Group Fairness with Uncertain Sensitive Attributes


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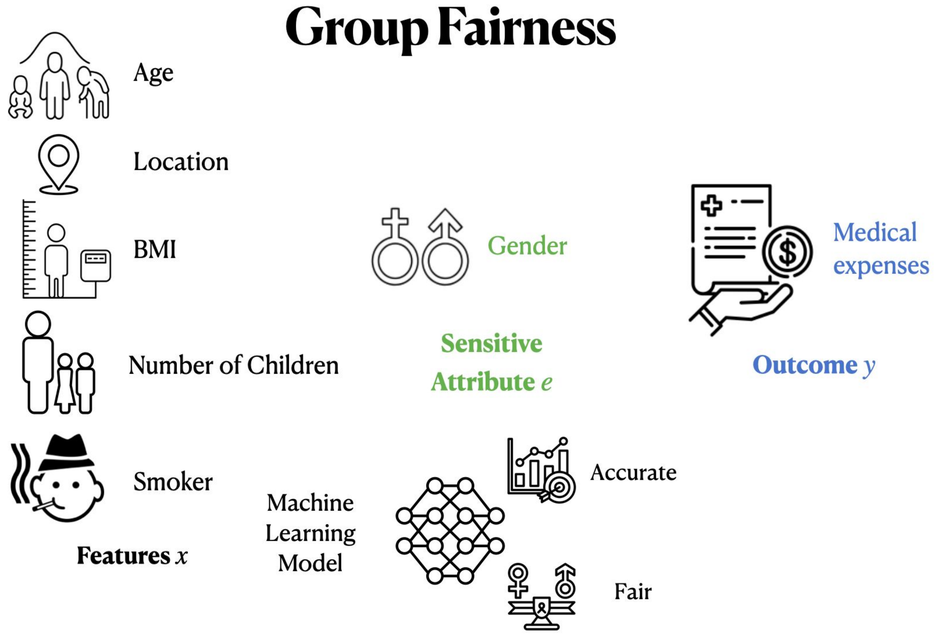
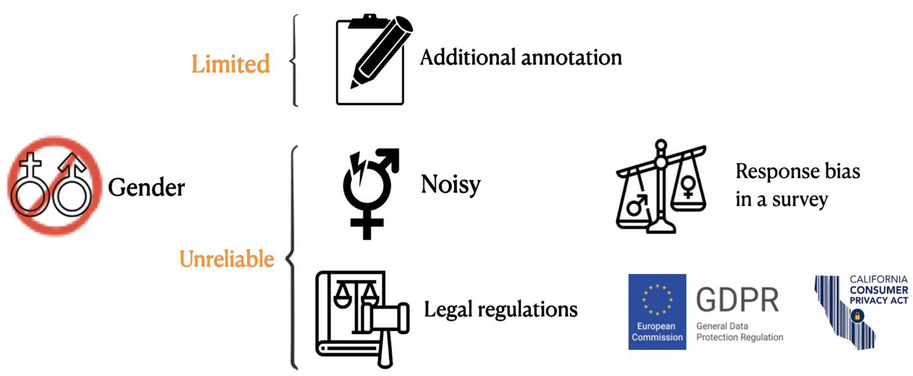
arXiv Link

Group Fairness



Uncertainty in Sensitive Attribute



Age	Location	BMI	Number of children	Smoker	Medical expenses	Gender	Limited Gender	Unreliable Gender
19	Southwest	27.9	0	Yes	16884	Female	?	Male
28	Southeast	33	3	No	4449	Male	Male	Male
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
62	Southeast	26.29	0	Yes	27808	Female	?	Female

Goal — Learn a fair model despite uncertain sensitive attribute data

Limitations of Existing Work

A. Proxy variables — effectiveness depends on the degree of correlation between the sensitive attribute and the proxy variables

B. Perturbed sensitive attribute — focus on specific perturbation models

Problem Formulation

Design a randomized mapping $p_{u|x}$ such that the representation u is maximally informative about y while limiting how informative it is about e

$$\min_{p_{u|x}} \min_{\hat{y}(u)} MSE\big(y, \hat{y}(u)\big) \quad \text{s.t} \quad \text{Dependence}(e; u) \le \epsilon$$

Gaussian Data

Model the distribution of (x, y, e, u) as Gaussian

$$\max_{a \in \mathcal{B}(0,1)} \langle a, b_{yx} \rangle^2 \quad \text{s.t} \quad \langle a, b_{ex} \rangle^2 \le \epsilon \quad \text{where} \quad a = b_{ux} \text{ and } b_{vw} \triangleq \Sigma_v^{-1/2} \Sigma_{vw} \Sigma_w^{-1/2}$$

Quadratically Constrained Quadratic Program (QCQP)

An optimal solution $a^\star$ of the above QCQP lies in the subspace spanned by the vectors b_{yx} and b_{ex}

Baseline

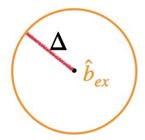
$$\max_{a \in \mathcal{B}(0,1)} \langle a, b_{yx} \rangle^2 \quad \text{s.t} \quad \langle a, \hat{b}_{ex} \rangle^2 \le \epsilon$$

This does not guarantee fairness

Robust QCQP

Uncertainty in sensitive attributes

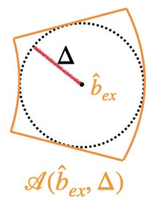
$$\max_{a \in \mathcal{B}(0,1)} \langle a, b_{yx} \rangle^2 \quad \text{s.t} \quad \langle a, b \rangle^2 \le \epsilon \quad \text{for all} \quad b \in \mathcal{B}(\hat{b}_{ex}, \Delta)$$

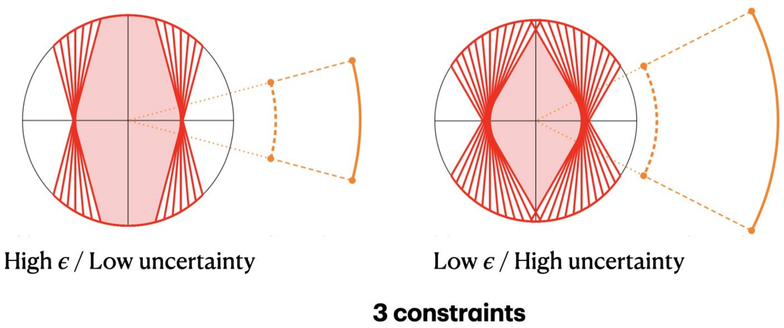


An optimal solution $a^\star$ of the above QCQP lies in the subspace spanned by the vectors b_{yx} and $\hat{b}_{ex}$

Relaxing the uncertainty

$$\max_{a \in \mathcal{B}(0,1)} \langle a, b_{yx} \rangle^2 \quad \text{s.t} \quad \langle a, b \rangle^2 \le \epsilon \quad \text{for all} \quad b \in \mathcal{A}(\hat{b}_{ex}, \Delta)$$



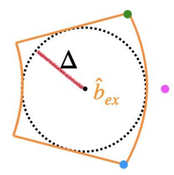


High ϵ / Low uncertainty

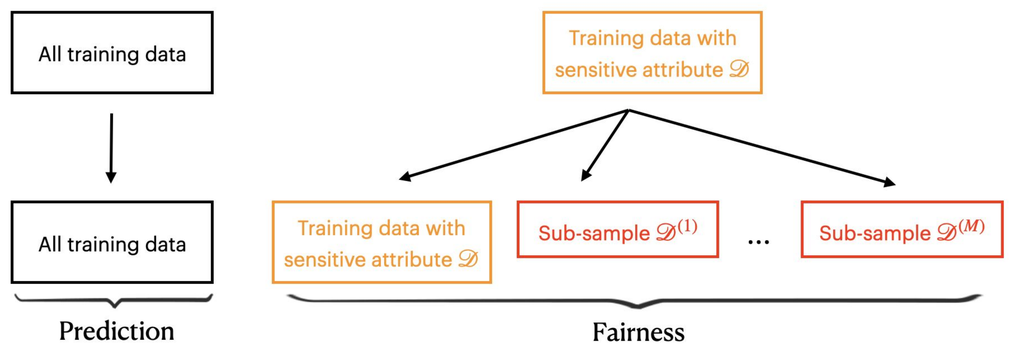
Low ϵ / High uncertainty

3 constraints

$$\max_{a \in \mathcal{B}(0,1)} \langle a, b_{yx} \rangle^2 \quad \text{s.t} \quad \langle a, b^{(i)} \rangle^2 \le \epsilon \quad \text{for all} \quad i \in [3]$$



Algorithm



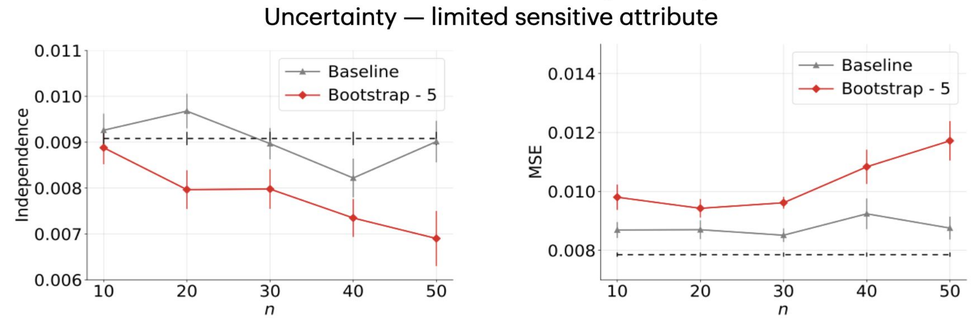
For some $k \in [n]$ and $M \ge 1$, uniformly draw $\mathcal{D}^{(1)}, \cdots, \mathcal{D}^{(M)}$ each of size k from $\mathcal{D}$ with replacement

Baseline :— $\min$ Prediction Loss $+ \lambda$ Fairness Loss$(\mathcal{D})$

Bootstrap-M :— $\min$ Prediction Loss $+ \lambda$ Fairness Loss$(\mathcal{D}) + \dfrac{\lambda}{M} \sum_{i \in [M]}$ Fairness Loss$(\mathcal{D}^{(i)})$

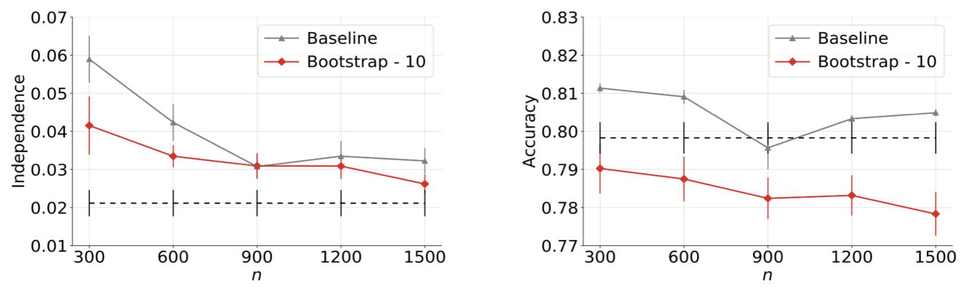
Insurance Dataset

Task — predict an individual's medical expenses (Regression)
Sensitive attribute — Gender (Discrete)
Uncertainty — limited sensitive attribute



Adult Dataset

Task — predict whether an individual's income > $50k (Classification)
Sensitive attribute — Gender (Discrete)
Uncertainty — limited sensitive attribute



Crime Dataset

Task— predict density of violent crimes (Regression)
Sensitive attribute — Race (Continuous)
Uncertainty — unreliable sensitive attribute