Lasso Regression

L1 Regularization

Regularization

- L1 regularization adds a penalty equal to the **absolute value** of the magnitude of coefficients.

$$\sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2 + \lambda\sum_{j=1}^{p}|\beta_j| = \mathrm{RSS} + \boxed{\lambda\sum_{j=1}^{p}|\beta_j|}$$

Regularization

- L1 regularization adds a penalty equal to the **absolute value** of the magnitude of coefficients.
    - Limits the size of the coefficients.
    - Can yield sparse models where some coefficients can become zero.

Regularization

- LASSO can force some of the coefficient estimates to be exactly equal to zero when the tuning parameter λ is sufficiently large.
- Similar to subset selection, the LASSO performs variable selection.
- Models generated from the LASSO are generally much easier to interpret.

Regularization

- LassoCV with sklearn operates on checking a number of alphas within a range, instead of providing the alphas directly.
- Let’s explore the results of LASSO in Python and Scikit-Learn!

03-Regularization-Ridge-Lasso-ElasticNet[LECs8-9].ipynb

Elastic Net

L1 and L2 Regularization

Regularization

- We’ve been able to perform Ridge and Lasso regression.
- We know Lasso is able to shrink coefficients to zero, but we haven’t taken a deeper dive into how or why that is.
- This ability becomes more clear when learning about **elastic net** which combines Lasso and Ridge together!

Regularization

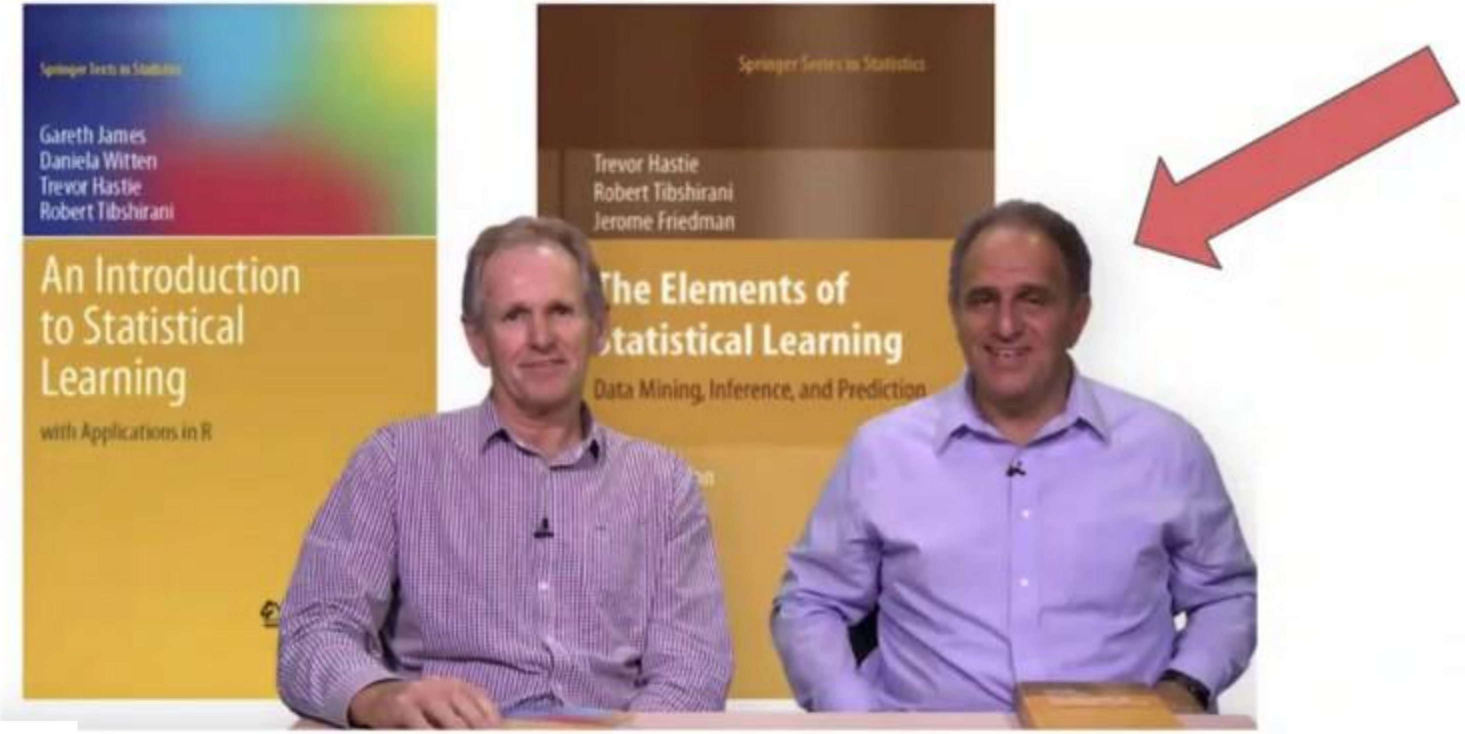
- Let’s dive a little deeper into Lasso.
- Lasso was originally introduced in geophysics literature in 1986 by Symes and Santosa.
- It was later independently rediscovered and popularized in 1996 by Robert Tibshirani who coined the term “Lasso”.

Regularization

- Does the name Robert Tibshirani sound familiar?

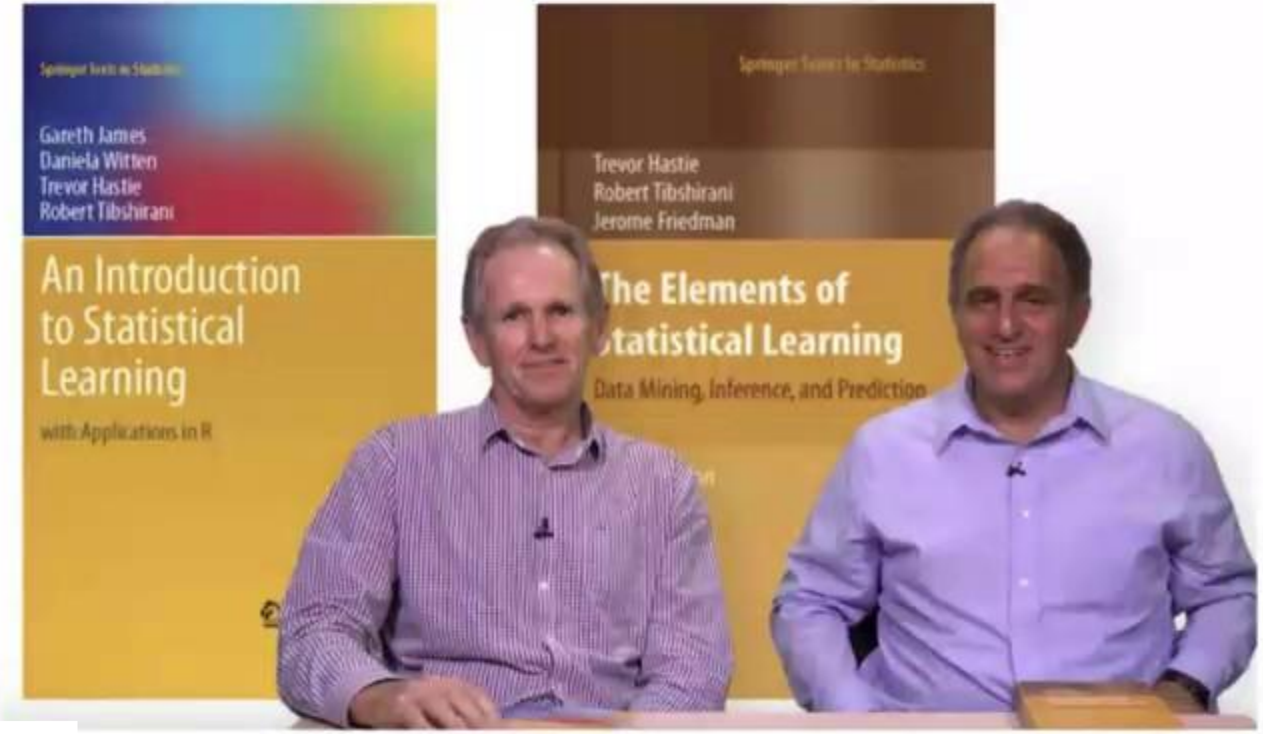
Regularization

- Robert Tibshirani is one of the authors of ISLR!



Regularization

- All the authors have a history of very impressive accomplishments!



Regularization

- We can rewrite Lasso and Ridge:

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} |\beta_j| \leq s$$

and

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} \beta_j^2 \leq s,$$

Regularization

- There is some sum s which allows to rewrite the penalty as a requirement:

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} |\beta_j| \leq s$$

and

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} \beta_j^2 \leq s,$$

Regularization

- There is some sum s which allows to rewrite the penalty as a requirement:

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} |\beta_j| \leq s$$

and

$$\underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij} \right)^2 \right\} \quad \text{subject to} \quad \sum_{j=1}^{p} \beta_j^2 \leq s,$$

Elastic Net

- Start with a simple thought experiment:
  - A simple equation:
    - $\hat{y} = \beta_1 x_1 + \beta_2 x_2$
  - We know that regularization can be expressed as an additional requirement that RSS is subject to.

Elastic Net

- Start with a simple thought experiment:
  - A simple equation:
    - $\hat{y} = \beta_1 x_1 + \beta_2 x_2$
  - L1 constrains the sum of absolute values.
    - $\sum|\beta|$
  - L2 constrains the sum of squared values.
    - $\sum\beta^2$

Elastic Net

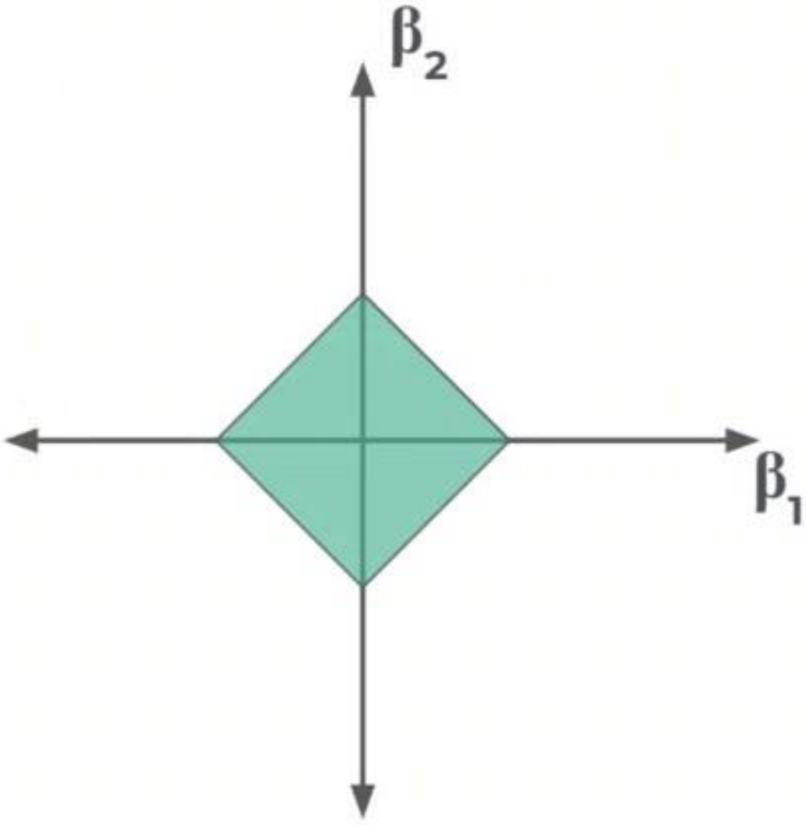
- Start with a simple thought experiment:
  - A simple equation:
    - $\hat{y} = \beta_1 x_1 + \beta_2 x_2$
  - There is some sum **s** that the penalty is less than.

Elastic Net

- For the case of only two features:
  - $\hat{y} = \beta_1 x_1 + \beta_2 x_2$
- Lasso Regression Penalty:
  - $|\beta_1| + |\beta_2| \leq s$
- Ridge Regression Penalty:
  - $\beta_1^2 + \beta_2^2 \leq s$

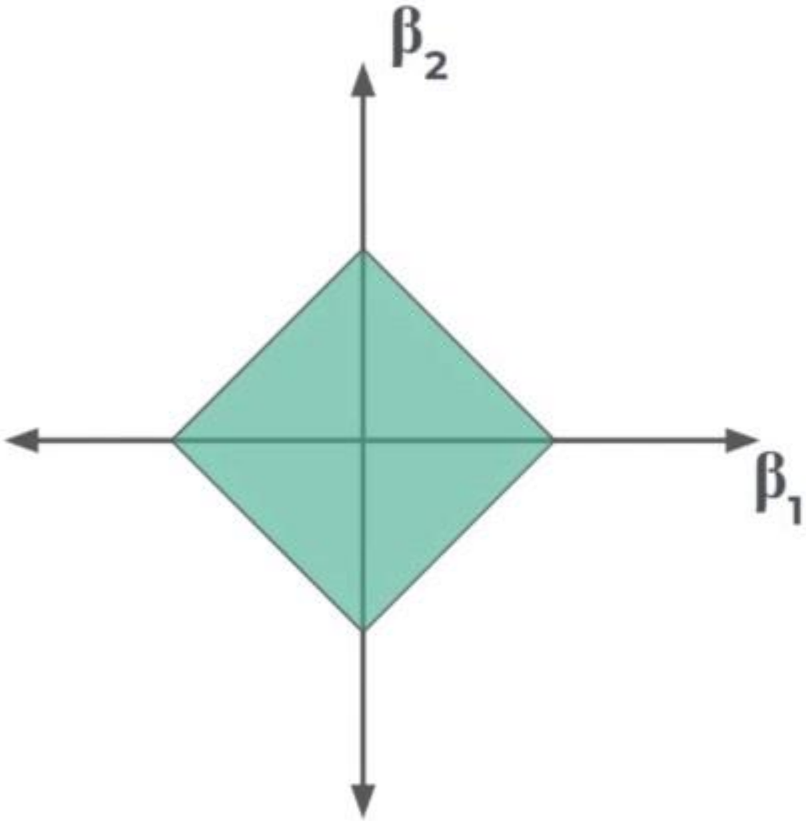
Elastic Net

- Let's plot Lasso: $|\beta_1| + |\beta_2| \leq s$



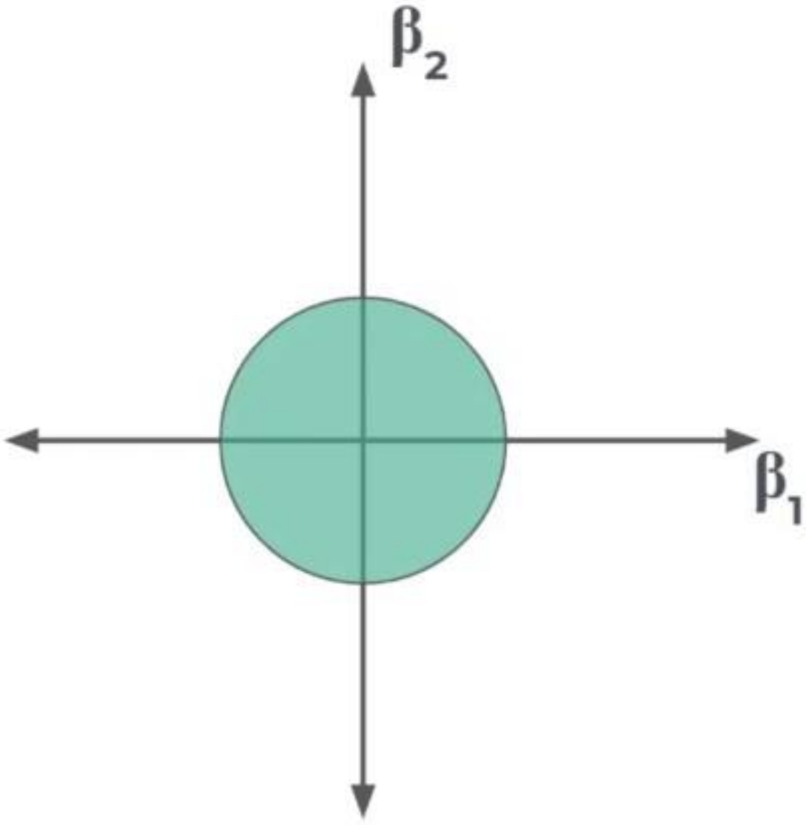
Elastic Net

- Let's plot Lasso: $|\beta_1| + |\beta_2| \leq s$



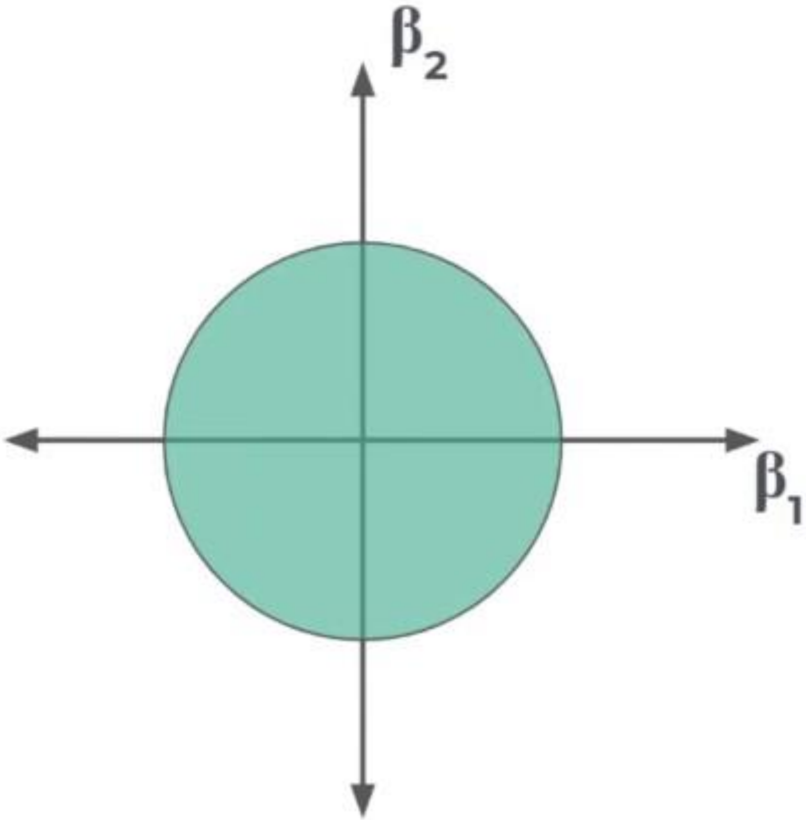
Elastic Net

- Let's plot Ridge: $\beta_1^2 + \beta_2^2 \leq s$



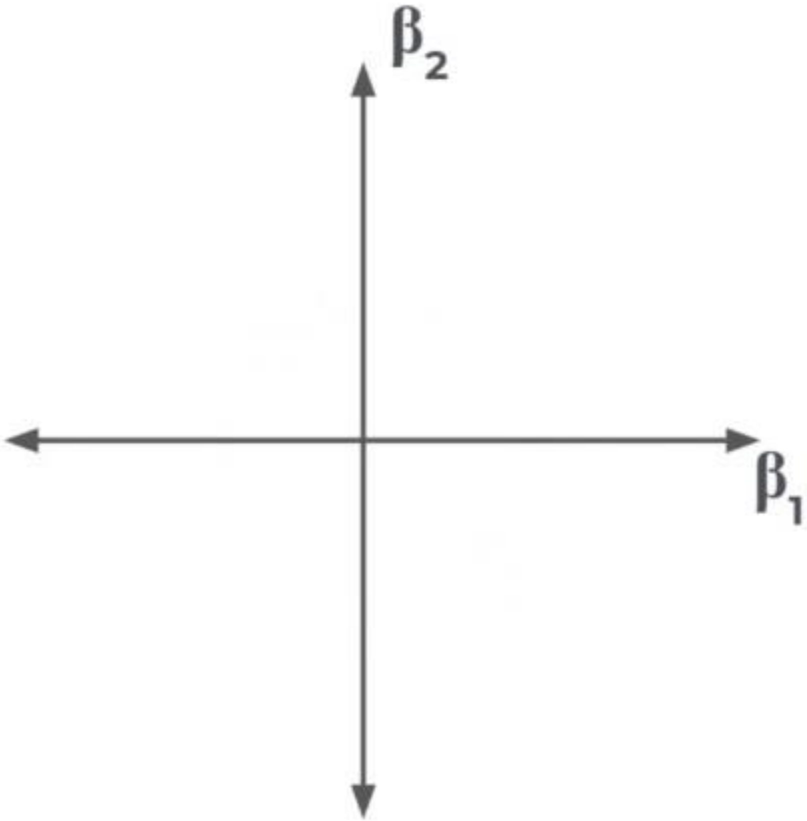
Elastic Net

- Let's plot Ridge: $\beta_1^2 + \beta_2^2 \leq s$



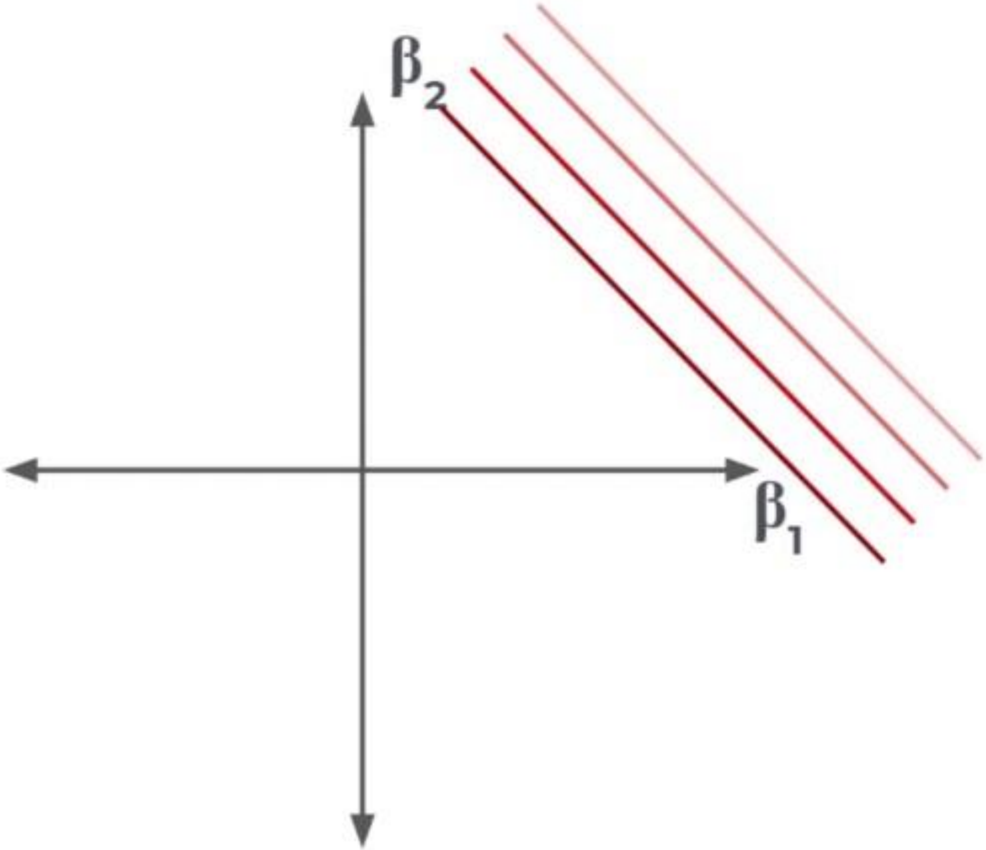
Elastic Net

- What would RSS look like?



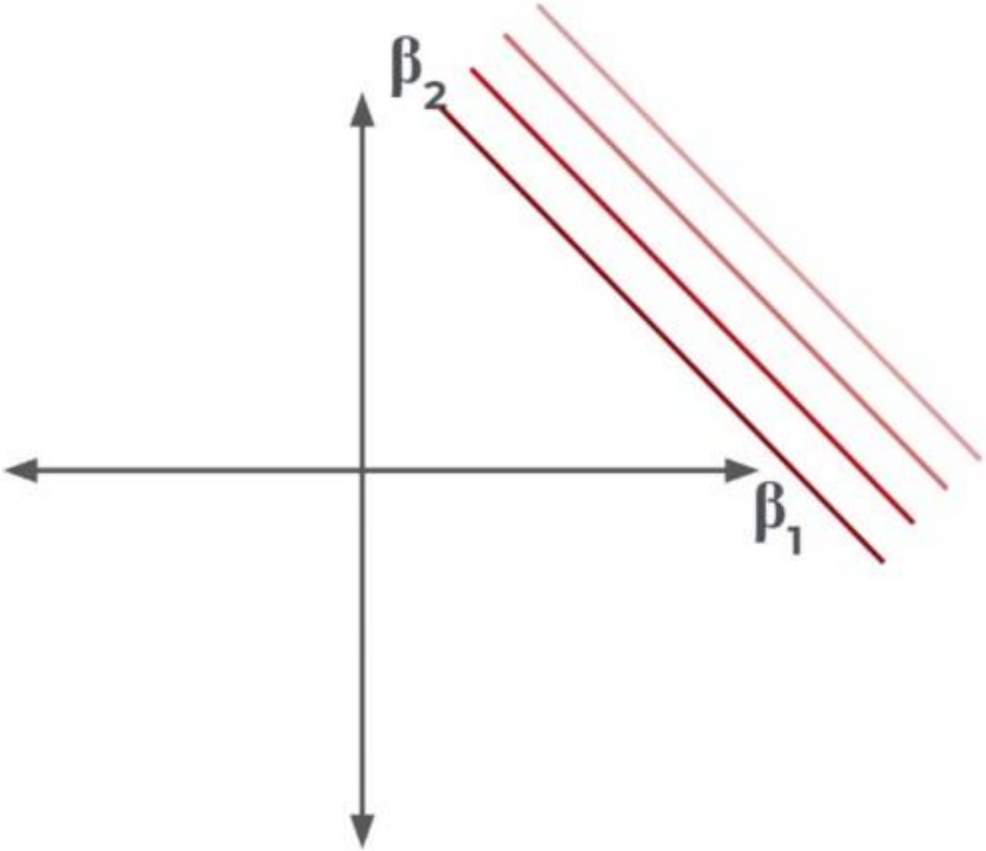
Elastic Net

- What would RSS look like?



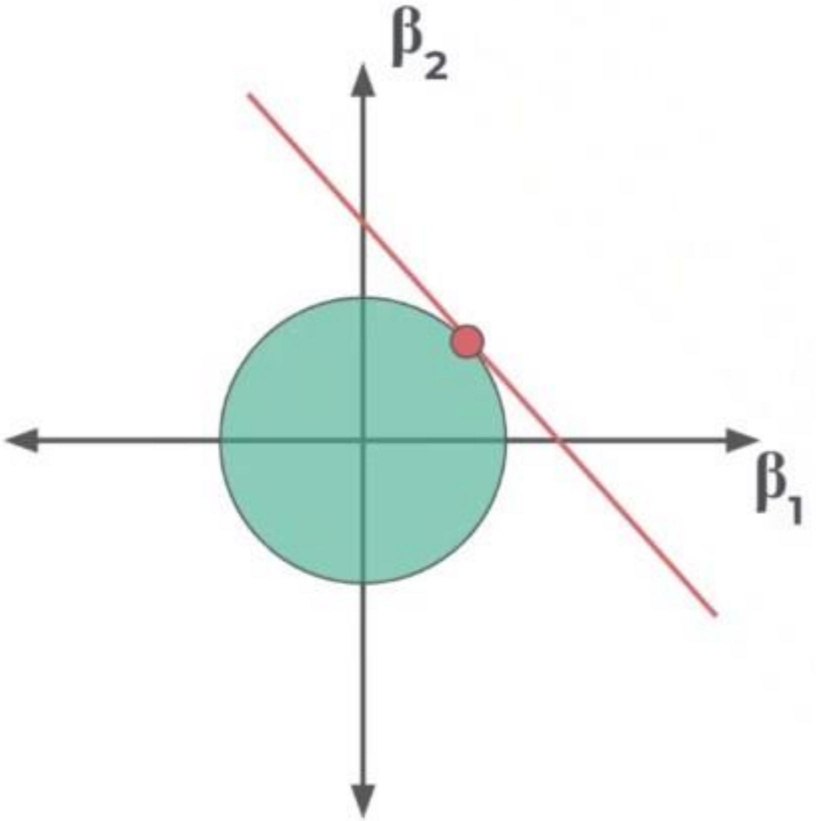
Elastic Net

- But were subject to the penalty!



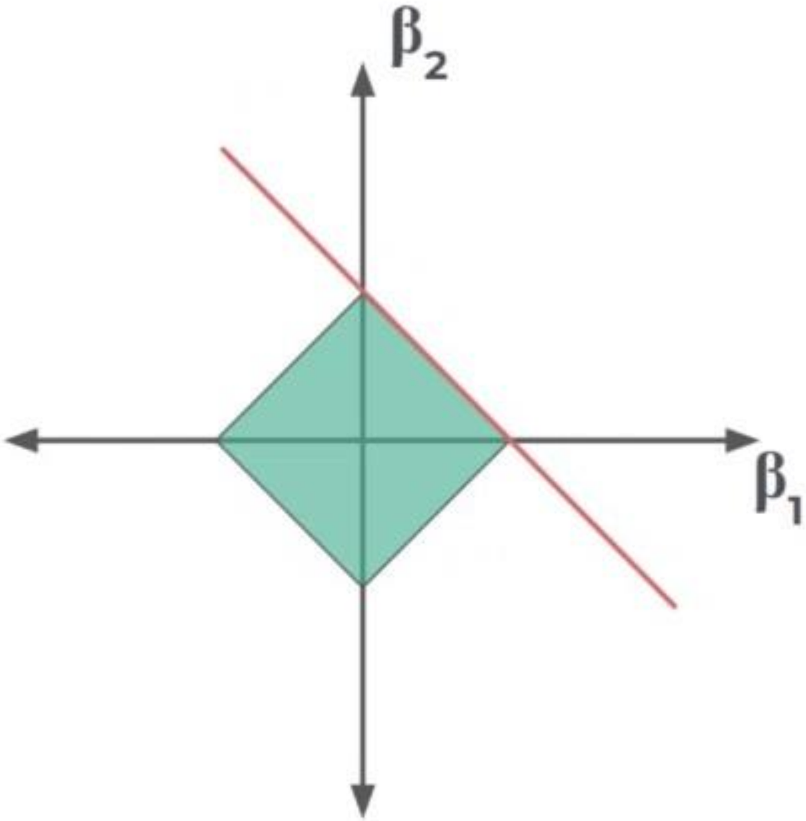
Elastic Net

- Penalty for Ridge: $\beta_1^2 + \beta_2^2 \leq s$



Elastic Net

- Penalty for Lasso: $|\beta_1| + |\beta_2| \leq s$



Elastic Net

- Lasso:
  - A convex object that lies tangent to the boundary, is likely to encounter a corner of a hypercube, for which some components of β are identically zero.

Elastic Net

- Ridge: In the case of an n-sphere, the points on the boundary for which some of the components of β are zero are not distinguished from the others and the convex object is no more likely to contact a point at which some components of β are zero than one for which none of them are.

Elastic Net

- Elastic Net seeks to improve on both L1 and L2 Regularization by combining them:

$$\text{Error} = \sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2 + \lambda_1\sum_{j=1}^{p}\beta_j^2 + \lambda_2\sum_{j=1}^{p}|\beta_j|$$

Elastic Net

- Here we seek to minimize RSS and **both** the squared and absolute value terms:

$$\text{Error} = \sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2 + \lambda_1\sum_{j=1}^{p}\beta_j^2 + \lambda_2\sum_{j=1}^{p}|\beta_j|$$

Elastic Net

- Notice there are **two** distinct lambda values for each penalty:

$$\text{Error} = \sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2 + \lambda_1\sum_{j=1}^{p}\beta_j^2 + \lambda_2\sum_{j=1}^{p}|\beta_j|$$

Elastic Net

- We can alternatively express this as a ratio between L1 and L2:

$$\frac{\sum_{i=1}^{n}(y_i - x_i^J\hat{\beta})^2}{2n} + \lambda\left(\frac{1-\alpha}{2}\sum_{j=1}^{m}\hat{\beta}_j^2 + \alpha\sum_{j=1}^{m}|\hat{\beta}_j|\right)$$

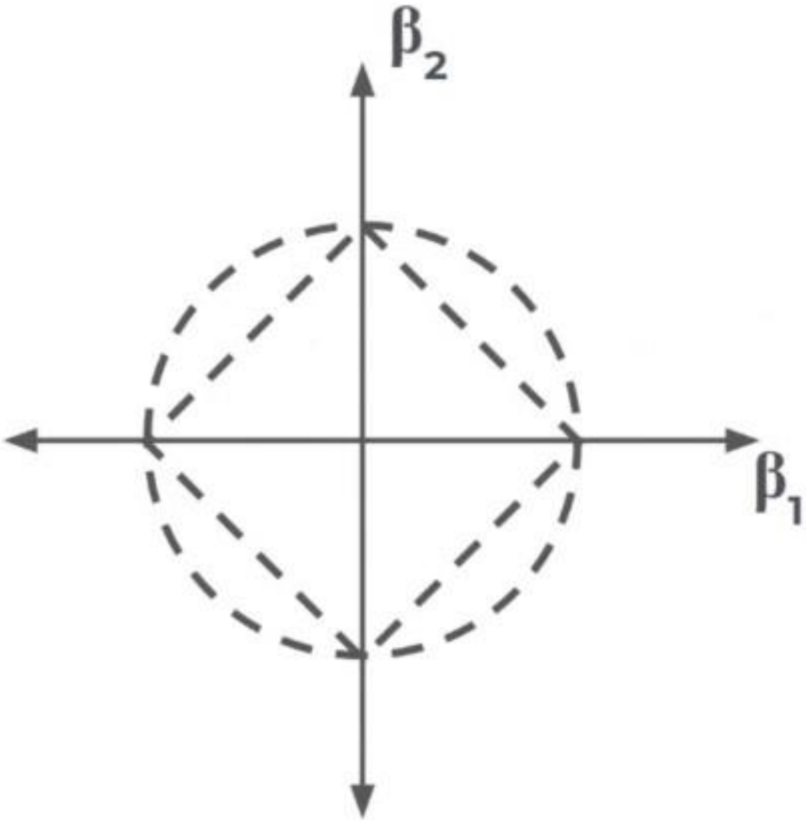
Elastic Net

- We can also use simplified notation:

$$\hat{\beta} \equiv \underset{\beta}{\operatorname{argmin}}(\|y - X\beta\|^2 + \lambda_2 \|\beta\|^2 + \lambda_1 \|\beta\|_1)$$

Elastic Net

- Elastic Net Penalty Region:



Elastic Net

- Let’s explore how to perform Elastic Net with Python and Scikit-learn!

$$\frac{\sum_{i=1}^{n}(y_i - x_i^J \hat{\beta})^2}{2n} + \lambda \left(\frac{1-\alpha}{2} \sum_{j=1}^{m} \hat{\beta}_j^2 + \alpha \sum_{j=1}^{m} |\hat{\beta}_j| \right)$$

03-Regularization-Ridge-Lasso-ElasticNet[LECs8-9].ipynb

Linear Regression Project Data Set

Project Data Set

- Most data sets require cleaning, analysis, and feature engineering before being used for machine learning.
- Let's quickly review the data set for the Linear Regression Project.
- In the next sections, we will focus on setting up the data for machine learning!

04-Linear-Regression-Project-DataSet .ipynb