.40^{2.75}$ | -13.38 | 14.60 | 16.92 |

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