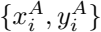


Problem Statement

PARADES

$$w(x) \coloneqq \frac{P_X^B(x)}{P_X^A(x)}.$$







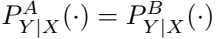
ADDITIONAL INFORMATION

$$L(h, P_{X,Y}^B) = \sum_{i=1}^{N^A} w(x_i^A) L(y_i^A, h(x_i^A)), \quad (1)$$









Past work past work

Ratio Matching Methods

Generalization



BRADLEY



$$E_{X \sim P_X^A(\cdot)}[d_f(w(X), \hat{w}(X))] = E_{X \sim P_X^A(\cdot)}[f(w(X)) - f(\hat{w}(X)) - \nabla f(\hat{w}(X))(w(X) - \hat{w}(X))] \quad (2)$$

$$= -E_{X \sim P_X^A(\cdot)}[f(\hat{w}(X))] - E_{X \sim P_X^A(\cdot)}[\nabla f(\hat{w}(X))w(X)] + E_{X \sim P_X^A(\cdot)}[\nabla f(\hat{w}(X))\hat{w}(X)] \quad (3)$$

$$= -E_{X \sim P_X^A(\cdot)}[f(\hat{w}(X))] - E_{X \sim P_X^B(\cdot)}[\nabla f(\hat{w}(X))] + E_{X \sim P_X^A(\cdot)}[\nabla f(\hat{w}(X))\hat{w}(X)] \quad (4)$$



$$\hat{E}_{X \sim P_X^A(\cdot)}[d_f(w(X), \hat{w}(X))] = -\frac{1}{N^A} \sum_i f(\hat{w}(x_i^A)) - \frac{1}{N^B} \sum_i \nabla f(\hat{w}(x_i^B)) + \frac{1}{N^B} \sum_i \nabla f(\hat{w}(x_i^A)) \hat{w}(x_i^A) \quad (5)$$

PALEO





Education with K12 as our main provider



100%

Wish you were here

$$\hat{E}_{X \sim P_X^A(\cdot)}[d_f(w(X), \hat{w}(X))] = \frac{1}{N^A} \sum_i \hat{w}(x_i^A) - \frac{1}{N^B} \sum_i \log \hat{w}(x_i^B) \quad (6)$$

$$E_X \sim P_X^A(x) [v(x)] = \int_x P_X^A(x) \frac{P_X^B(x)}{P_X^A(x)} dx = \int_x P_X^B(x) dx = 1$$



1
N B
Z
w x
= 1

$$\min_{\{\hat{w}(x_i^B)\}_{i=1}^{N^B}} -\frac{1}{N^B} \sum_i \log \hat{w}(x_i^B) \quad \text{subject to} \quad (7)$$

$$\frac{1}{N^B} \sum_i \hat{w}(x_i^B) = 1 \quad (8)$$

$$\hat{w}(x_i^B) > 0 \quad (9)$$













A pixelated, black and white graphic of the word "Polaris". The letters are rendered in a stylized, outlined font with a dithered or pixelated texture. The "P" and "L" have long vertical strokes, while the "A" is composed of several small, dark pixels. The "R" is also pixelated and has a small tail. The "I" is a simple vertical bar. The "S" is a simple, slightly curved shape. The overall effect is that of a low-resolution digital image or a retro-style logo.

$$\hat{w}(\cdot) = \sum_k \alpha_k \phi_k(\cdot). \quad (10)$$

$$\min_{\{\alpha_k\}} -\frac{1}{N^B} \sum_i \log \sum_k \alpha_k \phi_k(x_i^B) \quad \text{subject to} \quad (11)$$

$$\frac{1}{N^B} \sum_i \sum_k \alpha_k \phi_k(x_i^B) = 1 \quad (12)$$

$$\alpha_k \geq 0 \quad (13)$$

Formulation with squared losses

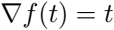




f *e* *a*

=

1 *2* *2*



$$\hat{E}_{X \sim P_X^A(\cdot)}[d_f(u(X), \hat{w}(X))] = \frac{1}{2N^A} \sum_i \hat{w}(x_i^A)^2 - \frac{1}{N^B} \sum_i \hat{w}(x_i^B) \quad (14)$$

$\phi(x) = \phi_1(x) \phi_2(x) \phi_3(x) \phi_4(x)$

Q19990121

$$\min_{\alpha} \frac{1}{2} \alpha' \left(\frac{1}{N^A} \sum_i \phi(x_i^A) \phi(x_i^A)' \right) \alpha - \left(\frac{1}{N^B} \sum_i \phi(x_i^B) \right)' \alpha \quad \text{subject to} \quad (15)$$

$$\alpha \geq 0 \quad (16)$$















cross-validation cross-validation



PALEO





PALEO



Education with dimensions in action







Q

E

R

D

X

W



Principles of

Principles of

+

Principles of



PALEO

$$P_A(x) - P_A(\text{Proj}(x)) - P_A(\text{Proj}(x) - \text{Proj}(x))$$

RECEIVED

$$P_{V|X}^A(\cdot) = P_{V|X}^B(\cdot), \quad \text{then} \quad (17)$$

$$w(x) = \frac{P_U^A(\text{Proj}_U(x)) P_{V|X}^A(\text{Proj}_V(x))}{P_U^B(\text{Proj}_U(x)) P_{V|X}^B(\text{Proj}_V(x))} = \frac{P_U^A(\text{Proj}_U(x))}{P_U^B(\text{Proj}_U(x))} \quad (18)$$











PAUSE

PELO

$$PD(P_U^A(\cdot), P_U^B(\cdot)) = E_{U \sim P_U^A(\cdot)} \left[\left(\frac{P_U^B(U)}{P_U^A(U)} - 1 \right)^2 \right] \quad (19)$$

Kernel Mean Matching

Education







PRAXIS
PRAXIS

$$w(\cdot) : x \rightarrow \frac{p_B(x)}{p_A(x)} : \cdot$$

$$\min_{w(\cdot)} \left| E_{X \sim P_X^B(\cdot)} [\phi(X)] - E_{X \sim P_X^A(\cdot)} [w(X)\phi(X)] \right| \quad \text{subject to} \quad (20)$$

$$w(x) \geq 0 \quad (21)$$

$$E_{X \sim P_X^A(\cdot)} [w(x)] = 1 \quad (22)$$

W A P A E

WORLD OF



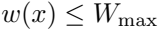
$$\min_{B(\cdot)} \left| \frac{1}{N^B} \sum_i \phi(x_i^B) - \frac{1}{N^A} \sum_i w(x_i^A) \phi(x_i^A) \right| \quad \text{subject to} \quad (23)$$

$$w(x_i^A) \in [0, W_{\max}] \quad (24)$$

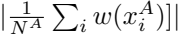
$$\left| \frac{1}{N^A} \sum_i w(x_i^A) \right| \leq 1 - \epsilon \quad (25)$$



WAVE











Dwight Davis



PALEO

BEAR

Q. I. W. I. A. E.

Classifier-based methods

Standalone Approaches













PALE



$$w(x) = \frac{P_X^B(x)}{P_X^A(x)} = \frac{P_{X|Z}(x|z=1)}{P_{X|Z}(x|z=0)} = \frac{\frac{P_{Z|X}(z=1|x)P_X(x)}{P_Z(z=1)}}{\frac{P_{Z|X}(z=0|x)P_X(x)}{P_Z(z=0)}} = \frac{P_{Z|X}(z=1|x)}{P_{Z|X}(z=0|x)} \frac{P_Z(z=0)}{P_Z(z=1)} \quad (26)$$



$$P_z = 1 = \frac{NB}{NA + NB}$$





PELO





Joint Approaches



1992

$$v^*(\cdot) = \arg \min_{v(\cdot)} \{ J(v(\cdot)) ; \{ x_i^A \}, \{ x_i^B \} \}$$







$f^*(x) = \arg\min_{z \in A} f(z)$







$$\operatorname{argmin}_{w(\cdot), f(\cdot)} L_w(w(\cdot); \{x_i^A\}, \{x_i^B\}) + \sum_i w(x_i^A) L_f(f(x_i^A), y_i^a) \quad (27)$$











Supervised Dimension Reduction for Ratio Estimation









Standalone or Joint Approach?





PROVE IT

WAVE

PROVE IT



PROVE IT

PAVE



Arabic (A) and (A) (A)



$$w(x) = \frac{P_V^B(\text{proj}_V(x))}{P_V^A(\text{proj}_V(x))}$$







