Lecture 09 Prediction and Leverage with ASA Flight Data

30 September 2015

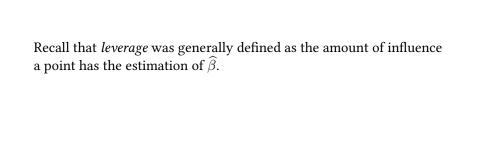
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Goals for today

- Quantify leverage of an observation
- Formulate prediction and confidence intervals for multivariate regression
- Apply to ASA airline dataset





Recall that *leverage* was generally defined as the amount of influence a point has the estimation of $\widehat{\beta}$.

We can formally define leverage as the diagonal elements of the projection matrix:

$$l_i = P_{ii}$$

= $[X(X^tX)^{-1}X^t]_{ii}$

$$l_i = \sum_j p_{i,j} p_{j,i}$$

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$$= \sum_{j} p_{i,j}^2$$

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eq i} p_{i,j}^2 \end{array}$$

Notice that l_i will be a number between 0 and 1; because P is

idempotent and symmetric:
$$l_i = \sum_j p_{i,j} p_{j,i}$$

 $= \sum_{i} p_{i,j}^2$

 $= p_{i,i}^2 + \sum_{j \neq i} p_{i,j}^2$

 $= l_i^2 + \sum_{j
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So then $l_i \ge l_i^2$, which shows the bounds on the leverage values.

$$\mathbb{V}(r|X) = \mathbb{E}(rr^t|X)$$

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So the variance of an individual residual is $\sigma^2(1-l_i)$, so for a leverage close to 1 the regression line will generally pass very close to the point i.

The individual variance of the *i*'th residual suggests that we could standardize each residual as such:

$$\frac{r_i}{\sqrt{s^2(1-l_i)}}$$

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This is known as the Studentized residual. If s^2 is modifed to be calculated without the point i, externally studentized, then this quantity follows a t distribution with n-p degrees of freedom. (Note: This is actually very easy to prove given our already established results.)

CONFIDENCE AND PREDICTION INTERVALS

Now, we consider the case where we observe a new set of observations that were not used in the estimation of $\widehat{\beta}$:

$$y_{new} = X_{new}\beta + \epsilon_{new}$$

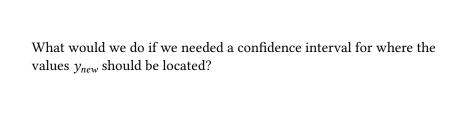
Often we do not actually observe the new values of y, but wish to estimate them from the estimate of β and the new data points.

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$$\mathbb{E}(\hat{y}_{new}|X) = \mathbb{E}(X_{new}\widehat{\beta}|X)$$
$$= X_{new}\beta$$

Where the conditional on X is with respect to the original data and the new data matrix X_{new} .



What would we do if we needed a confidence interval for where the values y_{new} should be located? We need to calculate the variance of our estimator:

$$\mathbb{V}(\hat{y}_{new}|X) = \mathbb{V}(X_{new}\widehat{\beta}|X)$$

$$= X_{new}\mathbb{V}(\widehat{\beta}|X)X_{new}^{t}$$

$$= \sigma^{2}X_{new}(X^{t}X)^{-1}X_{new}^{t}$$

Notice that in the special case that row j of X_{new} is equal to row i of X, we have:

$$\mathbb{V}([\hat{y}_{new}]_j | X) = \sigma^2 P_{ii}$$
$$= \sigma^2 l_i$$

So points with high leverage are points where predictions are particularly variable.

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So points with high leverage are points where predictions are particularly variable. Counterintuitive?

This suggests that we construct the following confidence interval for the mean of y_{new} :

$$\widehat{\mathbb{E}(\widehat{y_{new}}|X)} \in X_{new}\widehat{\beta} \pm t_{n-p,1-\alpha/2} \cdot \sqrt{s^2 X_{new}(X^t X)^{-1} X_{new}^t}$$

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To calculate the variance of the actual prediction, see that (k is the number of row of X_{new})

$$\mathbb{V}(y_{new} - \hat{y}_{new}|X) = \mathbb{V}(y_{new}|X) + \mathbb{V}(\hat{y}_{new}|X)$$
$$= \sigma^2 I_k + \sigma^2 X_{new} (X^t X)^{-1} X_{new}^t$$
$$= \sigma^2 \left[I_k + X_{new} (X^t X)^{-1} X_{new}^t \right]$$

From here, we now have the following prediction interval:

$$y_{new}|X \in X_{new}\widehat{\beta} \pm t_{n-p,1-\alpha/2} \cdot \sqrt{s^2 \left[I_k + X_{new}(X^t X)^{-1} X_{new}^t\right]}$$

Which is exactly a factor of *s* wider than the confidence interval.

APPLICATION TO ASA DATA