

Advanced Statistical Modeling

Non-parametric models - Estimating conditional variance

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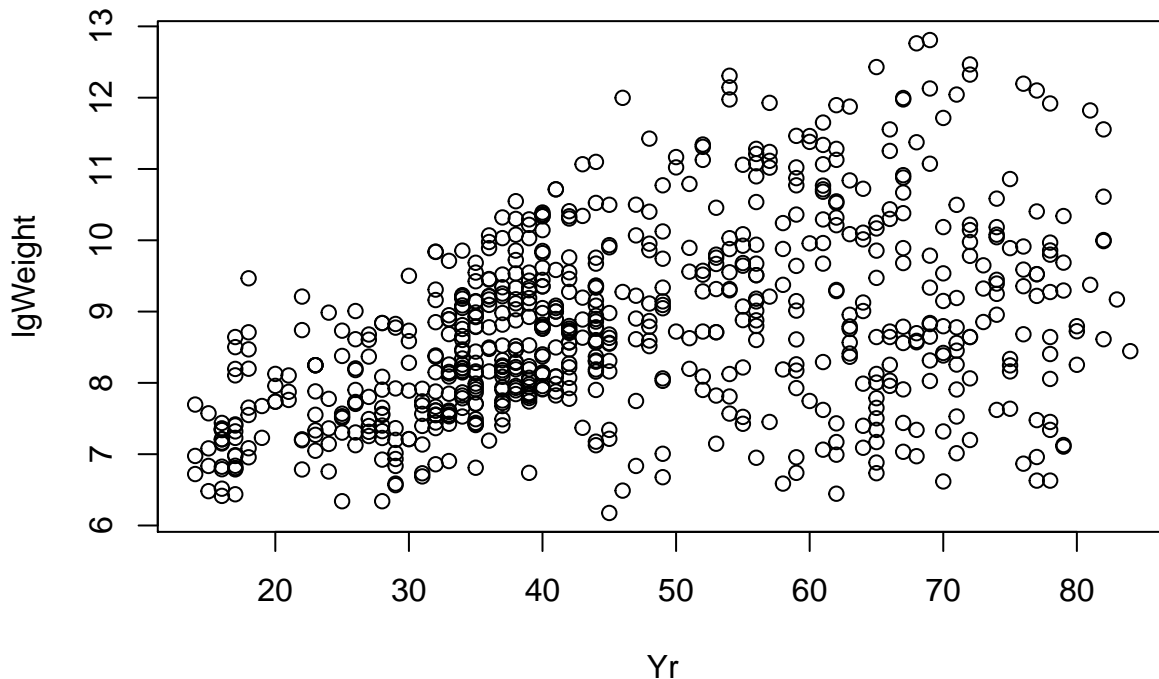
Having the heteroscedastic regression model

$$Y = m(x) + \sigma(x)\varepsilon = m(x) + \epsilon,$$

, where $E(\varepsilon) = 0, V(\varepsilon) = 1$

we want to estimate the function that represents the conditional variance σ^2 of the variable lgWeight (log(Weight)) from the aircraft dataset, given that the explanatory variable (Yr) is equal to a value x . We will use nonparametric methods to do that. Below is the plot of the response variable vs the explanatory variable.

```
data(aircraft)
attach(aircraft)
lgWeight <- log(Weight)
plot(Yr, lgWeight)
```



Initially, we are going to fit a local linear regression model to obtain an estimation $\hat{m}(x)$ of every point x . The general idea is to build a grid of intervals (t_i) centered around each point x and estimate a local linear regression in each interval. Doing this, we are going to try multiple values for the smoothing parameter h , which controls weight concentration around each point x .

To make the regression function smooth weights are assigned to each pair (t_i, y_i) using a kernel function, which, in this case, is the Normal density function centered at 0, with h as standard deviation.

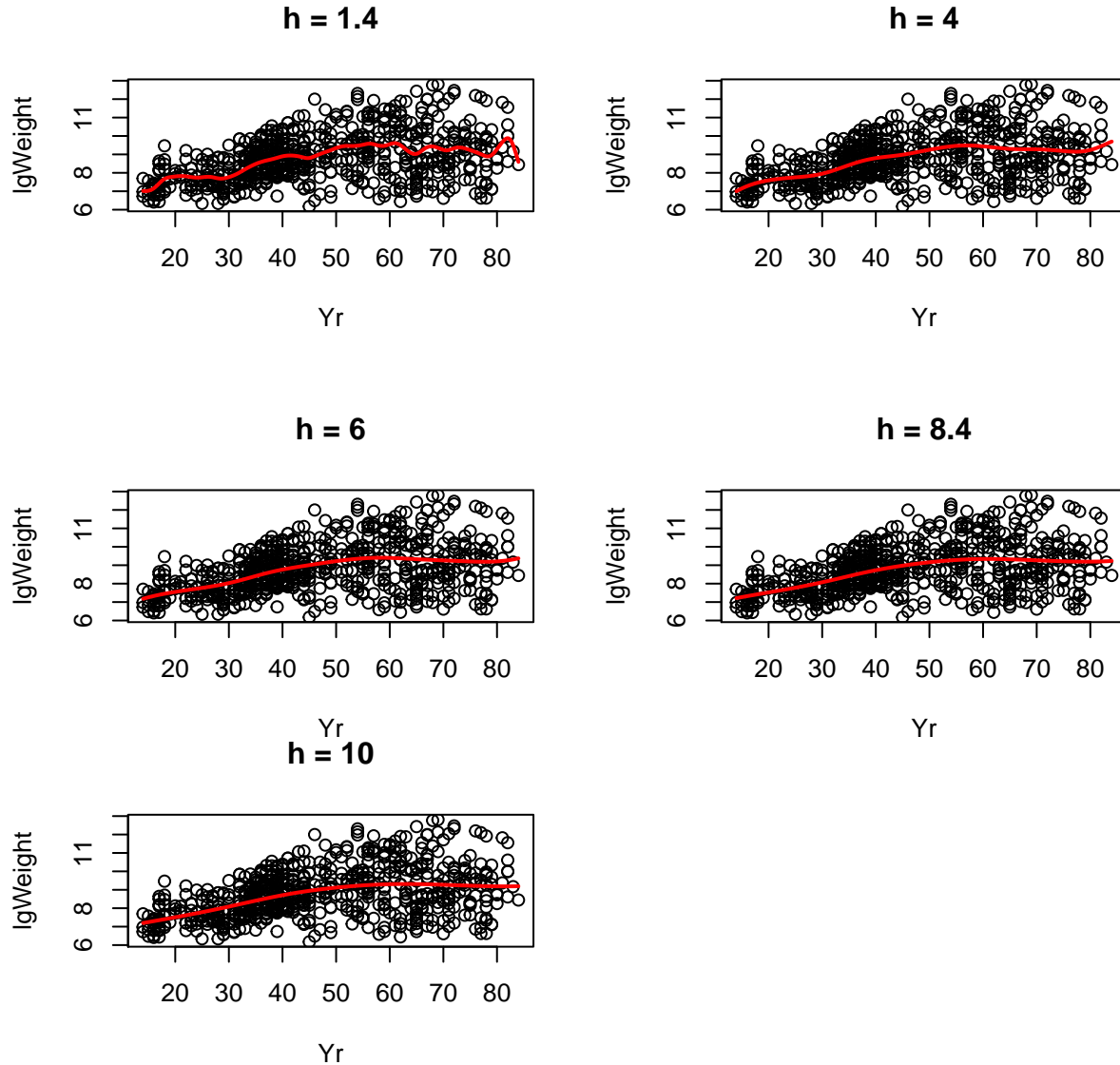
The result is shown below, where we can see a smooth function (in red) of the estimates.

```
# step 1 Fit a nonparametric regression to data (xi,yi) and save
# the estimated values m-hat(xi).
par(mfrow=c(2,2))
```

```

hs <- c(1.4,4,6,8.4,10)
tg = seq(min(Yr), max(Yr), length=709)
for (h in hs) {
  llr <- loc.lin.reg(x=Yr, y=lgWeight, h=h, tg=tg)
  plot(Yr,lgWeight, main = paste("h = ", h, sep = ""))
  lines(tg, llr$mt, col=2, lwd=2)
}

```



Changing the smoothing parameter we can see that as h increases the function curve becomes smoother. We will choose the combination $h = 4$

```

h <- 4
llr <- loc.lin.reg(x=Yr, y=lgWeight, h=h, tg=tg)

```

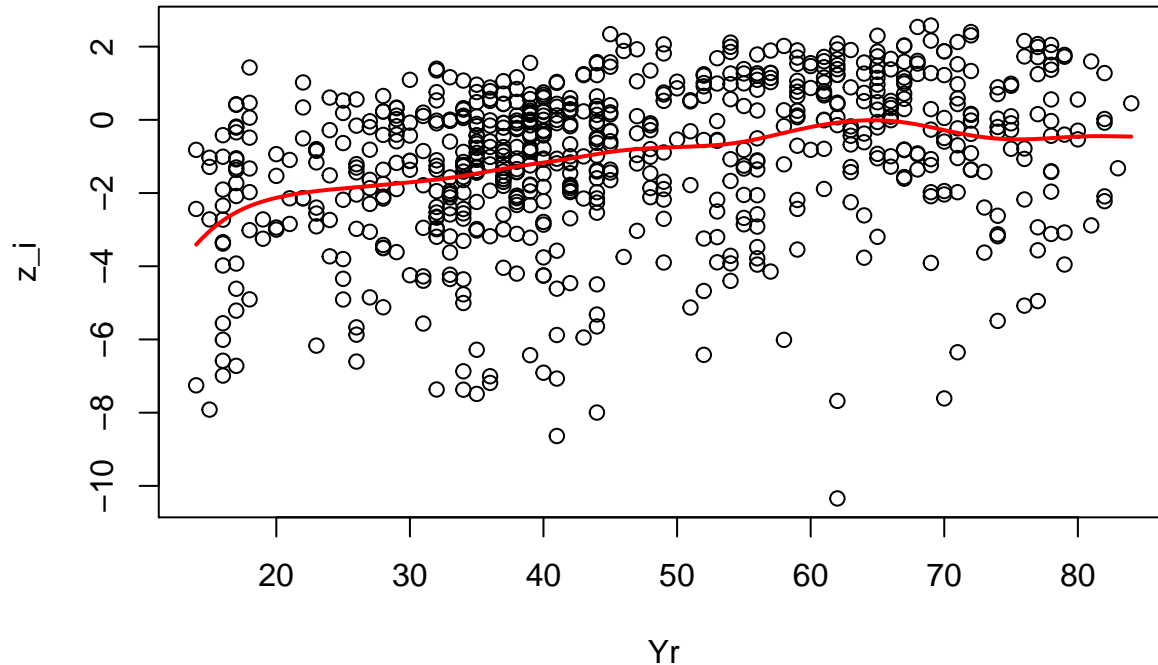
Now we are going to transform the estimated residuals applying logarithm to the square of it $\hat{\epsilon}_i = (y_i - \hat{m}(x_i))^2$, which represents the variance (the square deviation) of the model.

$$z_i = \log \epsilon_i^2 = \log((y_i - \hat{m}(x_i))^2)$$

```
# step 2 Transform the estimated residuals  $z_i = \log((y_i - \text{llr}\$mt)^2)$ 
z_i = log((lgWeight - llr$mt)^2)
```

Then we perform a nonparametric regression over (x_i, z_i) to obtain the estimation of the (logarithm of the) variance $\log\sigma^2(x)$.

```
# step 3 Fit a nonparametric regression to data (Yr, z_i) and
# call the estimated function  $\hat{q}(x)$ .
llr2 <- loc.lin.reg(x=Yr, y=z_i, h=h, tg=tg)
plot(Yr, z_i)
lines(tg, llr2$mt, col=2, lwd=2)
```

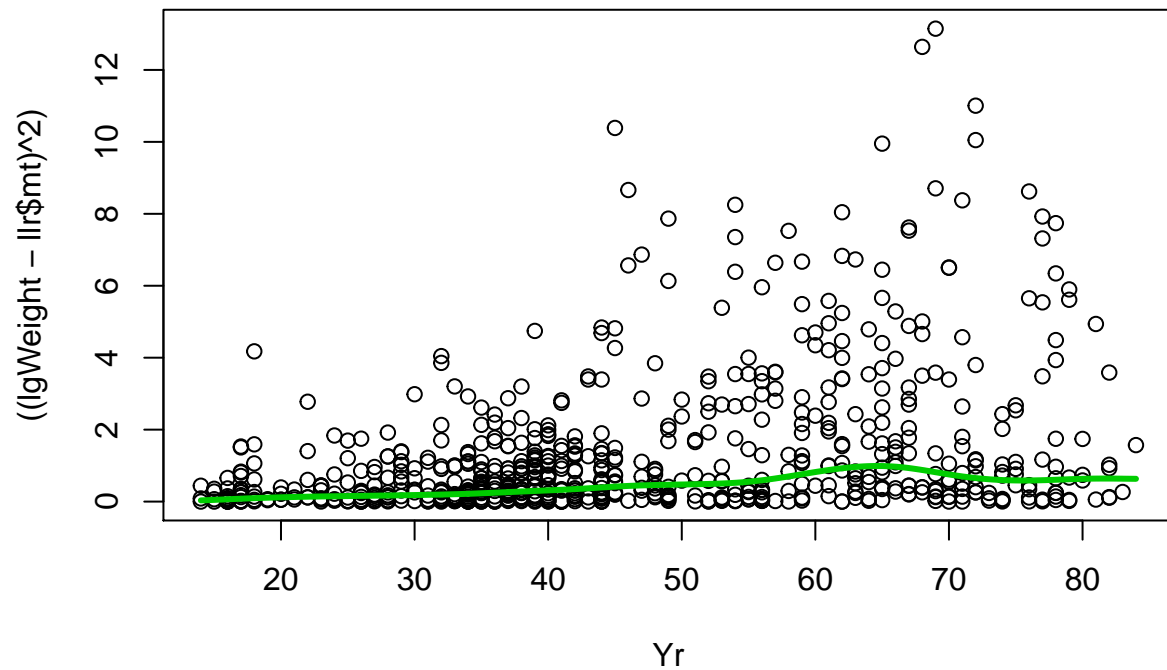


Finally, we can obtain the conditional variance applying exponential to the estimation obtained before

```
# step 4 Estimate  $\sigma_2(x)$ 
sigma_2 = exp(llr2$mt)
```

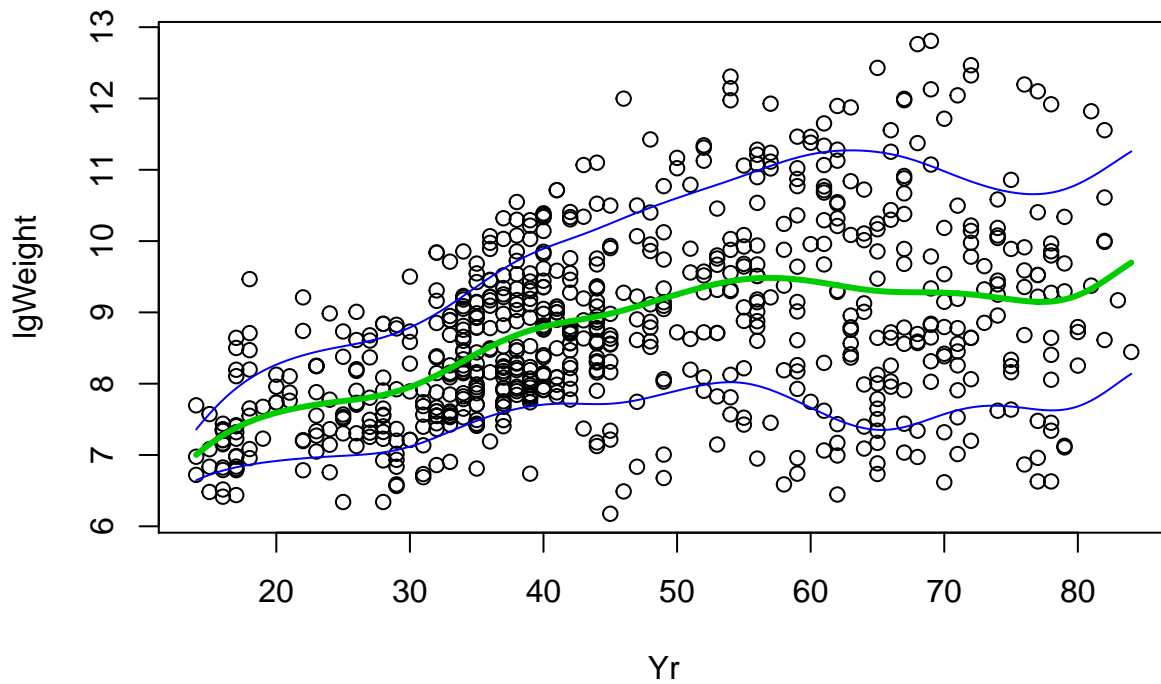
Plotting the residuals against x_i we superimpose the estimated function $\hat{\sigma}^2(x)$

```
plot(Yr, ((lgWeight - llr$mt)^2)) # residual square against  $x_i$ 
lines(tg, sigma_2, col=3, lwd=3)
```



Here we present the draw of the function $\hat{m}(x)$ and the superimposed bands $\hat{m}(x) \pm 1.96\hat{\sigma}(x)$

```
sigma = sqrt(sigma_2)
plot(Yr,lgWeight)
lines(tg,llr$mt,col=3,lwd=3) # mt from step 1
lines(tg,llr$mt+1.96*sigma,col=4,lwd=1)
lines(tg,llr$mt-1.96*sigma,col=4,lwd=1)
```



After fitting a linear regression we are going to try with local polynomial regression of different degrees, using normalechnikov as the kernel function.

```

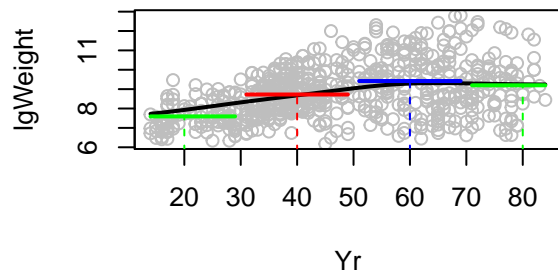
par(mfrow=c(2,2))

degrees <- c(0,1,2,3,4,5)

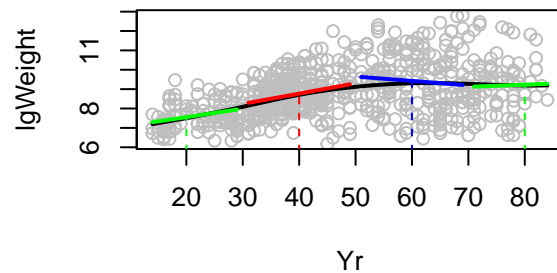
for (d in degrees) {
  lpr_visual(x=Yr, y=lgWeight, h=10, q=d, tg=c(20,40,60,80), #
    xlab="Yr", ylab="lgWeight",
    main=paste('Degree local pol.: q = ', d, sep = ""), type.kernel="normal")
}

```

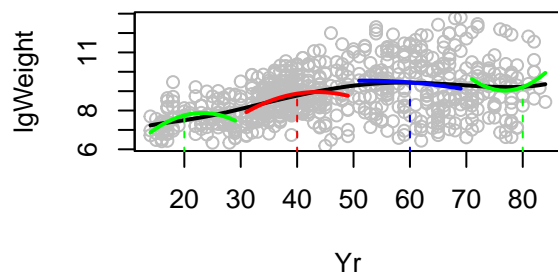
Degree local pol.: q = 0



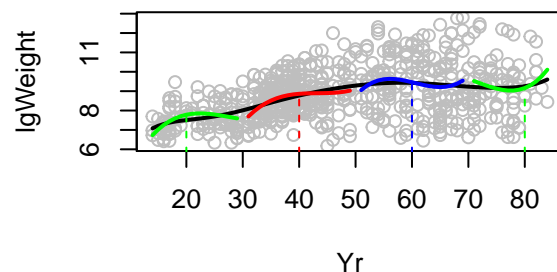
Degree local pol.: q = 1



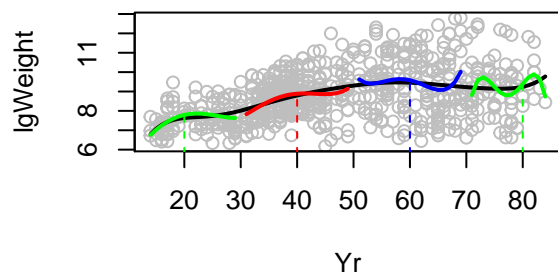
Degree local pol.: q = 2



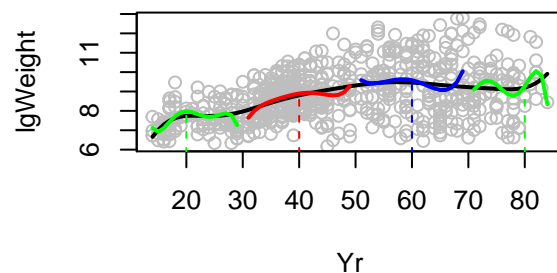
Degree local pol.: q = 3



Degree local pol.: q = 4



Degree local pol.: q = 5



We can see that the degree that allows to approximate better the curve is 3, therefore, we are going to use this degree and variate the smoothing parameter to obtain the best fit.

```

par(mfrow=c(2,2))
degree <- 3
hs <- c(10,13,16,20)
for (h in hs) {
  lpr_visual(x=Yr, y=lgWeight, h=h, q=degree, tg=c(20,40,60,80),
    xlab="Yr", ylab="lgWeight",

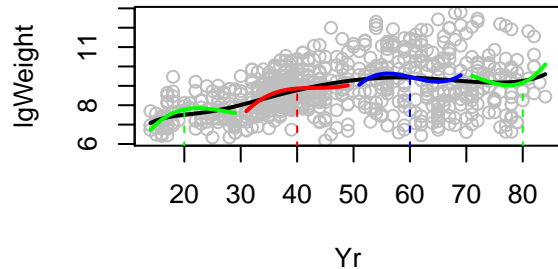
```

```

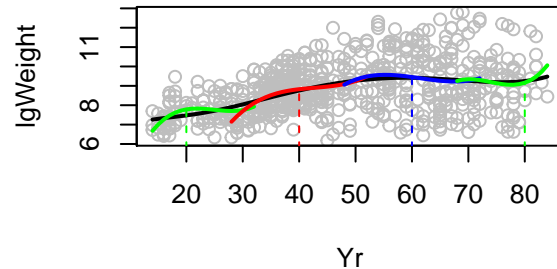
    main=paste('Degree local pol.: q =', paste(degree, paste(", h = ", h))),
    type.kernel="normal")
}

```

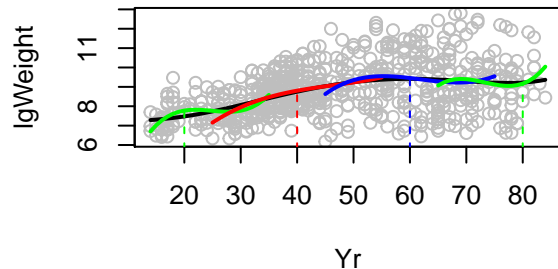
Degree local pol.: q = 3 , h = 10



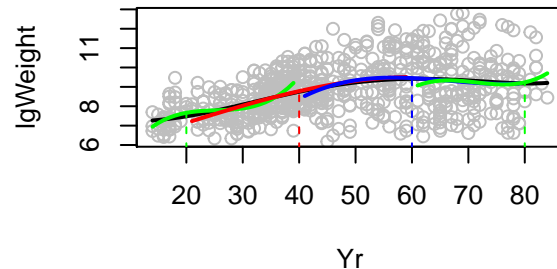
Degree local pol.: q = 3 , h = 13



Degree local pol.: q = 3 , h = 16



Degree local pol.: q = 3 , h = 20



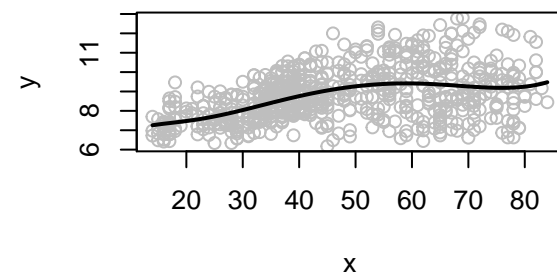
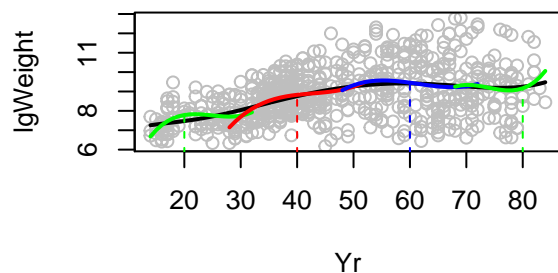
After tuning the smoothing parameter h we see that the best fit was obtained using $h = 13$, and we will build the polynomial regression with this

```

par(mfrow=c(2,2))
h <- 13
lpr_visual(x=Yr, y=lgWeight, h=h, q=degree, tg=c(20,40,60,80),
           xlab="Yr", ylab="lgWeight",
           main=paste('Degree local pol.: q =', paste(degree, paste(", h = ", h))), type.kernel="normal")
lpr <- locpolreg(x=Yr, y=lgWeight, h=h, q=degree, r=0, type.kernel="normal")

```

Degree local pol.: q = 3 , h = 13



Repeating the same procedure we used before for the local linear regression, we will transform the estimated residuals and perform the polynomial regression over z_i

```

par(mfrow=c(1,1))
# step 2 Transform the estimated residuals  $z_i = \log((y_i - lpr\$mtgr)^2)$ 

```

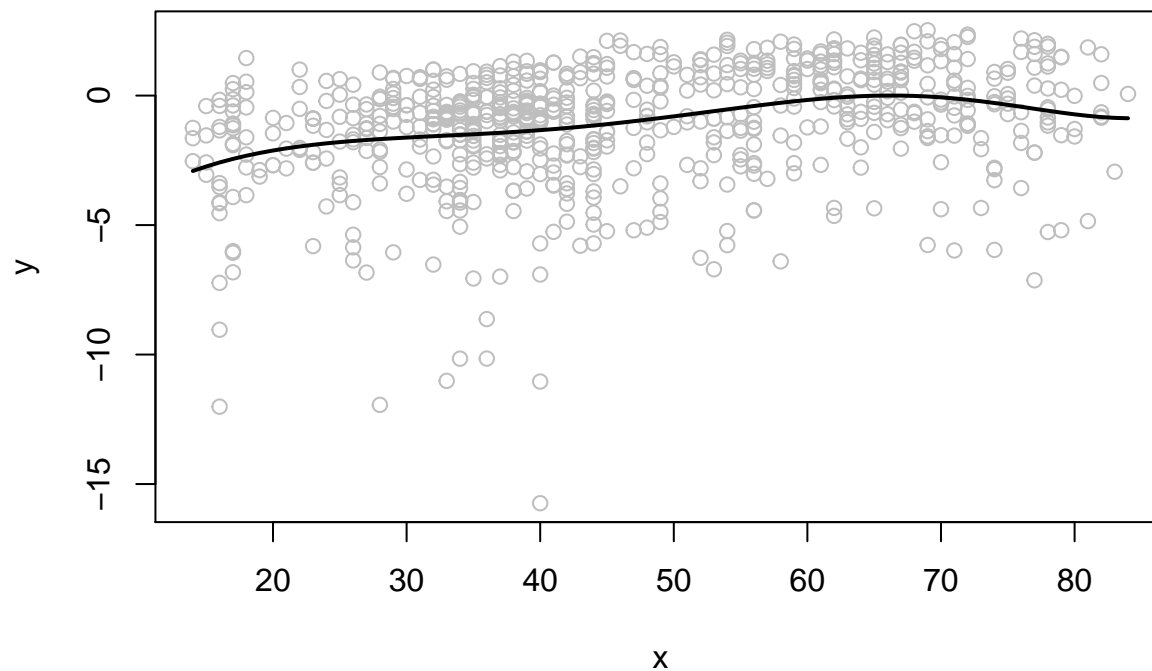
```

z_i = log((lgWeight - lpr$mtgr)^2)

# step 3 Fit a nonparametric regression to data (Yr,z_i) and
# call the estimated function  $\hat{q}(x)$ .
lpr2 <- locpolreg(x=Yr, y=z_i, h=h, q=degree, r=0, type.kernel="normal",
  main=paste("r=0, q=",q=",paste(degree, paste(", h=",h))))

```

r=0, q= 3 , h= 13

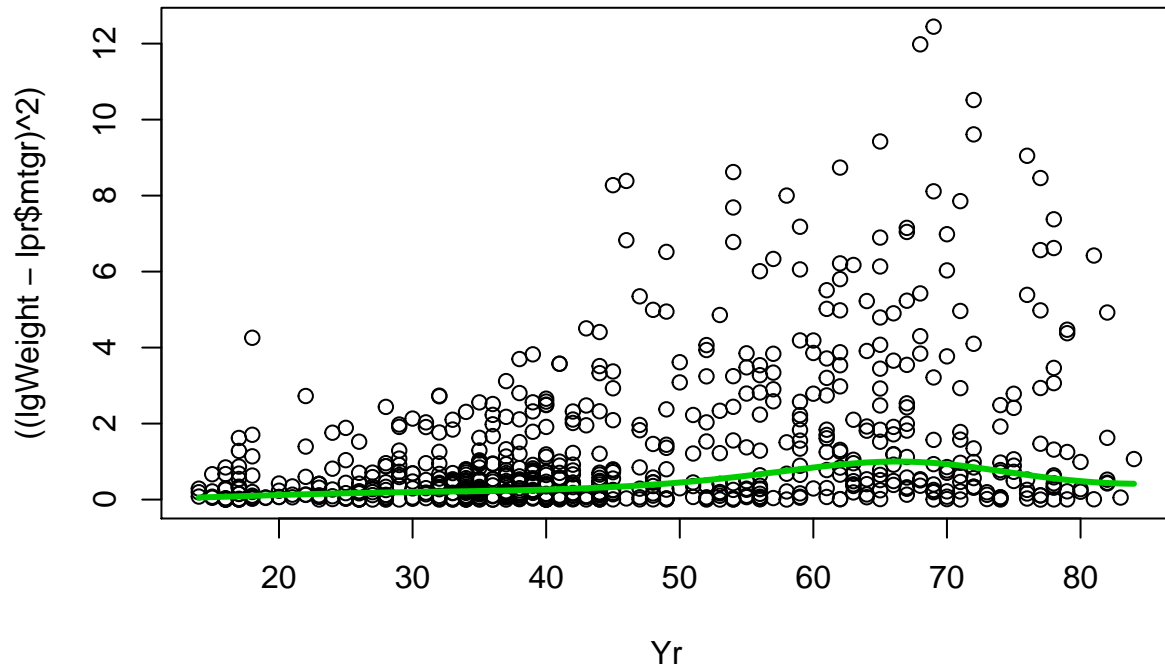


Finally, we estimate the variance σ^2

```

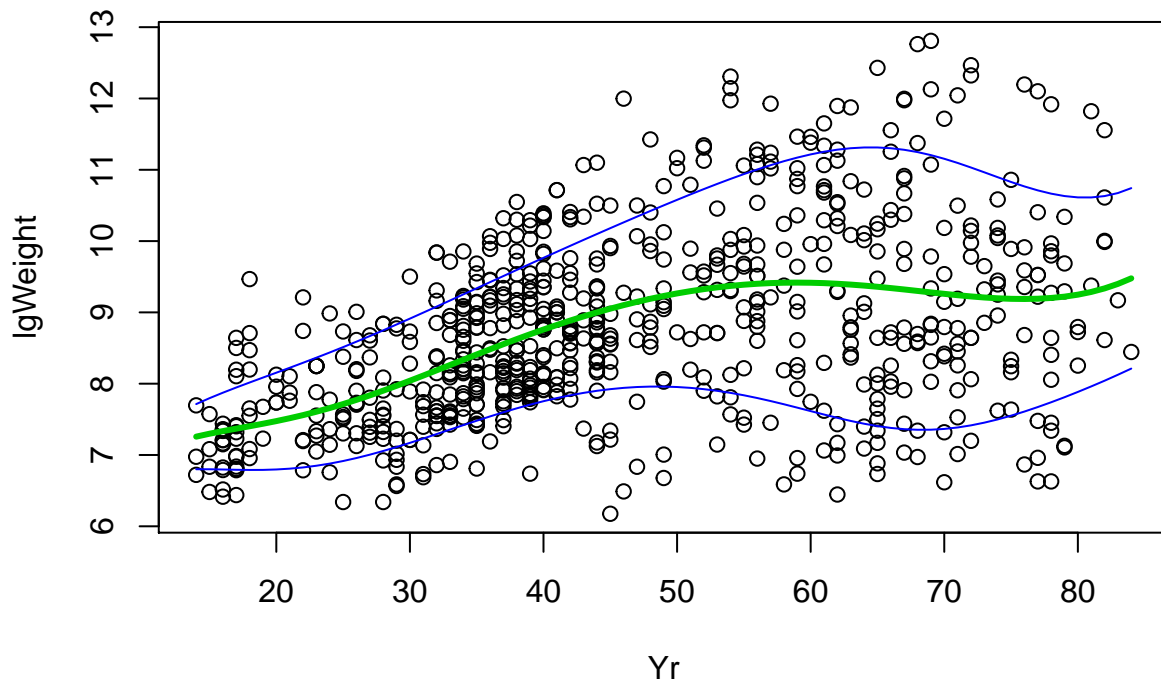
par(mfrow=c(1,1))
# step 4 Estimate sigma_2(x)
sigma_2 = exp(lpr2$mtgr)
plot(Yr,((lgWeight - lpr$mtgr)^2)) # residual square against x_i
lines(Yr, sigma_2, col=3, lwd=3)

```



Function $\hat{m}(x)$ and the superimposed bands $\hat{m}(x) \pm 1.96\hat{\sigma}(x)$

```
sigma = sqrt(sigma_2)
plot(Yr,lgWeight)
lines(Yr,lpr$mtgr,col=3,lwd=3)
lines(Yr,lpr$mtgr+1.96*sigma,col=4,lwd=1)
lines(Yr,lpr$mtgr-1.96*sigma,col=4,lwd=1)
```



After performing a local linear and polynomial regressions we can see that the results are comparable, the polynomial showing a smoother curve. Hence, we can say that for this scenario of the aircraft data both approaches are satisfactory.