Bayesian Regression

Learn about Bayesian regression techniques.

Chapter Goals:

- Learn about Bayesian regression techniques

A. Bayesian techniques

So far, we've discussed hyperparameter optimization through cross-validation. Another way to optimize the hyperparameters of a regularized regression model is with Bayesian (https://en.wikipedia.org/wiki/Bayesian_inference) techniques.

In Bayesian statistics, the main idea is to make certain assumptions about the probability distributions of a model's parameters *before* being fitted on data. These initial distribution assumptions are called *priors* for the model's parameters.

In a Bayesian ridge regression model, there are two hyperparameters to optimize: α and λ. The α hyperparameter serves the same exact purpose as it does for regular ridge regression; namely, it acts as a scaling factor for the penalty term.

The λ hyperparameter acts as the precision (https://en.wikipedia.org/wiki/Precision_(statistics)) of the model's weights. Basically, the smaller the λ value, the greater the variance between the individual weight values.

B. Hyperparameter priors

Both the α and λ hyperparameters have gamma distribution (https://en.wikipedia.org/wiki/Gamma_distribution) priors, meaning we assume both values come from a gamma probability distribution.

There's no need to know the specifics of a gamma distribution, other than the fact that it's a probability distribution defined by a shape parameter (https://en.wikipedia.org/wiki/Shape_parameter) and scale parameter (https://en.wikipedia.org/wiki/Scale_parameter).

Specifically, the α hyperparameter has prior:

$$\Gamma(\alpha_1, \alpha_2)$$

and the λ hyperparameter has prior:

$$\Gamma(\lambda_1, \lambda_2)$$

where Γ(k, θ) represents a gamma distribution with shape parameter k and scale parameter θ.

C. Tuning the model

When finding the optimal weight settings of a Bayesian ridge regression model for an input dataset, we also concurrently optimize the α and λ hyperparameters based on their prior distributions and the input data.

This can all be done with the `BayesianRidge` (https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.BayesianRidge.html#sklearn.linear_model.BayesianRidge) object (part of the `linear_model` module). Like all the previous regression objects, this one can be initialized with no required arguments.

```
# predefined dataset from previous chapter
print('Data shape: {}\n'.format(data.shape))
print('Labels shape: {}\n'.format(labels.shape))

from sklearn import linear_model
reg = linear_model.BayesianRidge()
reg.fit(data, labels)
print('Coefficients: {}\n'.format(repr(reg.coef_)))
print('Intercept: {}\n'.format(reg.intercept_))
print('R2: {}\n'.format(reg.score(data, labels)))
print('Alpha: {}\n'.format(reg.alpha_))
print('Lambda: {}\n'.format(reg.lambda_))
```

Output

1.519s

```
Data shape: (150, 4)

Labels shape: (150,)

Coefficients: array([-0.11174619, -0.03900476,  0.24330537,  0.57343721])

Intercept: 0.17022693722601356

R2: 0.9303454031271241
```

We can manually specify the α_1 and α_2 gamma parameters for α with the `alpha_1` and `alpha_2` keyword arguments when initializing `BayesianRidge`. Similarly, we can manually set λ_1 and λ_2 with the `lambda_1` and `lambda_2` keyword arguments. The default value for each of the four gamma parameters is 10^{-6}.

Time to Code!

The coding exercise in this chapter uses the `BayesianRidge` object of the `linear_model` module (imported in backend) to complete the `bayes_ridge` function.

The function will fit a Bayesian ridge regression model to the input data and labels.

Set `reg` equal to `linear_model.BayesianRidge`, initialized with no input arguments.

Call `reg.fit` with `data` and `labels` as the two input arguments. Then return `reg`.

```
def bayes_ridge(data, labels):
  # CODE HERE
  pass
```

Solution

```
def bayes_ridge(data, labels):
  reg = linear_model.BayesianRidge()
  reg.fit(data, labels)
  return reg
```

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