Modeling IV

Introduction

- Instructions

  - Download Tutorial Zip

  - Unzip Folder

  - Required Packages
    - `library(modelr)`

    - `library(tidyverse)`

    - `library(purrr)`

    - `library(broom)`

  - Open .Rmd File and Knit

Discussion

- Problems With Current Approach

  - Same Model For All Locations

  - Not All Locations Used in Train

  - Not All Locations Used in Test

  - Residuals Indicate that Model Can Be Improved

  - Not Helpful for Forecasting

  - Ambiguous Results: No Clear Winner

Part 1:
Cross Validation
by Location

- Previously

  - Split Data in Train and Test
    - Train (28 Rivers)
    - Test (3 Rivers)

  - Purpose
    - Estimate Out-of-Sample Error
    - Pick Best Model Based on This Estimate
    - Combat Overfitting
    - Robustification

  - Goal: Find the Simplest Model that Adequately Predicts

**Part 1:
Cross Validation
by Location**

- Current Issues

  - Decision on Final Model Heavily Influenced by the Test Data
  - Loss of Data in Model Fitting
  - Not Appropriate in Small Datasets

- Cross Validation Idea

  - Split Data Into Many Groups
  - Each Group Acts as a Test Set
  - All Data is Used in Both Model Fitting and Model Testing
  - Help: Chapter 5 (ISLR)

**Part 1:
Cross Validation
by Location**

- Tidyverse Concepts

  - Chapter 20 (R4DS)

  - List-Columns
    - Columns in Data Frames or Tibbles Can Be Lists
    - What this Means
      - Column of Tables
      - Column of Models
      - Column of Functions

  - Functions
    - nest(): Converts Rows of a Data Frame into a List
    - unnest(): What do You Think It Does?

Part 1:
Cross Validation by Location

- Run Chunk 1

  - Observe the Output
  - Column of Tibbles

- Run Chunk 2

  - Imagine We Wanted to Split
    - Test: Data For Location 103
    - Train: All Remaining Data
  - Use of filter() and unnest()
  - First Glimpse -> 365 x 8
  - Second Glimpse -> 10,972 x 8

**Part 1:
Cross Validation
by Location**

- Chunk 3

  - Run Each Line
  - What is Happening?
  - Use View() on DATA2 and Scan Through the Data
  - What do You Notice?

- Chunk 4

  - Create a Loop that Repeats this Process for Each Location
  - Each Location Is a Test Set
  - Predictions Saved are All Out-of-Sample
  - Run Chunk 4 to Test Your Code

Part 1:
Cross Validation by Location

- Chunk 4 (Continued)

```
DATA2=DATA
DATA2$linpred=NA

for(k in unique(DATA2$L)){
  TEST = NEST.DATA %>% filter(L==k) %>%
unnest()
  TRAIN  = NEST.DATA %>% filter(L!=k) %>%
unnest()

  linmod=lm(W~A, data=TRAIN)
  linmodpred=predict(linmod,newdata=TEST)

  DATA2$linpred[which(DATA2$L==k)]=linmodpred
}
```

**Part 1:
Cross Validation
by Location**

- Chunk 5

  - In Our Data, We Have:
    - Actual Water Temperatures
    - Out-of-Sample Predicted Water Temperatures
  - Create RMSE.func() With Two Arguments
    - actual= vector of actual water temperatures
    - predict=vector of predicted water temperatures
  - Use This Function on the Two Columns in DATA2 for RMSE
    - actual=W
    - predict=linpred

Part 1: Cross Validation by Location

- Chunk 5 (Continued)

```
RMSE.func = function(actual,predict){
  mse=mean((actual-predict)^2,na.rm=T)
  rmse=sqrt(mse)
  return(rmse)
}

RMSE.func(actual=DATA2$W,
          predict=DATA2$linpred)
```

```
RMSE.func(actual=DATA2$W,predict=DATA2$linpred)
[] 3.147084
```

Intermission

- Current

  - Using the Natural Grouping of Data for 31-Fold Cross Validation
  - Only Fit One Linear Model
  - Should Use Cross-Validation for Multiple Different Models and Compare Cross-Validated RMSE

- Next

  - Randomly Assign Observations to K-Folds
 - CV Function: crossv_kfold(K)

Part 2: K-Fold CV

- Overview (*K*=10)

  - Randomly Split Observations Into *K* Groups
  - Each Fold Acts as a Test Set
  - If Each Fold Contains Approximately the Same # of Observations,

Training set

Training folds   Test fold

1st iteration $\Rightarrow E_1$

2nd iteration $\Rightarrow E_2$

3rd iteration $\Rightarrow E_3$

...

10th iteration $\Rightarrow E_{10}$

$$E = \frac{1}{10}\sum_{i=1}^{10} E_i$$

Part 2:
K-Fold CV

- Run Chunk 1

  - Variables (Julian Day)
  - Clear Non-Linear Relationship
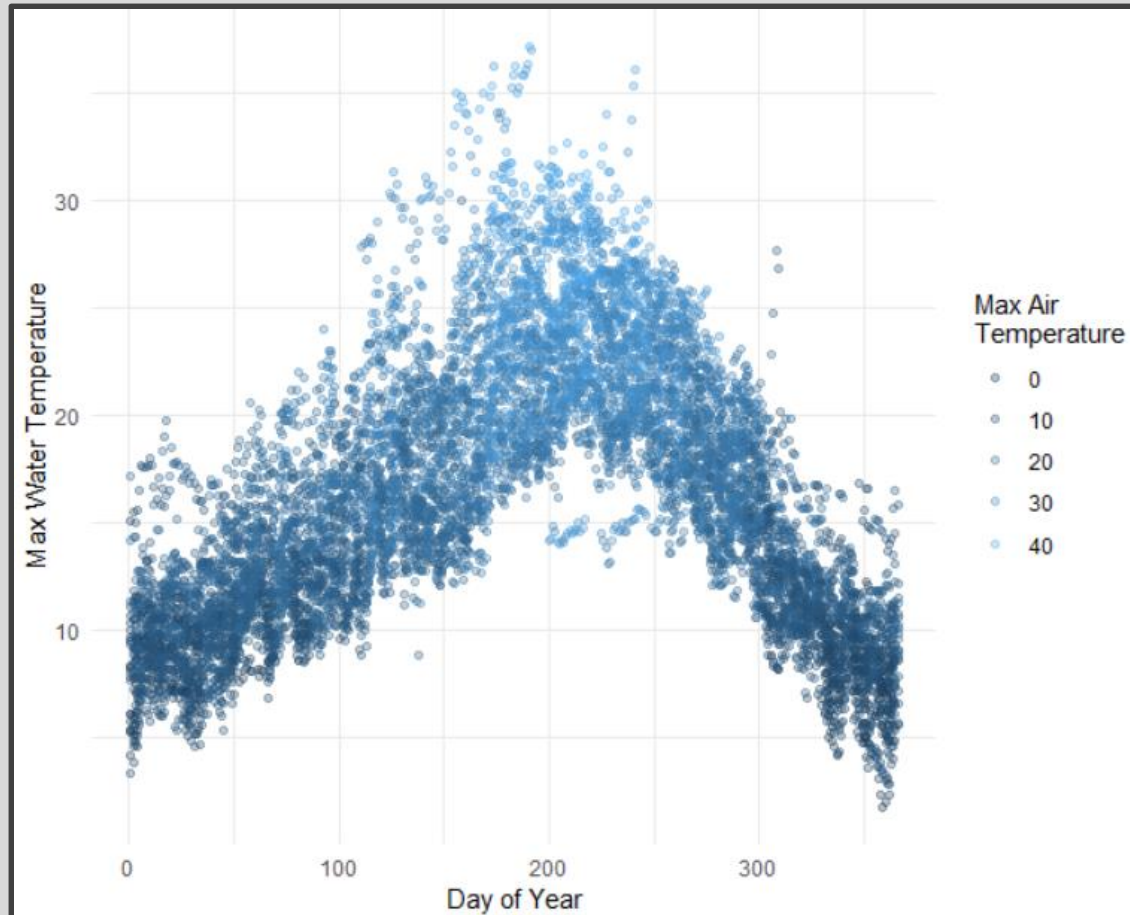
Part 2: K-Fold CV

- General Polynomial Model

$$W = a + \sum_{i=1}^{I} b_i A^i + \sum_{j=1}^{J} c_j D^j + \varepsilon$$

  - Perform K-Fold CV to Estimate Out-of-Sample RMSE for Choices of *I=4* and *J=3*

  - Ultimate Goal is To Select Best *I* and *J*

Part 2: K-Fold CV

- Run Chunk 2

  - Fit Model with $I=4$ and $J=3$
  - Functions from broom Package
    - tidy()
    - glance()
  - Used to Preview Models

```
tidy(polymodel)
A tibble: 8 x 5
term                   estimate std.error statistic  p.value
<chr>                    <dbl>     <dbl>      <dbl>    <dbl>
(Intercept)              16.2     0.0273     595.     0.
poly(A, 4)1              328.     4.36        75.3    0.
poly(A, 4)2              49.0     2.80        17.5    1.62e-67
poly(A, 4)3              2.85     2.78         1.02   3.06e- 1
poly(A, 4)4             -3.62     2.72        -1.33   1.84e- 1
poly(JULIAN_DAY, 3)1     46.0     2.78        16.6    8.85e-61
poly(JULIAN_DAY, 3)2   -226.     4.31       -52.5    0.
poly(JULIAN_DAY, 3)3    -59.3     2.89       -20.5    8.66e-92
```

```
glance(polymodel)
A tibble: 1 x 11
r.squared adj.r.squared sigma statistic p.value   df  logLik    AIC    BIC
  <dbl>        <dbl>    <dbl>    <dbl>    <dbl> <int>   <dbl>   <dbl>  <dbl>
  0.797        0.797    2.71    5525.        0     8 -23804. 47626. 47691.
```

Part 2:
K-Fold CV

- Run Chunk 3

  - Divide Data into 10 Folds
    - Use crossv_kfold() Function
    - Variables are Lists of Train and Test Sets
  - For Each Row, We Want to Fit on Train and Predict on Test

```
head(DATA3)
A tibble: 6 x 3
train                test               .id
<list>               <list>             <chr>
<S3: resample>       <S3: resample>     01
<S3: resample>       <S3: resample>     02
<S3: resample>       <S3: resample>     03
<S3: resample>       <S3: resample>     04
<S3: resample>       <S3: resample>     05
<S3: resample>       <S3: resample>     06
```

Part 2: K-Fold CV

- Run Chunk 4

  - Create Function to Fit Models
  - Apply Function to All Train Sets Using purrr::map() Function

```
DATA4=DATA3 %>%
        mutate(tr.model=map(train,train.model.func,i=i,j=j))
head(DATA4)
A tibble: 6 x 4
train            test            .id    tr.model
<list>           <list>          <chr>  <list>
<S3: resample>   <S3: resample>  01     <S3: lm>
<S3: resample>   <S3: resample>  02     <S3: lm>
<S3: resample>   <S3: resample>  03     <S3: lm>
<S3: resample>   <S3: resample>  04     <S3: lm>
<S3: resample>   <S3: resample>  05     <S3: lm>
<S3: resample>   <S3: resample>  06     <S3: lm>
```

- Functions from purrr Package
  - map() – Loop Over Train
  - map2() – Loop Over Fitted Models and Test

Part 2:
K-Fold CV

- Run Chunk 5

  - purrr::map2() Iterates Function Over Two Arguments
  - For Every Test Set and Trained Model, We Use augment() to Get Predictions

```
DATA4.PREDICT = DATA4 %>%
        mutate(predict=map2(test,tr.model,~augment(.y,newdata=.x))) %>%
        select(predict) %>%
        unnest()
head(DATA4.PREDICT)
A tibble: 6 x 10
JULIAN_DAY  YEAR      L      W       A  TIME MONTH    DAY .fitted .se.fit
   <int>   <int>  <int>  <dbl>  <dbl> <int> <int>  <int>   <dbl>   <dbl>
       9    2003    103    9.8    5.1     9     1      9    7.27   0.138
      12    2003    103    9.9    6.2    12     1     12    7.67   0.119
      25    2003    103    9.8   14      25     1     25   10.4    0.0744
      30    2003    103    9.5    9      30     1     30    9.14   0.0803
      47    2003    103   12.5   11.4    47     2     16   10.5    0.0621
      50    2003    103   10.7   14      50     2     19   11.5    0.0548
```

- Next, Compare Fitted With Actual Using RMSE.func()

```
RMSE.func(actual=DATA4.PREDICT$W,predict=DATA4.PREDICT$.fitted)
] 2.709727
```

Look Ahead

- What We Have Done
  - Specify I and J
  - Use 10-Fold Cross Validation to Estimate Out-of-Sample RMSE

- How We Should Use This
  - Choose Max I and Max J (Example: 10)
  - Initiate 10 x 10 Matrix of *NA*
  - Loop Through All i and j to Capture Out-of-Sample RMSE
  - Create a Tile Plot that Visualizes the RMSE for Each Combination of i and j
  - Choose Best i and j