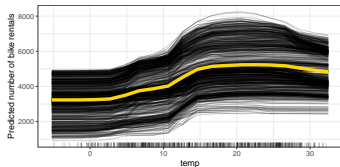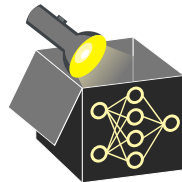# Interpretable Machine Learning

Feature Effects
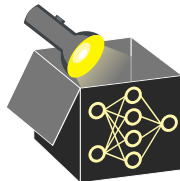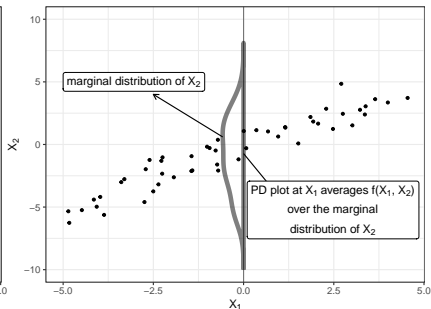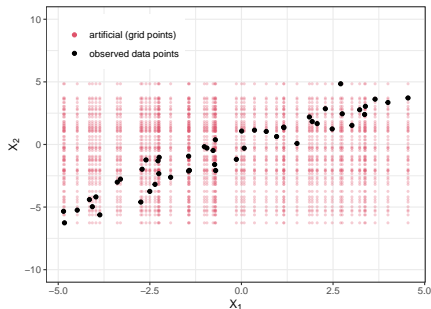## PDP - Comments and Extensions

Learning goals

- Extrapolation and Interactions in PDPs
- Centered ICE and PDP

COMMENTS ON EXTRAPOLATION

Extrapolation occurs in regions with few obs. or if features are correlated

- **Example:** Features x_1 and x_2 are strongly correlated
- **Black points:** Observed points of the original data
- **Red:** Grid points to calculate ICE/PD (many unrealistic x_1, x_2 combinations)
  - $\Rightarrow$ **PD at $x_1 = 0$:** Averages predictions over *full* marginal distribution of x_2
  - $\Rightarrow$ **Issue:** Model may behave strangely outside training distribution
  - $\Rightarrow$ Especially problematic for overfitted or interaction-heavy models

# COMMENTS ON INTERACTIONS

PD plots average ICE curves

⤳ May **obscure heterogeneous effects** (interactions)

- **Example:** Feature x_1 = treatment dosage; x_2 = gender
  - ⇒ Males ($\nearrow$) and females ($\searrow$) respond differently to dosage
  - ⇒ PD curve (yellow) hides this divergence
- Plotting ICE and PD together helps detect interaction
- Diverse ICE shapes suggest interaction (but not with which feature)
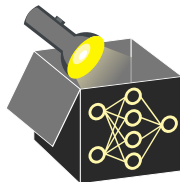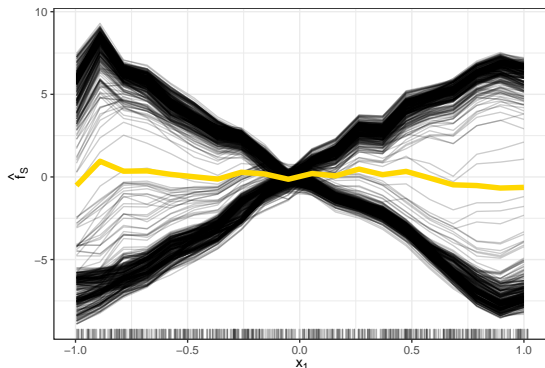
COMMENTS ON INTERACTIONS - 2D PD PLOT
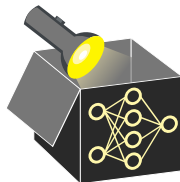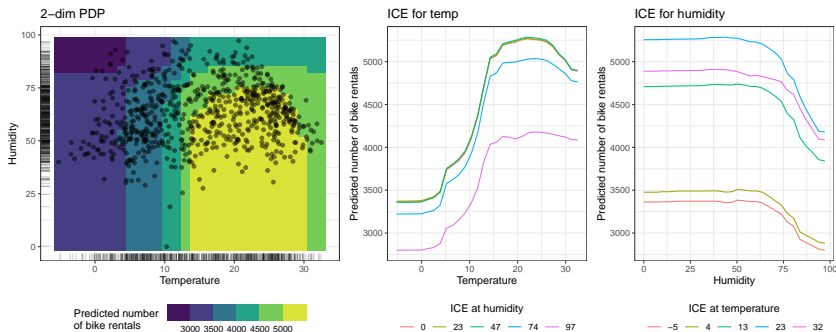
- Humidity and temperature interact at high values (see shape difference)
  ⤳ ICE curve shape changes across different (higher) values of other feat.
    - ICE (temp): At high humidity, temp effect flattens (pink line)
    - ICE (hum): At high temp., humidity effect falls steeper (blue/pink)
- Most rentals occur at *high temperature* and *low to medium humidity*
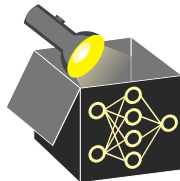
CENTERED ICE PLOT (C-ICE) ▸ "Goldstein et al." 2015

Issue: Varying-intercept (stacked) ICE curves obscure shape heterogeneity
Solution: Center ICE curves at fixed reference value, often $x' = \min(\mathbf{x}_S)$
$\Rightarrow$ Easier to identify heterogeneous shapes with c-ICE curves

$$\hat{f}_{S,cICE}^{(i)}(\mathbf{x}_S) = \hat{f}(\mathbf{x}_S, \mathbf{x}_{-S}^{(i)}) - \hat{f}(x', \mathbf{x}_{-S}^{(i)}) = \hat{f}_S^{(i)}(\mathbf{x}_S) - \hat{f}_S^{(i)}(x')$$
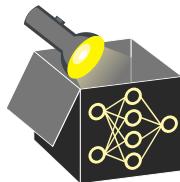
CENTERED ICE PLOT (C-ICE) ▶ "Goldstein et al." 2015

Issue: Varying-intercept (stacked) ICE curves obscure shape heterogeneity
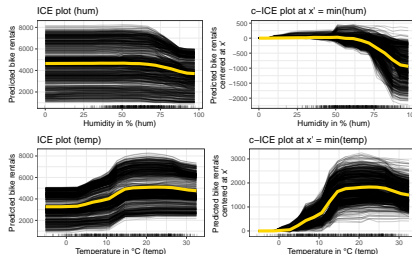**Solution:** Center ICE curves at fixed reference value, often $x' = \min(\mathbf{x}_S)$
$\Rightarrow$ Easier to identify heterogeneous shapes with c-ICE curves

$$\hat{f}^{(i)}_{S,cICE}(\mathbf{x}_S) = \hat{f}(\mathbf{x}_S, \mathbf{x}^{(i)}_{-S}) - \hat{f}(x', \mathbf{x}^{(i)}_{-S}) = \hat{f}^{(i)}_S(\mathbf{x}_S) - \hat{f}^{(i)}_S(x')$$
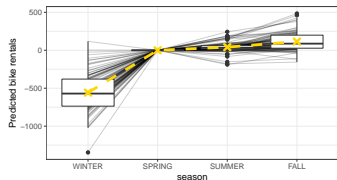
Interpretation

- Yellow: c-PDP (mean of c-ICE)
- **c-PDP:** At 97% humidity, predicted rentals are 1000 fewer than at 0% humidity (on average)
- **Opening of c-ICE curves:** suggests interaction or varying effect across instances

CENTERED ICE PLOT (C-ICE)

Categorical features: c-ICE plots can be interpreted as in LMs due to reference value

Interpretation:

- The reference category is $x' =$ SPRING
- Yellow crosses: Average rentals if we jump from SPRING to any other season $\Rightarrow$ Number of bike rentals drops by ~ 560 in WINTER and is slightly higher in SUMMER and FALL compared to SPRING