Homework 3

# Question 7.1

Describe a situation or problem from your job, everyday life, current events, etc., for which exponential smoothing would be appropriate. What data would you need? Would you expect the value of alpha (the first smoothing parameter) to be closer to 0 or 1, and why?

My answer: Problem: daily stock price for the company XXX Data needed: the stock price over the last 2 or 5 years,the longer the better I would expect the alpha to be closer to 1, which means there is not much randomness in the system. The stock price of the company should reflect the actual value of the company, when there is not much matket uncertainty (trade war etc.). The price stays within an acceptable range of fluctuation. If we observed a fluctuation today, it probably means today’s baseline is close to the observed data.

# Question 7.2

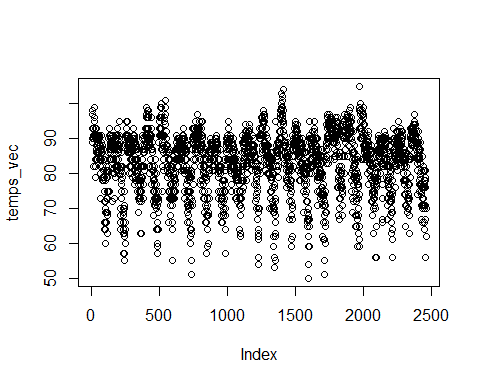
Using the 20 years of daily high temperature data for Atlanta (July through October) from Question 6.2 (file temps.txt), build and use an exponential smoothing model to help make a judgment of whether the unofficial end of summer has gotten later over the 20 years.

readin the data and plot it to see what the distribution looks like

temps<-read.table("temps.txt",header=TRUE)  
temps\_vec<-as.vector(unlist(temps[,2:21]))  
temps\_vec

## [1] 98 97 97 90 89 93 93 91 93 93 90 91 93 93 82 91 96  
## [18] 95 96 99 91 95 91 93 84 84 82 79 90 91 87 86 90 84  
## [35] 91 93 88 91 84 90 89 88 86 84 86 89 90 91 91 90 89  
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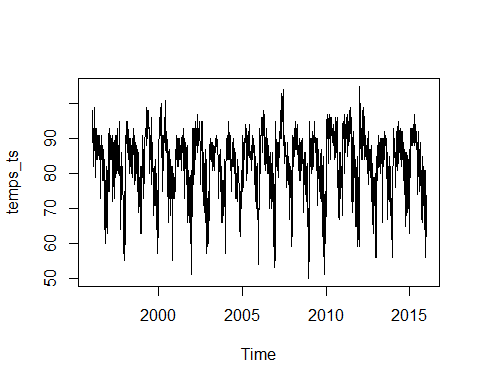
plot(temps\_vec)

 convert it to time series data and check the distribution

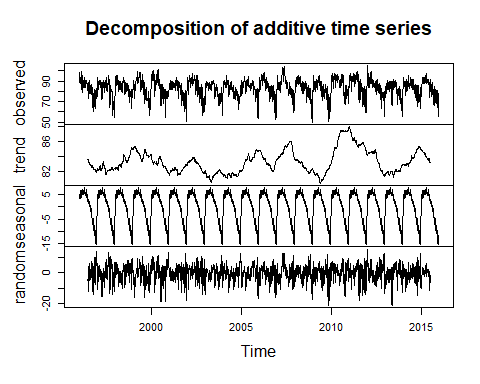
temps\_ts<-ts(temps\_vec,start=1996,frequency = 123)  
temps\_ts

## Time Series:  
## Start = c(1996, 1)   
## End = c(2015, 123)   
## Frequency = 123   
## [1] 98 97 97 90 89 93 93 91 93 93 90 91 93 93 82 91 96  
## [18] 95 96 99 91 95 91 93 84 84 82 79 90 91 87 86 90 84  
## [35] 91 93 88 91 84 90 89 88 86 84 86 89 90 91 91 90 89  
## [52] 90 91 91 91 84 88 84 86 88 84 82 80 73 87 84 87 89  
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## [154] 72 80 84 88 89 88 84 84 80 73 80 86 88 88 87 88 91  
## [171] 91 89 89 88 82 79 81 82 84 87 90 90 91 91 88 88 91  
## [188] 93 81 81 82 86 88 84 80 82 86 87 87 88 88 90 88 91  
## [205] 95 89 70 80 82 66 70 64 68 77 86 75 73 75 78 81 82  
## [222] 82 82 80 82 82 79 80 68 63 57 66 64 69 70 70 62 63  
## [239] 62 75 71 57 55 64 66 60 91 88 91 91 91 89 93 95 95  
## [256] 91 91 86 88 87 91 87 90 91 95 91 91 89 91 91 86 88  
## [273] 80 88 89 90 86 86 82 84 86 90 89 89 86 82 87 88 84  
## [290] 86 80 82 86 84 87 90 79 84 87 87 88 90 91 89 90 93  
## [307] 93 91 87 84 77 90 91 89 90 89 79 78 81 84 89 87 87  
## [324] 88 87 82 80 82 82 88 84 81 82 84 87 80 75 75 86 78  
## [341] 77 82 82 73 82 69 72 73 78 78 78 75 79 78 77 78 82  
## [358] 75 73 63 63 72 75 79 79 79 78 82 79 84 82 87 88 90  
## [375] 91 82 86 87 87 82 77 73 81 81 86 82 87 88 90 90 91  
## [392] 93 93 91 93 93 93 93 97 99 96 93 88 89 91 93 93 93  
## [409] 91 90 96 98 97 98 93 93 96 98 98 89 91 91 90 80 82  
## [426] 89 88 90 91 91 84 88 91 84 93 96 96 91 91 77 87 87  
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## [460] 77 71 73 75 84 71 73 71 73 73 72 72 73 70 64 75 73  
## [477] 77 80 71 66 60 64 73 57 59 64 69 75 73 72 75 75 89  
## [494] 91 93 95 96 96 96 91 96 99 96 93 91 93 93 93 91 97  
## [511] 100 99 93 96 87 82 75 82 88 91 89 87 86 86 81 84 88  
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## [545] 86 88 92 92 90 90 92 92 88 87 79 81 82 87 81 66 66  
## [562] 75 80 82 84 86 87 86 80 75 73 73 84 87 77 73 81 84  
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## [596] 73 75 75 77 80 80 80 73 73 75 79 75 75 78 75 78 80  
## [613] 75 77 78 84 87 87 84 86 87 87 89 91 87 90 90 86 82  
## [630] 82 84 87 88 90 87 84 87 90 84 82 88 90 84 89 89 87  
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## [681] 81 90 88 87 86 86 89 87 84 84 86 77 77 81 81 82 84  
## [698] 86 87 88 69 66 72 75 78 71 71 75 80 81 80 79 70 68  
## [715] 79 66 73 75 78 78 75 75 62 60 64 71 75 79 80 81 79  
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## [2432] 66 70 73 76 81 82 81 71 73 76 81 78 81 77 70 66 64  
## [2449] 71 76 79 81 76 71 67 56 78 70 70 62

plot(temps\_ts)



plot(decompose(temps\_ts))

 Apply the HoltWinters function to get the predicted value

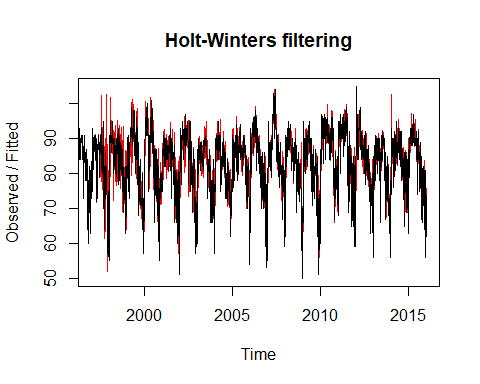
temps\_hw<-HoltWinters(temps\_ts,alpha = NULL, beta= NULL, gamma = NULL,seasonal = "multiplicative")  
temps\_hw

## Holt-Winters exponential smoothing with trend and multiplicative seasonal component.  
##   
## Call:  
## HoltWinters(x = temps\_ts, alpha = NULL, beta = NULL, gamma = NULL, seasonal = "multiplicative")  
##   
## Smoothing parameters:  
## alpha: 0.615003  
## beta : 0  
## gamma: 0.5495256  
##   
## Coefficients:  
## [,1]  
## a 73.679517064  
## b -0.004362918  
## s1 1.239022317  
## s2 1.234344062  
## s3 1.159509551  
## s4 1.175247483  
## s5 1.171344196  
## s6 1.151038408  
## s7 1.139383104  
## s8 1.130484528  
## s9 1.110487514  
## s10 1.076242879  
## s11 1.041044609  
## s12 1.058139281  
## s13 1.032496529  
## s14 1.036257448  
## s15 1.019348815  
## s16 1.026754142  
## s17 1.071170378  
## s18 1.054819556  
## s19 1.084397734  
## s20 1.064605879  
## s21 1.109827336  
## s22 1.112670130  
## s23 1.103970506  
## s24 1.102771209  
## s25 1.091264692  
## s26 1.084518342  
## s27 1.077914660  
## s28 1.077696145  
## s29 1.053788854  
## s30 1.079454300  
## s31 1.053481186  
## s32 1.054023885  
## s33 1.078221405  
## s34 1.070145761  
## s35 1.054891375  
## s36 1.044587771  
## s37 1.023285461  
## s38 1.025836722  
## s39 1.031075732  
## s40 1.031419152  
## s41 1.021827552  
## s42 0.998177248  
## s43 0.996049257  
## s44 0.981570825  
## s45 0.976510542  
## s46 0.967977608  
## s47 0.985788411  
## s48 1.004748195  
## s49 1.050965934  
## s50 1.072515008  
## s51 1.086532279  
## s52 1.098357400  
## s53 1.097158461  
## s54 1.054827180  
## s55 1.022866587  
## s56 0.987259326  
## s57 1.016923524  
## s58 1.016604903  
## s59 1.004320951  
## s60 1.019102781  
## s61 0.983848662  
## s62 1.055888360  
## s63 1.056122844  
## s64 1.043478958  
## s65 1.039475693  
## s66 0.991019224  
## s67 1.001437488  
## s68 1.002221759  
## s69 1.003949213  
## s70 0.999566344  
## s71 1.018636837  
## s72 1.026490773  
## s73 1.042507768  
## s74 1.022500795  
## s75 1.002503740  
## s76 1.004560984  
## s77 1.025536556  
## s78 1.015357769  
## s79 0.992176558  
## s80 0.979377825  
## s81 0.998058079  
## s82 1.002553395  
## s83 0.955429116  
## s84 0.970970220  
## s85 0.975543504  
## s86 0.931515830  
## s87 0.926764603  
## s88 0.958565273  
## s89 0.963250387  
## s90 0.951644060  
## s91 0.937362688  
## s92 0.954257999  
## s93 0.892485444  
## s94 0.879537700  
## s95 0.879946892  
## s96 0.890633648  
## s97 0.917134959  
## s98 0.925991769  
## s99 0.884247686  
## s100 0.846648167  
## s101 0.833696369  
## s102 0.800001437  
## s103 0.807934782  
## s104 0.819343668  
## s105 0.828571029  
## s106 0.795608740  
## s107 0.796609993  
## s108 0.815503509  
## s109 0.830111282  
## s110 0.829086181  
## s111 0.818367239  
## s112 0.863958784  
## s113 0.912057203  
## s114 0.898308248  
## s115 0.878723779  
## s116 0.848971946  
## s117 0.813891909  
## s118 0.846821392  
## s119 0.819121827  
## s120 0.851036184  
## s121 0.820416491  
## s122 0.851581233  
## s123 0.874038407

summary(temps\_hw)

## Length Class Mode   
## fitted 9348 mts numeric   
## x 2460 ts numeric   
## alpha 1 -none- numeric   
## beta 1 -none- numeric   
## gamma 1 -none- numeric   
## coefficients 125 -none- numeric   
## seasonal 1 -none- character  
## SSE 1 -none- numeric   
## call 6 -none- call

plot(temps\_hw)

 We can see from the plot that the predicted value(red line) agree pretty well with the observed values(black). The prediction begins at about year 1997, that’s because 1996’s data were used for prediction. The model works better with more data available. So it looks like the red line and black line align better at the later year.

Now let’s take a look at the seasonal factors

head(temps\_hw$fitted)

## xhat level trend season  
## [1,] 87.23653 82.87739 -0.004362918 1.052653  
## [2,] 90.42182 82.15059 -0.004362918 1.100742  
## [3,] 92.99734 81.91055 -0.004362918 1.135413  
## [4,] 90.94030 81.90763 -0.004362918 1.110338  
## [5,] 83.99917 81.93634 -0.004362918 1.025231  
## [6,] 84.04496 81.93247 -0.004362918 1.025838

temps\_hw\_sf<-matrix(temps\_hw$fitted[,4],nrow=123)  
head(temps\_hw\_sf)

## [,1] [,2] [,3] [,4] [,5] [,6] [,7]  
## [1,] 1.052653 1.049468 1.120607 1.103336 1.118390 1.108172 1.140906  
## [2,] 1.100742 1.099653 1.108025 1.098323 1.110184 1.116213 1.126827  
## [3,] 1.135413 1.135420 1.139096 1.142831 1.143201 1.138495 1.129678  
## [4,] 1.110338 1.110492 1.117079 1.125774 1.134539 1.126117 1.130758  
## [5,] 1.025231 1.025233 1.044684 1.067291 1.084725 1.097239 1.115055  
## [6,] 1.025838 1.025722 1.028169 1.042340 1.053954 1.067494 1.080203  
## [,8] [,9] [,10] [,11] [,12] [,13] [,14]  
## [1,] 1.140574 1.125438 1.122063 1.161415 1.198102 1.198910 1.243012  
## [2,] 1.154074 1.142187 1.131889 1.144549 1.134661 1.153433 1.165431  
## [3,] 1.156092 1.165657 1.147982 1.149459 1.135756 1.153310 1.155197  
## [4,] 1.137722 1.150639 1.146992 1.142497 1.150162 1.151169 1.157751  
## [5,] 1.103877 1.120818 1.133733 1.132167 1.142714 1.139244 1.112909  
## [6,] 1.094312 1.102680 1.092178 1.075766 1.088547 1.082185 1.103092  
## [,15] [,16] [,17] [,18] [,19]  
## [1,] 1.243781 1.238435 1.300204 1.290647 1.254521  
## [2,] 1.172935 1.190735 1.191956 1.219190 1.228826  
## [3,] 1.157286 1.169773 1.189915 1.172309 1.169045  
## [4,] 1.163844 1.159343 1.166605 1.167993 1.158956  
## [5,] 1.132435 1.132045 1.145230 1.168161 1.170449  
## [6,] 1.115071 1.118575 1.121598 1.134962 1.145475

temps\_hw\_smoothed<-matrix(temps\_hw$fitted[,1],nrow=123)  
temps\_hw\_smoothed

## [,1] [,2] [,3] [,4] [,5] [,6] [,7]  
## [1,] 87.23653 65.04516 90.29613 83.39938 87.68863 78.07509 73.10059  
## [2,] 90.42182 84.87634 85.44878 86.44444 84.78855 86.02384 72.13247  
## [3,] 92.99734 89.61560 85.65942 92.85774 88.70570 90.23022 77.77739  
## [4,] 90.94030 88.47600 84.80741 91.55309 86.98750 87.27931 83.52416  
## [5,] 83.99917 83.11178 81.14293 88.80208 81.40681 86.06745 83.86090  
## [6,] 84.04496 88.00054 85.21673 91.04477 81.83758 87.87757 78.93483  
## [7,] 75.06333 79.16627 81.76000 85.53361 78.26787 84.57088 76.14107  
## [8,] 87.04945 101.73335 90.62904 100.56627 87.39561 89.58810 83.97486  
## [9,] 84.02220 94.23796 86.16667 94.18067 90.19628 90.87944 89.24516  
## [10,] 87.06445 98.14237 88.22532 96.51614 91.96891 90.35935 89.43210  
## [11,] 84.05272 90.55054 85.96049 95.66733 86.35832 89.97627 83.97802  
## [12,] 88.05141 95.18590 85.54340 96.95181 88.73793 85.94746 82.89367  
## [13,] 86.03178 87.51833 80.31334 94.75432 89.75739 79.69193 86.55329  
## [14,] 89.92787 91.83509 78.28257 98.14391 92.56837 84.39853 90.59650  
## [15,] 90.89514 89.77962 81.95325 96.42187 87.70892 89.31829 88.81225  
## [16,] 90.93680 90.49864 80.42732 94.77465 84.91834 92.23933 88.70603  
## [17,] 88.91874 86.35333 83.37434 91.53214 82.64572 92.02329 87.66374  
## [18,] 88.89374 88.52662 82.22725 92.27433 87.33837 93.94839 88.73723  
## [19,] 88.86666 89.96005 85.55693 95.06253 87.64849 93.63384 88.60074  
## [20,] 89.83703 93.99549 86.34055 97.56065 87.94279 91.31864 86.46959  
## [21,] 88.79334 90.99112 88.08131 97.47310 85.37091 88.94263 86.56331  
## [22,] 83.82979 85.78181 84.79696 90.90420 82.87834 92.10373 86.11103  
## [23,] 87.02152 90.94522 91.13163 95.70924 84.19253 90.45678 85.05561  
## [24,] 88.03833 92.05251 93.13039 90.76903 88.04785 87.72297 81.00385  
## [25,] 89.02771 92.45980 92.89644 84.88694 84.64987 86.63572 80.62517  
## [26,] 89.19019 88.63122 93.17998 80.37017 87.34506 90.19397 87.42373  
## [27,] 91.19587 90.34555 92.94438 81.30626 88.75419 88.74025 89.24129  
## [28,] 91.20560 84.10078 96.51293 87.96008 91.32532 88.81200 88.17203  
## [29,] 89.13435 84.66499 92.44079 88.82128 85.27144 90.97117 89.03023  
## [30,] 88.00292 86.32935 91.56319 88.71071 86.94974 89.98388 87.00091  
## [31,] 71.84081 72.35333 79.58941 75.88916 78.68154 80.44218 79.35490  
## [32,] 79.85674 89.62603 97.22483 83.24872 83.37241 84.24926 82.41633  
## [33,] 83.92934 91.73385 99.70362 86.71634 83.69269 89.48854 81.86096  
## [34,] 88.04492 89.88008 101.17300 86.71767 88.11725 93.94451 85.53327  
## [35,] 88.94256 87.19187 95.17142 88.36831 89.45440 96.47537 88.06969  
## [36,] 87.84357 85.37699 91.50010 89.43698 89.01599 95.47417 87.08129  
## [37,] 83.78960 84.06971 86.97874 87.53390 85.97577 91.15649 84.19823  
## [38,] 83.73355 86.92183 89.86943 88.26339 83.29080 94.20044 79.92442  
## [39,] 79.86675 83.93596 87.36933 86.11145 81.75216 87.13212 81.36144  
## [40,] 72.87791 77.67002 83.31669 82.17564 80.53764 81.96715 78.95256  
## [41,] 79.86607 87.94583 95.08070 95.02797 85.79337 84.81478 83.45545  
## [42,] 85.83089 93.79846 97.61011 101.68592 90.61220 88.74211 86.95630  
## [43,] 87.84293 92.23253 98.12269 95.65618 90.64831 91.80235 87.69954  
## [44,] 87.87486 87.09867 99.69677 92.58543 89.40006 92.05358 84.21165  
## [45,] 87.04117 85.49378 95.86987 89.31066 83.87936 93.69853 87.33046  
## [46,] 88.16633 83.17559 99.54801 89.55161 87.15778 90.82563 88.75194  
## [47,] 91.26671 85.43211 99.41198 96.07519 87.99513 93.16148 93.55426  
## [48,] 91.24096 85.91642 95.02883 97.79521 90.34134 92.05947 90.17042  
## [49,] 89.10351 82.91302 94.96893 98.29599 90.80802 91.37052 89.96827  
## [50,] 88.98271 85.39603 96.88707 99.59663 90.34673 91.00741 88.32648  
## [51,] 87.97149 87.21678 93.38251 94.93472 83.56428 87.35596 86.90390  
## [52,] 82.05789 76.60801 88.04839 95.02640 82.06333 88.37378 84.41198  
## [53,] 79.16500 78.30412 86.93974 87.38872 84.45364 89.76239 84.57437  
## [54,] 81.10871 85.82979 90.04738 86.28677 88.27636 89.68961 86.66974  
## [55,] 82.12695 87.70479 91.02447 85.88100 87.52209 93.57880 88.12999  
## [56,] 84.02904 90.03060 86.23211 93.36216 93.02249 93.54700 88.56826  
## [57,] 87.04126 93.25608 86.19932 97.05005 94.37828 95.15418 90.26920  
## [58,] 90.17163 95.17176 90.25019 94.02634 94.25224 92.69983 90.99857  
## [59,] 90.29310 91.58039 90.02265 93.23609 94.56528 87.20953 90.97296  
## [60,] 91.27188 91.77910 91.76475 94.11811 87.57743 87.92346 95.06476  
## [61,] 91.24459 92.67801 91.25276 92.88335 86.08974 83.00918 90.10470  
## [62,] 84.25877 86.74185 85.87526 84.38050 79.29655 77.95080 87.54900  
## [63,] 80.51733 83.90163 79.35376 82.67013 76.58676 73.34099 86.43188  
## [64,] 77.72033 79.43400 78.70182 75.36957 75.59514 75.93270 82.48520  
## [65,] 102.39420 92.98923 92.48410 80.35293 75.86207 81.04410 84.67826  
## [66,] 93.27164 79.47995 89.19763 85.65915 77.93358 91.86669 90.91723  
## [67,] 88.82479 90.03013 93.67320 88.18573 79.65148 95.20562 88.76614  
## [68,] 86.01454 93.68956 97.02477 84.82626 83.89035 90.15648 83.03239  
## [69,] 83.68771 92.42281 98.63643 73.82753 89.90097 92.74011 77.58172  
## [70,] 85.13833 91.07385 94.15698 69.87250 92.76624 93.68932 78.89113  
## [71,] 88.92440 90.14966 90.39614 69.61912 85.64102 88.07865 80.66449  
## [72,] 79.33060 78.00900 79.18668 77.36553 85.98473 90.57771 82.37925  
## [73,] 81.68431 79.82644 86.22223 80.90943 88.22035 92.75240 79.43785  
## [74,] 83.80257 82.82348 89.14082 84.54115 88.91896 94.81504 79.06885  
## [75,] 75.52504 75.86386 82.14344 81.10153 82.43692 89.59247 76.12673  
## [76,] 83.66133 83.29172 81.91655 82.36720 80.62238 78.67906 82.01736  
## [77,] 93.22283 91.17418 88.89196 87.34847 84.26284 76.02819 82.77930  
## [78,] 85.81989 85.98411 87.62050 80.19480 77.61225 84.38945 79.25579  
## [79,] 87.21610 87.39493 83.22530 77.56064 77.90599 88.22661 80.67225  
## [80,] 84.63587 83.07599 77.88723 72.31591 78.36944 85.18583 78.89491  
## [81,] 87.87254 83.45434 80.92318 72.04141 81.58531 83.76962 81.38991  
## [82,] 89.87110 81.74469 80.92710 77.95553 79.65821 80.07822 83.63612  
## [83,] 91.86176 79.40697 71.18580 86.48230 81.26794 82.70188 83.68864  
## [84,] 93.66411 79.40859 75.58365 77.69872 82.06096 81.43103 79.38081  
## [85,] 82.06845 93.28728 77.35234 79.16001 91.70378 83.05168 81.67512  
## [86,] 80.83164 88.35836 76.88652 82.11481 91.45169 79.81521 77.41456  
## [87,] 84.41654 81.90533 77.24030 83.49469 77.18130 77.37783 80.38615  
## [88,] 70.53082 83.41424 81.06037 83.51060 68.20737 73.33562 85.11016  
## [89,] 65.96298 78.33457 77.89446 70.42765 70.39825 74.35102 82.94872  
## [90,] 61.40063 81.54528 74.05394 68.30233 71.92505 73.68730 82.22943  
## [91,] 62.84325 78.93023 75.58507 69.58934 72.02505 71.81394 70.65449  
## [92,] 63.61506 69.29105 71.16071 66.43030 67.15638 69.24549 66.25543  
## [93,] 79.91419 69.89014 69.97230 71.26502 68.48675 74.66196 68.11505  
## [94,] 83.92780 85.64960 72.46503 75.32378 72.56235 79.35970 70.13701  
## [95,] 90.12375 93.54797 83.62868 87.10251 84.63747 87.57926 71.80614  
## [96,] 67.32195 74.51818 79.80358 77.83223 78.02723 82.03899 66.14609  
## [97,] 69.67696 74.65890 70.16830 77.82944 77.50004 80.11634 72.37049  
## [98,] 74.35139 76.00527 67.12308 75.30142 72.17815 76.81786 69.48795  
## [99,] 74.14035 69.58630 68.02458 72.52493 68.58443 80.21850 69.22061  
## [100,] 102.73294 93.58477 77.79141 72.88139 69.54055 83.94891 72.33510  
## [101,] 80.78130 73.89895 75.07664 62.36809 78.71319 74.38168 71.97988  
## [102,] 82.72991 74.94450 75.40762 59.53633 76.13751 76.58724 80.85507  
## [103,] 78.91909 71.43955 72.72821 62.44792 75.25418 74.16946 80.09855  
## [104,] 80.82615 74.51851 71.35147 65.95246 72.75906 75.27793 71.11802  
## [105,] 84.30297 80.57035 72.90673 70.92210 75.95880 79.90219 72.81309  
## [106,] 88.32901 81.50619 68.81487 78.48328 80.78218 81.24465 75.01762  
## [107,] 77.73427 80.40923 76.41455 78.14257 79.56998 75.56592 77.55380  
## [108,] 67.82727 79.21806 74.04565 78.55924 78.41245 62.99156 76.36359  
## [109,] 62.68712 84.45198 80.29879 83.33821 70.77160 68.25243 75.74947  
## [110,] 52.09185 66.28908 70.11921 71.38738 58.17941 62.95470 70.14452  
## [111,] 56.72255 70.02729 67.26600 72.51486 57.12541 62.58532 67.03403  
## [112,] 69.37749 80.44384 65.91991 71.02641 64.32625 65.56891 69.34518  
## [113,] 81.04889 86.58862 68.39817 79.82001 76.84533 74.11298 76.46493  
## [114,] 76.18954 79.19245 65.62063 79.60737 81.92503 74.84775 81.99313  
## [115,] 57.53302 62.96712 67.13764 71.55955 73.76098 63.82339 75.76154  
## [116,] 64.48533 64.91087 64.11453 78.96585 82.09923 62.14080 81.62032  
## [117,] 63.00914 72.43246 62.85827 80.63005 84.82826 67.85428 75.27271  
## [118,] 72.30786 73.10585 63.33752 79.84462 77.87388 62.62527 76.69680  
## [119,] 71.50660 73.25489 63.76594 74.48394 68.76195 63.83408 69.01589  
## [120,] 67.54725 83.28482 74.61136 77.92048 58.55706 71.59036 69.98451  
## [121,] 60.54091 86.39494 78.01719 82.87582 57.40645 77.53892 64.14973  
## [122,] 62.64525 81.14651 76.06534 81.01774 63.85349 80.16958 69.44403  
## [123,] 63.87067 78.67855 72.54863 76.32379 67.95633 70.62168 72.01451  
## [,8] [,9] [,10] [,11] [,12] [,13] [,14]  
## [1,] 87.27074 92.29714 78.50826 81.58696 84.72917 79.51855 86.74604  
## [2,] 85.01878 92.85614 88.18138 88.52648 80.39548 85.65722 81.47324  
## [3,] 82.68648 92.33884 92.43570 86.72311 84.53380 88.31357 82.29310  
## [4,] 83.37312 87.29596 92.69774 83.30574 89.62822 88.56597 82.90566  
## [5,] 83.64904 84.25223 90.58916 84.18954 89.27001 89.12501 80.92784  
## [6,] 86.79140 85.75665 86.91496 82.21750 84.28967 79.32562 84.52016  
## [7,] 83.56614 78.99398 78.93860 82.18499 79.01020 82.40393 84.70387  
## [8,] 86.98872 76.21770 81.64559 84.02962 86.14848 85.10549 89.42264  
## [9,] 87.22847 83.84048 80.84969 82.33899 89.94650 83.57984 95.37129  
## [10,] 86.91074 86.49872 79.47922 83.27640 85.29171 80.53253 92.70088  
## [11,] 87.19963 80.48580 83.84717 86.86739 87.29068 83.56512 91.77443  
## [12,] 88.43501 81.15168 87.18261 84.78976 88.26559 85.57226 93.50424  
## [13,] 90.01499 85.38235 89.45464 85.61502 90.20861 85.31346 87.05043  
## [14,] 92.92808 86.10074 92.60545 87.29938 87.66498 86.30815 92.28340  
## [15,] 95.04134 87.78374 91.74219 85.55576 87.85776 88.11929 91.25794  
## [16,] 90.36134 88.48017 94.59590 85.19467 92.43042 91.54215 95.41881  
## [17,] 86.06863 86.86866 94.22949 87.88149 92.69411 92.69103 92.88917  
## [18,] 85.41217 89.62795 94.60852 89.56814 90.45596 91.36843 89.70901  
## [19,] 86.72704 89.24987 92.85066 89.43312 90.20432 85.88472 86.56570  
## [20,] 83.78099 89.27980 94.97641 87.71559 89.76851 82.06281 89.80443  
## [21,] 85.72139 88.22030 93.28070 86.54729 92.51414 81.81726 91.27362  
## [22,] 85.27142 86.89919 91.08497 84.37429 90.87129 81.30105 89.22953  
## [23,] 85.68380 88.20785 89.51888 79.05664 91.26066 81.63059 91.87978  
## [24,] 89.64251 88.94918 86.05574 80.53402 89.01940 85.96190 95.38045  
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I am using the predicted value (Xhat) and the observed value (data from original temps.txt) to see if summer has gotten later over the 20 years. When the difference between the predicted value and the observed value reached max, which means predicted value is much higher than the observed value, among the whole period, I assume that day is the summer end date (the model thought the temperature was still high, while the actual temperature already went down). Then I compare the date from year 1997 to year 2015 to see how the date varies.

fit<-temps\_hw$fitted  
  
y1997<- data.frame(fit = fit[1:123,1], obs = temps[,2])  
y1997$dif <-y1997$fit - y1997$obs  
head(y1997)

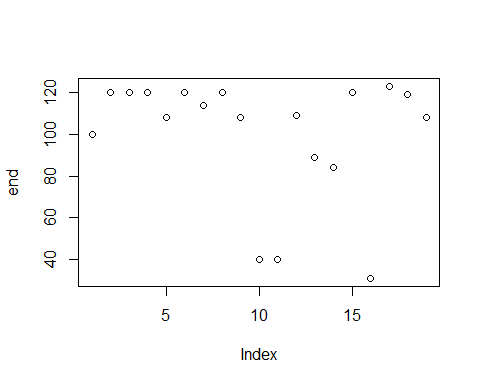
## fit obs dif  
## 1 87.23653 98 -10.7634671  
## 2 90.42182 97 -6.5781811  
## 3 92.99734 97 -4.0026586  
## 4 90.94030 90 0.9402979  
## 5 83.99917 89 -5.0008320  
## 6 84.04496 93 -8.9550380

a<-which.max(y1997$dif)  
y1997[which.max(y1997$dif),]

## fit obs dif  
## 100 102.7329 78 24.73294

the 100th day is the day where predicted tempererature is much higher than the actual temperature.

y1998<- data.frame(fit = fit[124:246,1], obs = temps[,3])  
y1998$dif <-y1998$fit - y1998$obs  
b<-which.max(y1998$dif)  
  
y1999<- data.frame(fit = fit[247:369,1], obs = temps[,3])  
y1999$dif <-y1999$fit - y1999$obs  
c<-which.max(y1999$dif)  
  
y2000<- data.frame(fit = fit[370:492,1], obs = temps[,3])  
y2000$dif <-y2000$fit - y2000$obs  
d<-which.max(y2000$dif)  
  
y2001<- data.frame(fit = fit[493:615,1], obs = temps[,3])  
y2001$dif <-y2001$fit - y2001$obs  
e<-which.max(y2001$dif)  
  
y2002<- data.frame(fit = fit[616:738,1], obs = temps[,3])  
y2002$dif <-y2002$fit - y2002$obs  
f<-which.max(y2002$dif)  
  
y2003<- data.frame(fit = fit[739:861,1], obs = temps[,3])  
y2003$dif <-y2003$fit - y2003$obs  
g<-which.max(y2003$dif)  
  
y2004<- data.frame(fit = fit[862:984,1], obs = temps[,3])  
y2004$dif <-y2004$fit - y2004$obs  
h<-which.max(y2004$dif)  
  
y2005<- data.frame(fit = fit[985:1107,1], obs = temps[,3])  
y2005$dif <-y2005$fit - y2005$obs  
i<-which.max(y2005$dif)  
  
y2006<- data.frame(fit = fit[1108:1230,1], obs = temps[,3])  
y2006$dif <-y2006$fit - y2006$obs  
j<-which.max(y2006$dif)  
  
y2007<- data.frame(fit = fit[1231:1353,1], obs = temps[,3])  
y2007$dif <-y2007$fit - y2007$obs  
k<-which.max(y2007$dif)  
  
y2008<- data.frame(fit = fit[1354:1476,1], obs = temps[,3])  
y2008$dif <-y2008$fit - y2008$obs  
l<-which.max(y2008$dif)  
  
y2009<- data.frame(fit = fit[1477:1599,1], obs = temps[,3])  
y2009$dif <-y2009$fit - y2009$obs  
m<-which.max(y2009$dif)  
  
y2010<- data.frame(fit = fit[1600:1722,1], obs = temps[,3])  
y2010$dif <-y2010$fit - y2010$obs  
n<-which.max(y2010$dif)  
  
y2011<- data.frame(fit = fit[1723:1845,1], obs = temps[,3])  
y2011$dif <-y2011$fit - y2011$obs  
o<-which.max(y2011$dif)  
  
y2012<- data.frame(fit = fit[1846:1968,1], obs = temps[,3])  
y2012$dif <-y2012$fit - y2012$obs  
p<-which.max(y2012$dif)  
  
y2013<- data.frame(fit = fit[1969:2091,1], obs = temps[,3])  
y2013$dif <-y2013$fit - y2013$obs  
q<-which.max(y2013$dif)  
  
y2014<- data.frame(fit = fit[2092:2214,1], obs = temps[,3])  
y2014$dif <-y2014$fit - y2014$obs  
r<-which.max(y2014$dif)  
  
y2015<- data.frame(fit = fit[2215:2337,1], obs = temps[,3])  
y2015$dif <-y2015$fit - y2015$obs  
s<-which.max(y2015$dif)  
  
end<-c(a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s)  
plot(end)



The plot shows the end days stays within a range of 100 -120 days from July 1st. So I would say the summer does not get later over the 20 years.

# Question 8.1

Describe a situation or problem from your job, everyday life, current events, etc., for which a linear regression model would be appropriate. List some (up to 5) predictors that you might use. My answer:

The height of an adult predictors: mother’s height father’s height gender calories intake each week height at age ten

# Question 8.2

Using crime data from <http://www.statsci.org/data/general/uscrime.txt> (file uscrime.txt,description at <http://www.statsci.org/data/general/uscrime.html> ), use regression (a useful R function is lm or glm) to predict the observed crime rate in a city with the following data: M = 14.0 So = 0 Ed = 10.0 Po1 = 12.0 Po2 = 15.5 LF = 0.640 M.F = 94.0 Pop = 150 NW = 1.1 U1 = 0.120 U2 = 3.6 Wealth = 3200 Ineq = 20.1 Prob = 0.04 Time = 39.0

Show your model (factors used and their coefficients), the software output, and the quality of fit.

crime<- read.table("http://www.statsci.org/data/general/uscrime.txt",header=TRUE)  
head(crime)

## M So Ed Po1 Po2 LF M.F Pop NW U1 U2 Wealth Ineq  
## 1 15.1 1 9.1 5.8 5.6 0.510 95.0 33 30.1 0.108 4.1 3940 26.1  
## 2 14.3 0 11.3 10.3 9.5 0.583 101.2 13 10.2 0.096 3.6 5570 19.4  
## 3 14.2 1 8.9 4.5 4.4 0.533 96.9 18 21.9 0.094 3.3 3180 25.0  
## 4 13.6 0 12.1 14.9 14.1 0.577 99.4 157 8.0 0.102 3.9 6730 16.7  
## 5 14.1 0 12.1 10.9 10.1 0.591 98.5 18 3.0 0.091 2.0 5780 17.4  
## 6 12.1 0 11.0 11.8 11.5 0.547 96.4 25 4.4 0.084 2.9 6890 12.6  
## Prob Time Crime  
## 1 0.084602 26.2011 791  
## 2 0.029599 25.2999 1635  
## 3 0.083401 24.3006 578  
## 4 0.015801 29.9012 1969  
## 5 0.041399 21.2998 1234  
## 6 0.034201 20.9995 682

model1<-lm(Crime~.,crime)  
summary(model1)

##   
## Call:  
## lm(formula = Crime ~ ., data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -395.74 -98.09 -6.69 112.99 512.67   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -5.984e+03 1.628e+03 -3.675 0.000893 \*\*\*  
## M 8.783e+01 4.171e+01 2.106 0.043443 \*   
## So -3.803e+00 1.488e+02 -0.026 0.979765   
## Ed 1.883e+02 6.209e+01 3.033 0.004861 \*\*   
## Po1 1.928e+02 1.061e+02 1.817 0.078892 .   
## Po2 -1.094e+02 1.175e+02 -0.931 0.358830   
## LF -6.638e+02 1.470e+03 -0.452 0.654654   
## M.F 1.741e+01 2.035e+01 0.855 0.398995   
## Pop -7.330e-01 1.290e+00 -0.568 0.573845   
## NW 4.204e+00 6.481e+00 0.649 0.521279   
## U1 -5.827e+03 4.210e+03 -1.384 0.176238   
## U2 1.678e+02 8.234e+01 2.038 0.050161 .   
## Wealth 9.617e-02 1.037e-01 0.928 0.360754   
## Ineq 7.067e+01 2.272e+01 3.111 0.003983 \*\*   
## Prob -4.855e+03 2.272e+03 -2.137 0.040627 \*   
## Time -3.479e+00 7.165e+00 -0.486 0.630708   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 209.1 on 31 degrees of freedom  
## Multiple R-squared: 0.8031, Adjusted R-squared: 0.7078   
## F-statistic: 8.429 on 15 and 31 DF, p-value: 3.539e-07

I am using 0.05 as the threshold. Based on the p-value, I will keep M,Ed,Ineq,Prob,to fit a new model.

model2<-lm(Crime~M+Ed+Ineq+Prob,crime)  
summary(model2)

##   
## Call:  
## lm(formula = Crime ~ M + Ed + Ineq + Prob, data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -532.97 -254.03 -55.72 137.80 960.21   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1339.35 1247.01 -1.074 0.28893   
## M 35.97 53.39 0.674 0.50417   
## Ed 148.61 71.92 2.066 0.04499 \*   
## Ineq 26.87 22.77 1.180 0.24458   
## Prob -7331.92 2560.27 -2.864 0.00651 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 347.5 on 42 degrees of freedom  
## Multiple R-squared: 0.2629, Adjusted R-squared: 0.1927   
## F-statistic: 3.745 on 4 and 42 DF, p-value: 0.01077

Now only the Ed and Prob still remains significant. The adjusted R-squred dropped from 0.7078 to 0.1927. I will fit a new model to see what happens.

model3<-lm(Crime~Ed+Prob,crime)  
summary(model3)

##   
## Call:  
## lm(formula = Crime ~ Ed + Prob, data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -650.98 -279.57 -14.06 198.00 957.48   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 517.30 588.48 0.879 0.3842   
## Ed 63.67 50.26 1.267 0.2119   
## Prob -6049.00 2472.93 -2.446 0.0185 \*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 351.2 on 44 degrees of freedom  
## Multiple R-squared: 0.2115, Adjusted R-squared: 0.1756   
## F-statistic: 5.899 on 2 and 44 DF, p-value: 0.005373

Now only Prob remains significant. The adjusted R-squred dropped from 0.1927. to 0.1756. So the first model with all the variables included truns out to be the best model so far. Next, I will try to use every combination to find the “best” model.

create a NULL vector called model so we have something to add our layers to

model<-NULL

create a vector of the dataframe column names used to build the formula

vars <-names(crime)

Remove the response variable (it’s in the 16th column)

vars <-vars[-16]

The combn function will run every different combination of variables and then run the lm

for(i in 1:length(vars)){  
 xx = combn(vars,i)  
 if(is.null(dim(xx))){  
 fla = paste("Crime ~", paste(xx, collapse="+"))  
 model[[length(model)+1]]=lm(as.formula(fla),data=crime)  
 } else {  
 for(j in 1:dim(xx)[2]){  
 fla = paste("Crime ~", paste(xx[1:dim(xx)[1],j], collapse="+"))  
 model[[length(model)+1]]=lm(as.formula(fla),data=crime)   
 }  
 }  
 }

see how many models were build using the loop above

length(model)

## [1] 32767

create a vector to extract AIC and BIC values from the model variable

AICs <- NULL  
BICs <- NULL  
 for(i in 1:length(model)){  
 AICs[i] = AIC(model[[i]])  
 BICs[i] = BIC(model[[i]])  
 }

see which models were chosen as best by AIC and BIC

which(AICs==min(AICs))

## [1] 18494

which(BICs==min(BICs))

## [1] 5817

see which variables are in those models, and the corresponding adjusted R-squared.

summary(model[[18494]])

##   
## Call:  
## lm(formula = as.formula(fla), data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -444.70 -111.07 3.03 122.15 483.30   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -6426.10 1194.61 -5.379 4.04e-06 \*\*\*  
## M 93.32 33.50 2.786 0.00828 \*\*   
## Ed 180.12 52.75 3.414 0.00153 \*\*   
## Po1 102.65 15.52 6.613 8.26e-08 \*\*\*  
## M.F 22.34 13.60 1.642 0.10874   
## U1 -6086.63 3339.27 -1.823 0.07622 .   
## U2 187.35 72.48 2.585 0.01371 \*   
## Ineq 61.33 13.96 4.394 8.63e-05 \*\*\*  
## Prob -3796.03 1490.65 -2.547 0.01505 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 195.5 on 38 degrees of freedom  
## Multiple R-squared: 0.7888, Adjusted R-squared: 0.7444   
## F-statistic: 17.74 on 8 and 38 DF, p-value: 1.159e-10

summary(model[[24966]])

##   
## Call:  
## lm(formula = as.formula(fla), data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -457.83 -109.01 -4.51 125.53 495.77   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -6280.671 1350.943 -4.649 4.15e-05 \*\*\*  
## M 95.131 34.736 2.739 0.009431 \*\*   
## Ed 178.983 53.626 3.338 0.001935 \*\*   
## Po1 102.721 15.722 6.533 1.20e-07 \*\*\*  
## M.F 21.191 14.569 1.454 0.154240   
## U1 -6160.110 3395.044 -1.814 0.077724 .   
## U2 189.483 73.930 2.563 0.014578 \*   
## Ineq 61.562 14.167 4.346 0.000104 \*\*\*  
## Prob -4066.106 1877.730 -2.165 0.036873 \*   
## Time -1.431 5.920 -0.242 0.810259   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 198 on 37 degrees of freedom  
## Multiple R-squared: 0.7892, Adjusted R-squared: 0.7379   
## F-statistic: 15.39 on 9 and 37 DF, p-value: 4.971e-10

summary(model[[5817]])

##   
## Call:  
## lm(formula = as.formula(fla), data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -470.68 -78.41 -19.68 133.12 556.23   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -5040.50 899.84 -5.602 1.72e-06 \*\*\*  
## M 105.02 33.30 3.154 0.00305 \*\*   
## Ed 196.47 44.75 4.390 8.07e-05 \*\*\*  
## Po1 115.02 13.75 8.363 2.56e-10 \*\*\*  
## U2 89.37 40.91 2.185 0.03483 \*   
## Ineq 67.65 13.94 4.855 1.88e-05 \*\*\*  
## Prob -3801.84 1528.10 -2.488 0.01711 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 200.7 on 40 degrees of freedom  
## Multiple R-squared: 0.7659, Adjusted R-squared: 0.7307   
## F-statistic: 21.81 on 6 and 40 DF, p-value: 3.418e-11

summary(model[[11564]])

##   
## Call:  
## lm(formula = as.formula(fla), data = crime)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -480.89 -89.12 -6.63 140.27 576.79   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -4911.094 960.729 -5.112 8.79e-06 \*\*\*  
## M 106.659 33.877 3.148 0.003144 \*\*   
## Ed 189.408 48.288 3.922 0.000345 \*\*\*  
## Po1 115.704 13.993 8.269 4.16e-10 \*\*\*  
## U2 88.720 41.364 2.145 0.038249 \*   
## Ineq 67.728 14.083 4.809 2.28e-05 \*\*\*  
## Prob -4249.756 1880.672 -2.260 0.029502 \*   
## Time -2.310 5.538 -0.417 0.678810   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 202.8 on 39 degrees of freedom  
## Multiple R-squared: 0.7669, Adjusted R-squared: 0.7251   
## F-statistic: 18.33 on 7 and 39 DF, p-value: 1.553e-10

From the output, we can see the first two are the same model, and the last two are the same model. I will compare these two models with the model1, which has all the variables included

library(data.table)

## Warning: package 'data.table' was built under R version 3.5.2

AIC(model1,model[[18494]],model[[5817]])

## df AIC  
## model1 17 650.0291  
## model[[18494]] 10 639.3151  
## model[[5817]] 8 640.1661

BIC(model1,model[[18494]],model[[5817]])

## df BIC  
## model1 17 681.4816  
## model[[18494]] 10 657.8166  
## model[[5817]] 8 654.9673

data.table(model1=0.7078,model18494=0.7444,model5817=0.7307)

## model1 model18494 model5817  
## 1: 0.7078 0.7444 0.7307

In conclusion, I would say model18494 is the best model I can found. The equation of the model is: crime= -6426.10+93.32*M+180.12*Ed+102.65*Po1+22.34*M.F-6086.63*U1+187.35*U2+61.33*Ineq-3796.03*Prob

The corresponding AIC is 639.3151, BIC is 657.8166, and the adjusted R-squared is 0.7444

Use the seleted model to find the crime rate in the city with data provided:

crimerate=-6426.10+93.32\*14.0+180.12\*10.0+102.65\*12.0+22.34\*94.0-6086.63\*0.120+187.35\*3.6+61.33\*20.1-3796.03\*0.04   
crimerate

## [1] 1038.296