# # DEEP LEARNING

## 1. Artificial neural network with no hidden layers is just linear regression

**Artificial neural networks are available in package neuralnet.**

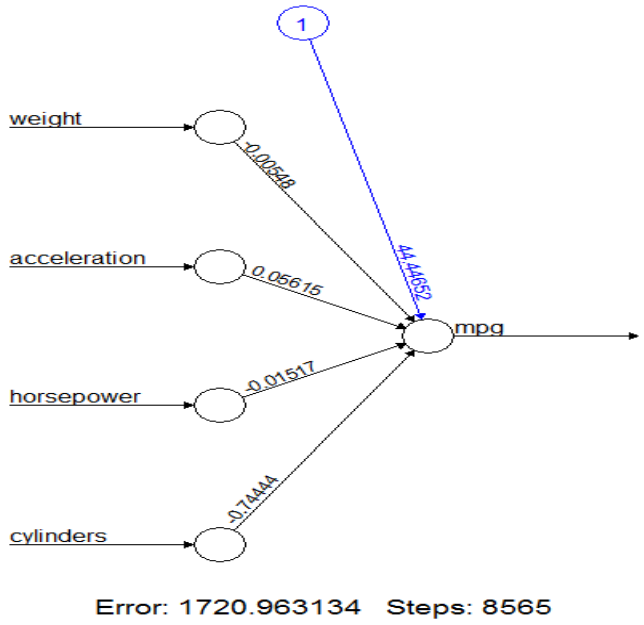
```
> library(neuralnet)
```

**Create the training and testing data.**

```
> attach(Auto)
> n = length(mpg)
> Z = sample(n,200)
> Auto.train = Auto[Z,]
> Auto.test = Auto[-Z,]
```

```
> nn0 = neuralnet( mpg ~ weight+acceleration+horsepower+cylinders, data=Auto.train, hidden=0 )
> nn0
          Error Reached Threshold Steps
1 1720.963134    0.009532195866  8565
```

```
> plot(nn0)
```




**This is the linear regression! Weights are slopes, and the intercept is shown in blue.**

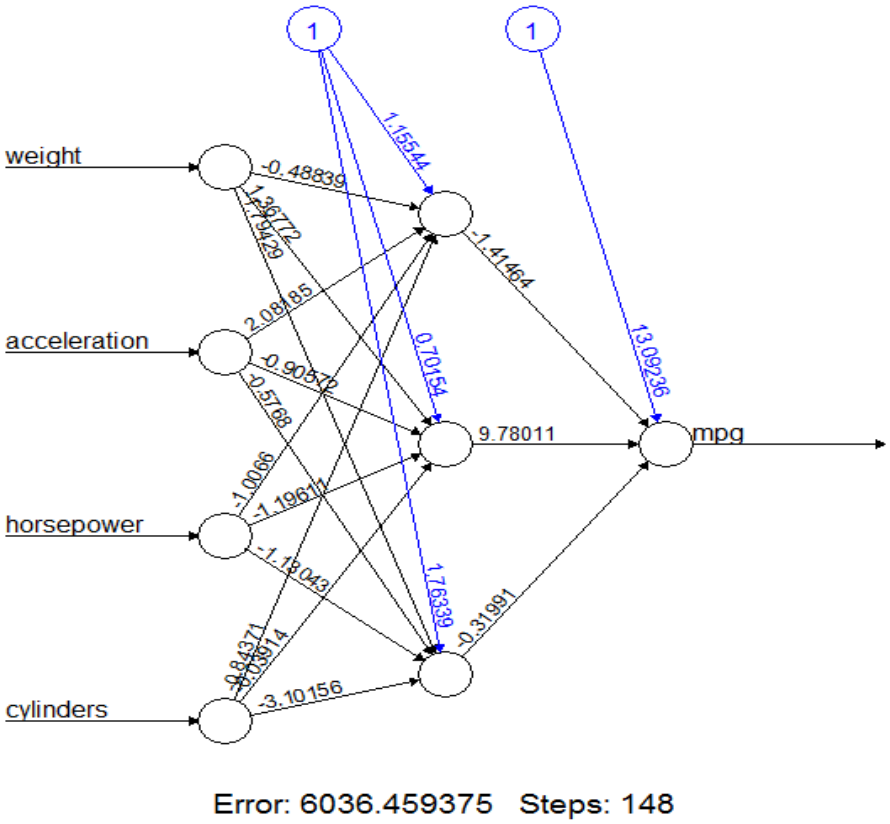
```
> lm( mpg ~ weight+acceleration+horsepower+cylinders, data=Auto.train )

Coefficients:
 (Intercept)        weight  acceleration    horsepower     cylinders
44.446611467  -0.005475864   0.056149012  -0.015172364  -0.744442628
```

## 2. Artificial neural network

**Now, introduce 3 hidden nodes.**

```
> nn3 = neuralnet( mpg ~ weight+acceleration+horsepower+cylinders, data=Auto.train, hidden=3 )
> plot(nn3)
```




## 3. Prediction power

**Which ANN gives a more accurate prediction? Use the test data for comparison.**

```
> Predict0 = compute( nn0,  subset(Auto.test, select=c(weight, acceleration, horsepower, cylinders) ) )
```

**This prediction consists of X-variables "neurons" and predicted Y-variable "net.result".**

```
> names(Predict0)
[1] "neurons"    "net.result"

> mean( (Auto.test$mpg - Predict0$net.result)^2 )
[1] 18.83350028
```

**Prediction MSE of this ANN is 18.83.**

```
> Predict3 = compute( nn3, subset(Auto.test, select=c(weight,acceleration,horsepower,cylinders) ) )
```

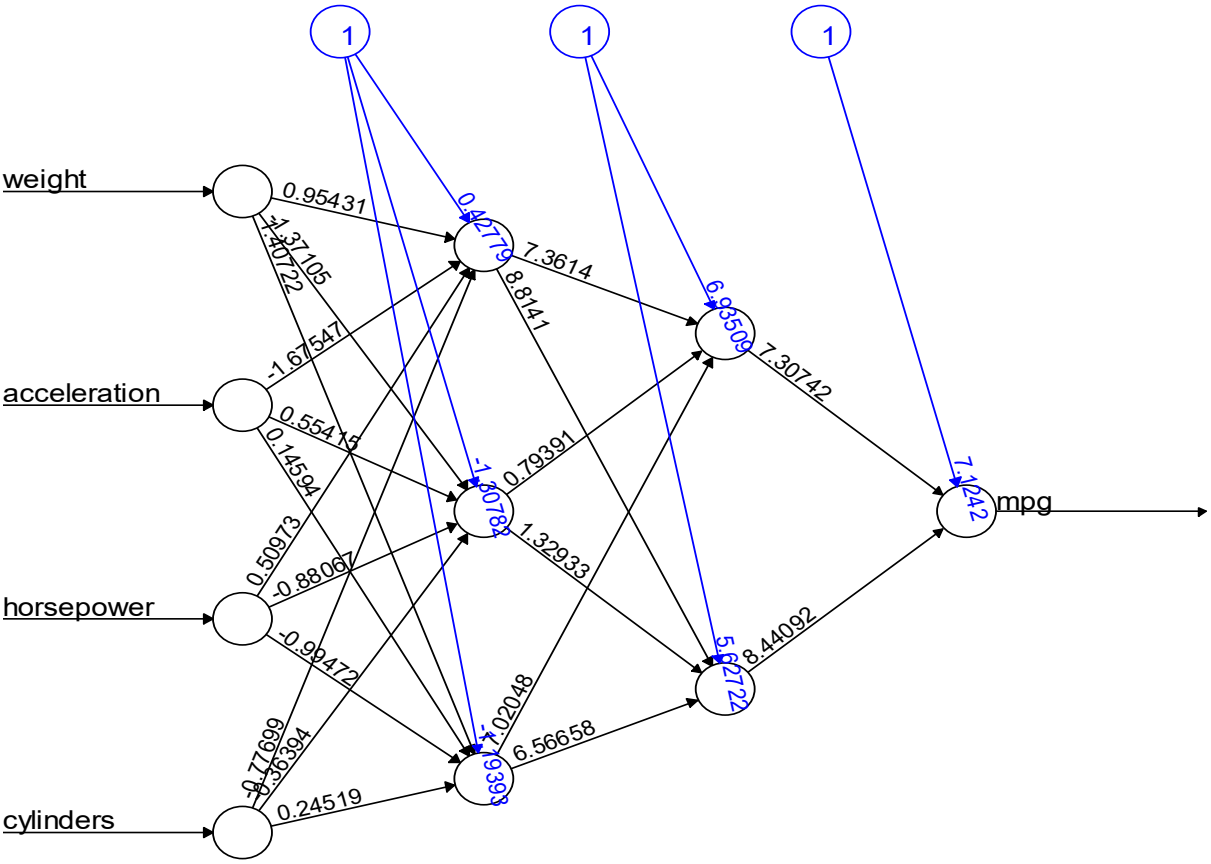
> mean( (Auto.test$mpg - Predict3$net.result)^2 )
[1] 61.84868054

**Its 3-node competitor has a much higher prediction MSE.**

## 4. Multilayer structure

**The number of hidden nodes can be given as a vector. Its components show the number of hidden nodes at each hidden layer.**

> nn3.2 = neuralnet( mpg ~ weight+acceleration+horsepower+cylinders, data=Auto.train, hidden=c(3,2) )
> plot(nn3.2)




Error: 6036.459375  Steps: 101

## 5. Artificial neural network for classification

> library(nnet)

**Prepare our categorical variables ECO and ECO4**

```
> ECO = ifelse( mpg > 22.75, "Economy", "Consuming" )
> ECO4 = rep("Economy",n)
> ECO4[mpg < 29] = "Good"
> ECO4[mpg < 22.75] = "OK"
> ECO4[mpg < 17] = "Consuming"
> Auto.train = Auto[Z,]
> Auto.test = Auto[-Z,]
```

**Train an artificial neural network to classify cars into "Economy" and "Consuming".**

```
> nn.class = nnet( as.factor(ECO) ~ weight + acceleration + horsepower + cylinders, data=Auto.train, size=3 )
# weights:  19
initial  value 169.471585
final  value 138.379332
converged
```

```
> summary(nn.class)
a 4-3-1 network with 19 weights
options were - entropy fitting
 b->h1 i1->h1 i2->h1 i3->h1 i4->h1
 -0.11  -0.35   0.12   0.32   0.16
 b->h2 i1->h2 i2->h2 i3->h2 i4->h2
  0.59  -0.37  -0.56   0.67   0.44
 b->h3 i1->h3 i2->h3 i3->h3 i4->h3
  0.50   0.16   0.41  -0.49   0.02
 b->o h1->o h2->o h3->o
-0.12 -0.27  0.03  0.02
```

**This ANN has p=4 inputs, one layer of M=3 hidden nodes, and a single (K=1) output. We need to estimate M(p+1)+K(M+1) = (3)(5)+(1)(4) = 19 weights.**

**Classification into K > 2 categories is similar.**

```
> nn.class = nnet( as.factor(ECO4) ~ weight+acceleration+horsepower+cylinders, data=Auto.train, size=3 )
# weights:  31
initial  value 333.799856
final  value 276.956630
converged
```

```
> summary(nn.class)
a 4-3-4 network with 31 weights
options were - softmax modelling
 b->h1 i1->h1 i2->h1 i3->h1 i4->h1
  0.39   0.69  -0.58   0.23   0.11
 b->h2 i1->h2 i2->h2 i3->h2 i4->h2
 -0.49  -0.67  -0.65  -0.68   0.11
 b->h3 i1->h3 i2->h3 i3->h3 i4->h3
 -0.67   0.24   0.59   0.43   0.00
 b->o1 h1->o1 h2->o1 h3->o1
  0.98  -0.25   0.32  -0.12
 b->o2 h1->o2 h2->o2 h3->o2
  0.13   0.41   0.19  -0.02
 b->o3 h1->o3 h2->o3 h3->o3
  0.20   0.28   0.34  -0.01
 b->o4 h1->o4 h2->o4 h3->o4
 -0.24   0.42  -0.09   0.41
```

**Here K = 4 categories, so we are estimating (3)(5) + (4)(4) = 31 weights.**