Learning fair representation with a parametric integral probability metric

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Learning fair representation (LFR)

- Learning a function $h(X, S) : \mathcal{X} \times \{0, 1\} \rightarrow \mathcal{Z} \subset \mathbb{R}^m$ that maps data including the sensitive information to feature vectors so that the distributions for each sensitive group are similar.
- Adversarial training scheme is a popular approach for LFR.
- But, most methods suffered from
  - lacking their theoretical properties.
  - unstability, so they are not appealing to practitioners.
- Need to develop a new method that
  - has concrete theoretical guarantees.
  - gives stable results for various initializations.

Sigmoid IPM (sIPM)

- We consider a IPM measure with the sigmoid function to learn fair representations:

$$d_{\mathcal{V}_{sig}}(\mathbb{P}, \mathbb{Q}) = \sup_{v \in \mathcal{V}} \left| \int v(\mathbf{z})(d\mathbb{P}(\mathbf{z}) - d\mathbb{Q}(\mathbf{z})) \right|,$$

where $\mathbb{P}, \mathbb{Q}$ are two probability measures and

$$\mathcal{V}_{sig} = \{\sigma(\theta^\top \mathbf{x} + \mu) : \theta \in \mathbb{R}^m, \mu \in \mathbb{R}\}.$$

  - $\sigma(\cdot)$: sigmoid function.

sIPM for LFR (sIPM-LFR)

- We use the sIPM as the regularization term.

1. Supervised learning

$$L(f \circ h) + \lambda d(\mathbb{P}_0^h, \mathbb{P}_1^h)$$

   - $\mathbb{P}_s^h$: distribution of $h(X, S)|S = s$
   - $f : \mathcal{Z} \to \mathbb{R}$: prediction function
   - L: classification loss function

2. Unsupervised learning

$$L_{recon}(f_D \circ h) + \lambda d(\mathbb{P}_0^h, \mathbb{P}_1^h)$$

   - $f_D : \mathcal{Z} \to \mathcal{X} \times \{0, 1\}$: decoder
   - L_{recon}: reconstruction loss function

Theoretical properties

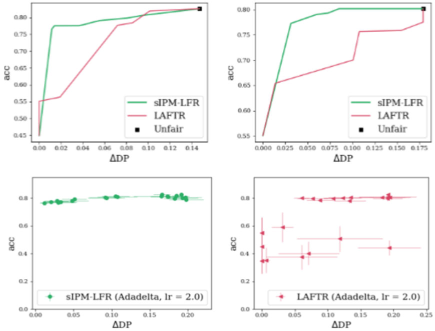
- We characterize the relationship between the level of the sIPM and the fairness of the final prediction model: $f \circ h$:

$$\sup_{f \in \mathcal{F}} DP_{\phi}(f \circ h) \leq \rho \left\{ d_{\mathcal{V}}(\mathbb{P}_0^h, \mathbb{P}_1^h) \right\},$$

  where DP_{ϕ} is the demographic parity and ρ is a non-decreasing function.
- Thus, we can achieve a fair prediction model by forcing representations to be fair with the sIPM.

Performance evaluation (Adult data set)

- Our method provides
  - better trade-offs between accuracy and fairness.
  - much more stable results.



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