WEEK 13 - LESSONS IN R

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Installing packages

```r
install.packages(c("neuralnet", "keras", "tensorflow"), dependancies = T)
```

```
## Installing packages into '/cloud/lib/x86_64-pc-linux-gnu-library/4.4'
## (as 'lib' is unspecified)
```

```r
library(neuralnet)
install.packages("tidyverse")
```

```
## Installing package into '/cloud/lib/x86_64-pc-linux-gnu-library/4.4'
## (as 'lib' is unspecified)
```

```r
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------- tidyverse_conflicts() --
## x dplyr::compute() masks neuralnet::compute()
## x dplyr::filter()  masks stats::filter()
## x dplyr::lag()     masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

Data analysis

```r
iris <- iris %>%mutate_if(is.character, as.factor)
head(iris)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
## 3          4.7         3.2          1.3         0.2  setosa
## 4          4.6         3.1          1.5         0.2  setosa
## 5          5.0         3.6          1.4         0.2  setosa
## 6          5.4         3.9          1.7         0.4  setosa
```

```r
summary(iris)
```

```
##   Sepal.Length    Sepal.Width     Petal.Length    Petal.Width
```

```
##  Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100
##  1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300
##  Median :5.800   Median :3.000   Median :4.350   Median :1.300
##  Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
##  3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
##  Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
##        Species
##  setosa    :50
##  versicolor:50
##  virginica :50
##
##
##
```

Train and test split

```r
set.seed(254)
data_rows <- floor(0.80 * nrow(iris))
train_indices <- sample(c(1:nrow(iris)), data_rows)
head(train_indices)
```

```
## [1]  55  37 146  70  45 124
```

```r
train_data <- iris[train_indices,]
head(train_data)
```

```
##     Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
## 55           6.5         2.8          4.6         1.5 versicolor
## 37           5.5         3.5          1.3         0.2     setosa
## 146          6.7         3.0          5.2         2.3  virginica
## 70           5.6         2.5          3.9         1.1 versicolor
## 45           5.1         3.8          1.9         0.4     setosa
## 124          6.3         2.7          4.9         1.8  virginica
```

```r
test_data <- iris[-train_indices, ]
head(test_data)
```

```
##    Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1           5.1         3.5          1.4         0.2  setosa
## 15          5.8         4.0          1.2         0.2  setosa
## 16          5.7         4.4          1.5         0.4  setosa
## 21          5.4         3.4          1.7         0.2  setosa
## 22          5.1         3.7          1.5         0.4  setosa
## 26          5.0         3.0          1.6         0.2  setosa
```

Two hidden layers with 4 and 2 neurons

```r
model <- neuralnet(Species ~ Sepal.Length + Sepal.Width + Petal.Length +
Petal.Width, data = train_data, hidden = c(4,2), linear.output = FALSE)
# Print the model summary
head(model)
```

```
## $call
## neuralnet(formula = Species ~ Sepal.Length + Sepal.Width + Petal.Length +
```

```
##       Petal.Width, data = train_data, hidden = c(4, 2), linear.output = FALSE)
##
## $response
##     versicolor setosa virginica
## 1        FALSE   TRUE     FALSE
## 2         TRUE  FALSE     FALSE
## 3        FALSE  FALSE      TRUE
## 4        FALSE   TRUE     FALSE
## 5         TRUE  FALSE     FALSE
## 6        FALSE  FALSE      TRUE
## 7         TRUE  FALSE     FALSE
## 8        FALSE   TRUE     FALSE
## 9        FALSE  FALSE      TRUE
## 10        TRUE  FALSE     FALSE
## 11       FALSE   TRUE     FALSE
## 12        TRUE  FALSE     FALSE
## 13       FALSE  FALSE      TRUE
## 14       FALSE  FALSE      TRUE
## 15       FALSE  FALSE      TRUE
## 16       FALSE  FALSE      TRUE
## 17       FALSE   TRUE     FALSE
## 18       FALSE  FALSE      TRUE
## 19       FALSE  FALSE      TRUE
## 20        TRUE  FALSE     FALSE
## 21       FALSE  FALSE      TRUE
## 22       FALSE  FALSE      TRUE
## 23       FALSE   TRUE     FALSE
## 24       FALSE  FALSE      TRUE
## 25       FALSE  FALSE      TRUE
## 26       FALSE  FALSE      TRUE
## 27       FALSE   TRUE     FALSE
## 28       FALSE  FALSE      TRUE
## 29        TRUE  FALSE     FALSE
## 30       FALSE   TRUE     FALSE
## 31       FALSE   TRUE     FALSE
## 32       FALSE   TRUE     FALSE
## 33       FALSE   TRUE     FALSE
## 34        TRUE  FALSE     FALSE
## 35        TRUE  FALSE     FALSE
## 36       FALSE   TRUE     FALSE
## 37       FALSE  FALSE      TRUE
## 38       FALSE  FALSE      TRUE
## 39       FALSE  FALSE      TRUE
## 40        TRUE  FALSE     FALSE
## 41        TRUE  FALSE     FALSE
## 42       FALSE   TRUE     FALSE
## 43        TRUE  FALSE     FALSE
## 44       FALSE   TRUE     FALSE
## 45        TRUE  FALSE     FALSE
## 46        TRUE  FALSE     FALSE
## 47        TRUE  FALSE     FALSE
## 48       FALSE   TRUE     FALSE
## 49        TRUE  FALSE     FALSE
## 50       FALSE   TRUE     FALSE
```

```
## 51     FALSE FALSE    TRUE
## 52     FALSE FALSE    TRUE
## 53     FALSE  TRUE   FALSE
## 54     FALSE FALSE    TRUE
## 55     FALSE  TRUE   FALSE
## 56     FALSE FALSE    TRUE
## 57      TRUE FALSE   FALSE
## 58      TRUE FALSE   FALSE
## 59      TRUE FALSE   FALSE
## 60     FALSE  TRUE   FALSE
## 61     FALSE  TRUE   FALSE
## 62     FALSE  TRUE   FALSE
## 63      TRUE FALSE   FALSE
## 64     FALSE FALSE    TRUE
## 65      TRUE FALSE   FALSE
## 66     FALSE FALSE    TRUE
## 67     FALSE  TRUE   FALSE
## 68      TRUE FALSE   FALSE
## 69      TRUE FALSE   FALSE
## 70     FALSE  TRUE   FALSE
## 71     FALSE  TRUE   FALSE
## 72      TRUE FALSE   FALSE
## 73     FALSE FALSE    TRUE
## 74      TRUE FALSE   FALSE
## 75     FALSE FALSE    TRUE
## 76     FALSE FALSE    TRUE
## 77     FALSE FALSE    TRUE
## 78      TRUE FALSE   FALSE
## 79      TRUE FALSE   FALSE
## 80     FALSE  TRUE   FALSE
## 81     FALSE  TRUE   FALSE
## 82      TRUE FALSE   FALSE
## 83      TRUE FALSE   FALSE
## 84     FALSE  TRUE   FALSE
## 85     FALSE FALSE    TRUE
## 86     FALSE FALSE    TRUE
## 87      TRUE FALSE   FALSE
## 88      TRUE FALSE   FALSE
## 89     FALSE FALSE    TRUE
## 90     FALSE  TRUE   FALSE
## 91      TRUE FALSE   FALSE
## 92      TRUE FALSE   FALSE
## 93     FALSE  TRUE   FALSE
## 94     FALSE  TRUE   FALSE
## 95      TRUE FALSE   FALSE
## 96     FALSE  TRUE   FALSE
## 97     FALSE FALSE    TRUE
## 98     FALSE  TRUE   FALSE
## 99     FALSE  TRUE   FALSE
## 100    FALSE FALSE    TRUE
## 101    FALSE  TRUE   FALSE
## 102    FALSE  TRUE   FALSE
## 103    FALSE  TRUE   FALSE
## 104    FALSE FALSE    TRUE
```

```
## 105      TRUE FALSE      FALSE
## 106      TRUE FALSE      FALSE
## 107      TRUE FALSE      FALSE
## 108     FALSE FALSE       TRUE
## 109     FALSE FALSE       TRUE
## 110      TRUE FALSE      FALSE
## 111     FALSE FALSE       TRUE
## 112      TRUE FALSE      FALSE
## 113     FALSE  TRUE      FALSE
## 114     FALSE  TRUE      FALSE
## 115     FALSE  TRUE      FALSE
## 116     FALSE  TRUE      FALSE
## 117      TRUE FALSE      FALSE
## 118     FALSE  TRUE      FALSE
## 119     FALSE FALSE       TRUE
## 120     FALSE FALSE       TRUE
##
## $covariate
##     Sepal.Length Sepal.Width Petal.Length Petal.Width
## 55           6.5         2.8          4.6         1.5
## 37           5.5         3.5          1.3         0.2
## 146          6.7         3.0          5.2         2.3
## 70           5.6         2.5          3.9         1.1
## 45           5.1         3.8          1.9         0.4
## 124          6.3         2.7          4.9         1.8
## 20           5.1         3.8          1.5         0.3
## 76           6.6         3.0          4.4         1.4
## 144          6.8         3.2          5.9         2.3
## 3            4.7         3.2          1.3         0.2
## 88           6.3         2.3          4.4         1.3
## 10           4.9         3.1          1.5         0.1
## 136          7.7         3.0          6.1         2.3
## 126          7.2         3.2          6.0         1.8
## 102          5.8         2.7          5.1         1.9
## 125          6.7         3.3          5.7         2.1
## 64           6.1         2.9          4.7         1.4
## 111          6.5         3.2          5.1         2.0
## 122          5.6         2.8          4.9         2.0
## 32           5.4         3.4          1.5         0.4
## 147          6.3         2.5          5.0         1.9
## 123          7.7         2.8          6.7         2.0
## 95           5.6         2.7          4.2         1.3
## 101          6.3         3.3          6.0         2.5
## 149          6.2         3.4          5.4         2.3
## 143          5.8         2.7          5.1         1.9
## 94           5.0         2.3          3.3         1.0
## 150          5.9         3.0          5.1         1.8
## 11           5.4         3.7          1.5         0.2
## 83           5.8         2.7          3.9         1.2
## 54           5.5         2.3          4.0         1.3
## 57           6.3         3.3          4.7         1.6
## 61           5.0         2.0          3.5         1.0
## 48           4.6         3.2          1.4         0.2
## 29           5.2         3.4          1.4         0.2
```

```
## 69            6.2         2.2          4.5          1.5
## 130           7.2         3.0          5.8          1.6
## 115           5.8         2.8          5.1          2.4
## 145           6.7         3.3          5.7          2.5
## 17            5.4         3.9          1.3          0.4
## 50            5.0         3.3          1.4          0.2
## 96            5.7         3.0          4.2          1.2
## 35            4.9         3.1          1.5          0.2
## 93            5.8         2.6          4.0          1.2
## 49            5.3         3.7          1.5          0.2
## 12            4.8         3.4          1.6          0.2
## 14            4.3         3.0          1.1          0.1
## 60            5.2         2.7          3.9          1.4
## 18            5.1         3.5          1.4          0.3
## 97            5.7         2.9          4.2          1.3
## 109           6.7         2.5          5.8          1.8
## 134           6.3         2.8          5.1          1.5
## 62            5.9         3.0          4.2          1.5
## 113           6.8         3.0          5.5          2.1
## 75            6.4         2.9          4.3          1.3
## 119           7.7         2.6          6.9          2.3
## 41            5.0         3.5          1.3          0.3
## 27            5.0         3.4          1.6          0.4
## 25            4.8         3.4          1.9          0.2
## 89            5.6         3.0          4.1          1.3
## 100           5.7         2.8          4.1          1.3
## 91            5.5         2.6          4.4          1.2
## 19            5.7         3.8          1.7          0.3
## 137           6.3         3.4          5.6          2.4
## 46            4.8         3.0          1.4          0.3
## 103           7.1         3.0          5.9          2.1
## 85            5.4         3.0          4.5          1.5
## 6             5.4         3.9          1.7          0.4
## 44            5.0         3.5          1.6          0.6
## 86            6.0         3.4          4.5          1.6
## 71            5.9         3.2          4.8          1.8
## 36            5.0         3.2          1.2          0.2
## 104           6.3         2.9          5.6          1.8
## 42            4.5         2.3          1.3          0.3
## 139           6.0         3.0          4.8          1.8
## 118           7.7         3.8          6.7          2.2
## 106           7.6         3.0          6.6          2.1
## 9             4.4         2.9          1.4          0.2
## 43            4.4         3.2          1.3          0.2
## 84            6.0         2.7          5.1          1.6
## 66            6.7         3.1          4.4          1.4
## 39            4.4         3.0          1.3          0.2
## 7             4.6         3.4          1.4          0.3
## 72            6.1         2.8          4.0          1.3
## 117           6.5         3.0          5.5          1.8
## 108           7.3         2.9          6.3          1.8
## 4             4.6         3.1          1.5          0.2
## 38            4.9         3.6          1.4          0.1
## 138           6.4         3.1          5.5          1.8
```

```
## 65           5.6          2.9          3.6          1.3
## 5            5.0          3.6          1.4          0.2
## 2            4.9          3.0          1.4          0.2
## 87           6.7          3.1          4.7          1.5
## 82           5.5          2.4          3.7          1.0
## 40           5.1          3.4          1.5          0.2
## 77           6.8          2.8          4.8          1.4
## 128          6.1          3.0          4.9          1.8
## 67           5.6          3.0          4.5          1.5
## 92           6.1          3.0          4.6          1.4
## 131          7.4          2.8          6.1          1.9
## 74           6.1          2.8          4.7          1.2
## 56           5.7          2.8          4.5          1.3
## 59           6.6          2.9          4.6          1.3
## 120          6.0          2.2          5.0          1.5
## 23           4.6          3.6          1.0          0.2
## 13           4.8          3.0          1.4          0.1
## 33           5.2          4.1          1.5          0.1
## 107          4.9          2.5          4.5          1.7
## 127          6.2          2.8          4.8          1.8
## 24           5.1          3.3          1.7          0.5
## 116          6.4          3.2          5.3          2.3
## 34           5.5          4.2          1.4          0.2
## 68           5.8          2.7          4.1          1.0
## 58           4.9          2.4          3.3          1.0
## 73           6.3          2.5          4.9          1.5
## 80           5.7          2.6          3.5          1.0
## 8            5.0          3.4          1.5          0.2
## 99           5.1          2.5          3.0          1.1
## 121          6.9          3.2          5.7          2.3
## 133          6.4          2.8          5.6          2.2
##
## $model.list
## $model.list$response
## [1] "versicolor" "setosa"      "virginica"
##
## $model.list$variables
## [1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"
##
##
## $err.fct
## function (x, y)
## {
##     1/2 * (y - x)^2
## }
## <bytecode: 0x5bfe53991878>
## <environment: 0x5bfe53992fa8>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
```
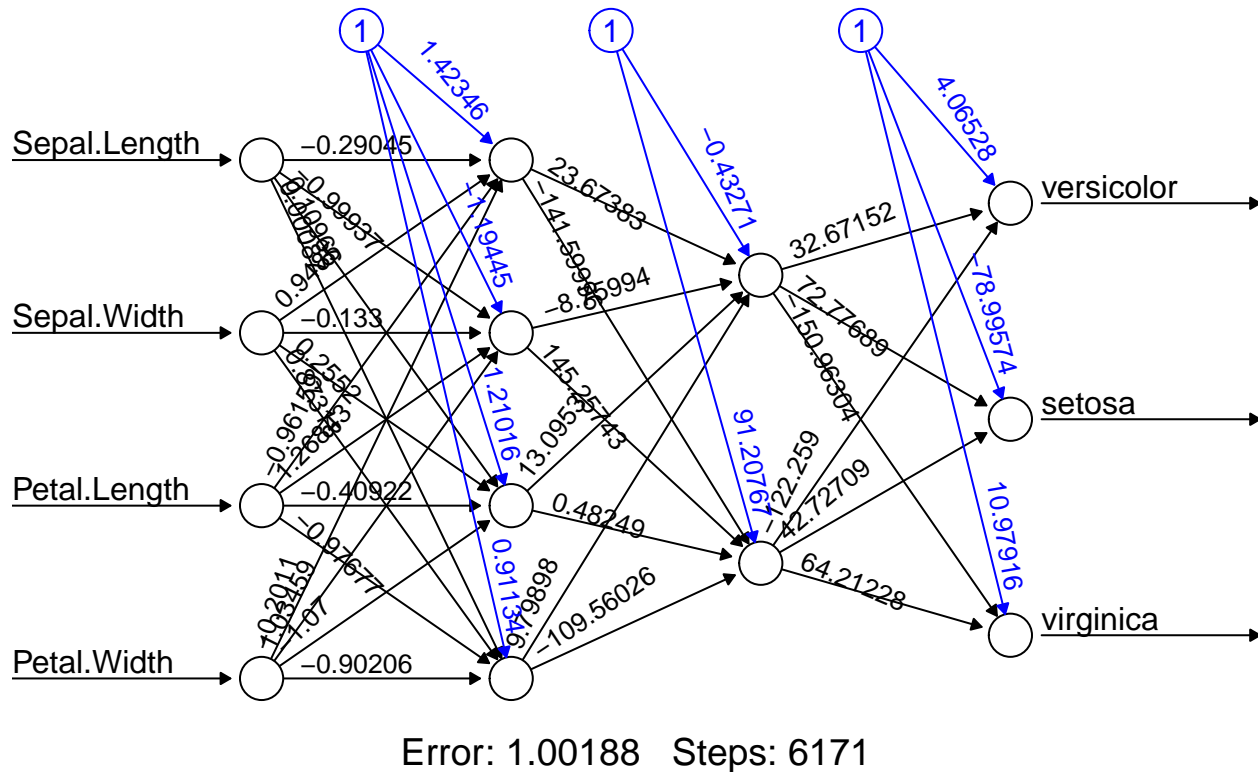
```
## }
## <bytecode: 0x5bfe53997cd8>
## <environment: 0x5bfe539985d0>
## attr(,"type")
## [1] "logistic"
```

```
plot(model, rep = 'best')
```


Error: 1.00188   Steps: 6171

```
pred <- predict(model, test_data)
pred
```

```
##                  [,1]         [,2]         [,3]
## 1    1.000000e+00 1.987582e-03 1.606099e-61
## 15   1.000000e+00 1.987582e-03 1.606099e-61
## 16   1.000000e+00 1.987582e-03 1.606099e-61
## 21   1.000000e+00 1.987582e-03 1.606099e-61
## 22   1.000000e+00 1.987582e-03 1.606099e-61
## 26   1.000000e+00 1.987582e-03 1.606099e-61
## 28   1.000000e+00 1.987582e-03 1.606099e-61
## 30   1.000000e+00 1.987582e-03 1.606099e-61
## 31   1.000000e+00 1.987582e-03 1.606099e-61
## 47   1.000000e+00 1.987582e-03 1.606099e-61
## 51   5.976903e-38 1.000000e+00 2.953469e-33
## 52   5.723452e-38 1.000000e+00 3.608146e-33
## 53   1.384220e-38 1.000000e+00 2.544987e-30
## 63   6.966252e-38 1.000000e+00 1.455306e-33
## 78   5.834333e-43 9.999693e-01 4.187287e-10
## 79   1.736209e-38 1.000000e+00 8.933657e-31
## 81   7.119429e-38 1.000000e+00 1.316157e-33
## 90   6.249596e-38 1.000000e+00 2.403280e-33
```

```
## 98  6.688873e-38 1.000000e+00 1.755865e-33
## 105 5.423696e-52 2.476923e-16 1.000000e+00
## 110 5.316714e-52 2.369408e-16 1.000000e+00
## 112 1.893062e-51 4.010254e-15 1.000000e+00
## 114 9.329015e-52 8.290613e-16 1.000000e+00
## 129 6.037474e-52 3.145041e-16 1.000000e+00
## 132 1.404842e-51 2.063591e-15 1.000000e+00
## 135 2.891381e-51 1.030162e-14 1.000000e+00
## 140 3.342740e-51 1.423096e-14 1.000000e+00
## 141 5.820653e-52 2.898980e-16 1.000000e+00
## 142 1.001202e-50 1.638601e-13 1.000000e+00
## 148 7.647401e-51 8.991549e-14 1.000000e+00
```

Three hidden layers with 8, 4 and 2 neurons

```r
model2 <- neuralnet(Species ~ Sepal.Length + Sepal.Width + Petal.Length + Petal.Width, data = train_data
# Print the model summary
head(model2)
```

```
## $call
## neuralnet(formula = Species ~ Sepal.Length + Sepal.Width + Petal.Length +
##     Petal.Width, data = train_data, hidden = c(8, 4, 2), linear.output = FALSE)
##
## $response
##    versicolor setosa virginica
## 1       FALSE   TRUE     FALSE
## 2        TRUE  FALSE     FALSE
## 3       FALSE  FALSE      TRUE
## 4       FALSE   TRUE     FALSE
## 5        TRUE  FALSE     FALSE
## 6       FALSE  FALSE      TRUE
## 7        TRUE  FALSE     FALSE
## 8       FALSE   TRUE     FALSE
## 9       FALSE  FALSE      TRUE
## 10       TRUE  FALSE     FALSE
## 11      FALSE   TRUE     FALSE
## 12       TRUE  FALSE     FALSE
## 13      FALSE  FALSE      TRUE
## 14      FALSE  FALSE      TRUE
## 15      FALSE  FALSE      TRUE
## 16      FALSE  FALSE      TRUE
## 17      FALSE   TRUE     FALSE
## 18      FALSE  FALSE      TRUE
## 19      FALSE  FALSE      TRUE
## 20       TRUE  FALSE     FALSE
## 21      FALSE  FALSE      TRUE
## 22      FALSE  FALSE      TRUE
## 23      FALSE   TRUE     FALSE
## 24      FALSE  FALSE      TRUE
## 25      FALSE  FALSE      TRUE
## 26      FALSE  FALSE      TRUE
## 27      FALSE   TRUE     FALSE
## 28      FALSE  FALSE      TRUE
```

```
## 29          TRUE  FALSE       FALSE
## 30         FALSE   TRUE       FALSE
## 31         FALSE   TRUE       FALSE
## 32         FALSE   TRUE       FALSE
## 33         FALSE   TRUE       FALSE
## 34          TRUE  FALSE       FALSE
## 35          TRUE  FALSE       FALSE
## 36         FALSE   TRUE       FALSE
## 37         FALSE  FALSE        TRUE
## 38         FALSE  FALSE        TRUE
## 39         FALSE  FALSE        TRUE
## 40          TRUE  FALSE       FALSE
## 41          TRUE  FALSE       FALSE
## 42         FALSE   TRUE       FALSE
## 43          TRUE  FALSE       FALSE
## 44         FALSE   TRUE       FALSE
## 45          TRUE  FALSE       FALSE
## 46          TRUE  FALSE       FALSE
## 47          TRUE  FALSE       FALSE
## 48         FALSE   TRUE       FALSE
## 49          TRUE  FALSE       FALSE
## 50         FALSE   TRUE       FALSE
## 51         FALSE  FALSE        TRUE
## 52         FALSE  FALSE        TRUE
## 53         FALSE   TRUE       FALSE
## 54         FALSE  FALSE        TRUE
## 55         FALSE   TRUE       FALSE
## 56         FALSE  FALSE        TRUE
## 57          TRUE  FALSE       FALSE
## 58          TRUE  FALSE       FALSE
## 59          TRUE  FALSE       FALSE
## 60         FALSE   TRUE       FALSE
## 61         FALSE   TRUE       FALSE
## 62         FALSE   TRUE       FALSE
## 63          TRUE  FALSE       FALSE
## 64         FALSE  FALSE        TRUE
## 65          TRUE  FALSE       FALSE
## 66         FALSE  FALSE        TRUE
## 67         FALSE   TRUE       FALSE
## 68          TRUE  FALSE       FALSE
## 69          TRUE  FALSE       FALSE
## 70         FALSE   TRUE       FALSE
## 71         FALSE   TRUE       FALSE
## 72          TRUE  FALSE       FALSE
## 73         FALSE  FALSE        TRUE
## 74          TRUE  FALSE       FALSE
## 75         FALSE  FALSE        TRUE
## 76         FALSE  FALSE        TRUE
## 77         FALSE  FALSE        TRUE
## 78          TRUE  FALSE       FALSE
## 79          TRUE  FALSE       FALSE
## 80         FALSE   TRUE       FALSE
## 81         FALSE   TRUE       FALSE
## 82          TRUE  FALSE       FALSE
```

```
## 83         TRUE  FALSE      FALSE
## 84        FALSE   TRUE      FALSE
## 85        FALSE  FALSE       TRUE
## 86        FALSE  FALSE       TRUE
## 87         TRUE  FALSE      FALSE
## 88         TRUE  FALSE      FALSE
## 89        FALSE  FALSE       TRUE
## 90        FALSE   TRUE      FALSE
## 91         TRUE  FALSE      FALSE
## 92         TRUE  FALSE      FALSE
## 93        FALSE   TRUE      FALSE
## 94        FALSE   TRUE      FALSE
## 95         TRUE  FALSE      FALSE
## 96        FALSE   TRUE      FALSE
## 97        FALSE  FALSE       TRUE
## 98        FALSE   TRUE      FALSE
## 99        FALSE   TRUE      FALSE
## 100       FALSE  FALSE       TRUE
## 101       FALSE   TRUE      FALSE
## 102       FALSE   TRUE      FALSE
## 103       FALSE   TRUE      FALSE
## 104       FALSE  FALSE       TRUE
## 105        TRUE  FALSE      FALSE
## 106        TRUE  FALSE      FALSE
## 107        TRUE  FALSE      FALSE
## 108       FALSE  FALSE       TRUE
## 109       FALSE  FALSE       TRUE
## 110        TRUE  FALSE      FALSE
## 111       FALSE  FALSE       TRUE
## 112        TRUE  FALSE      FALSE
## 113       FALSE   TRUE      FALSE
## 114       FALSE   TRUE      FALSE
## 115       FALSE   TRUE      FALSE
## 116       FALSE   TRUE      FALSE
## 117        TRUE  FALSE      FALSE
## 118       FALSE   TRUE      FALSE
## 119       FALSE  FALSE       TRUE
## 120       FALSE  FALSE       TRUE
##
## $covariate
##     Sepal.Length Sepal.Width Petal.Length Petal.Width
## 55           6.5         2.8          4.6         1.5
## 37           5.5         3.5          1.3         0.2
## 146          6.7         3.0          5.2         2.3
## 70           5.6         2.5          3.9         1.1
## 45           5.1         3.8          1.9         0.4
## 124          6.3         2.7          4.9         1.8
## 20           5.1         3.8          1.5         0.3
## 76           6.6         3.0          4.4         1.4
## 144          6.8         3.2          5.9         2.3
## 3            4.7         3.2          1.3         0.2
## 88           6.3         2.3          4.4         1.3
## 10           4.9         3.1          1.5         0.1
## 136          7.7         3.0          6.1         2.3
```

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```
## 126          7.2          3.2          6.0          1.8
## 102          5.8          2.7          5.1          1.9
## 125          6.7          3.3          5.7          2.1
## 64           6.1          2.9          4.7          1.4
## 111          6.5          3.2          5.1          2.0
## 122          5.6          2.8          4.9          2.0
## 32           5.4          3.4          1.5          0.4
## 147          6.3          2.5          5.0          1.9
## 123          7.7          2.8          6.7          2.0
## 95           5.6          2.7          4.2          1.3
## 101          6.3          3.3          6.0          2.5
## 149          6.2          3.4          5.4          2.3
## 143          5.8          2.7          5.1          1.9
## 94           5.0          2.3          3.3          1.0
## 150          5.9          3.0          5.1          1.8
## 11           5.4          3.7          1.5          0.2
## 83           5.8          2.7          3.9          1.2
## 54           5.5          2.3          4.0          1.3
## 57           6.3          3.3          4.7          1.6
## 61           5.0          2.0          3.5          1.0
## 48           4.6          3.2          1.4          0.2
## 29           5.2          3.4          1.4          0.2
## 69           6.2          2.2          4.5          1.5
## 130          7.2          3.0          5.8          1.6
## 115          5.8          2.8          5.1          2.4
## 145          6.7          3.3          5.7          2.5
## 17           5.4          3.9          1.3          0.4
## 50           5.0          3.3          1.4          0.2
## 96           5.7          3.0          4.2          1.2
## 35           4.9          3.1          1.5          0.2
## 93           5.8          2.6          4.0          1.2
## 49           5.3          3.7          1.5          0.2
## 12           4.8          3.4          1.6          0.2
## 14           4.3          3.0          1.1          0.1
## 60           5.2          2.7          3.9          1.4
## 18           5.1          3.5          1.4          0.3
## 97           5.7          2.9          4.2          1.3
## 109          6.7          2.5          5.8          1.8
## 134          6.3          2.8          5.1          1.5
## 62           5.9          3.0          4.2          1.5
## 113          6.8          3.0          5.5          2.1
## 75           6.4          2.9          4.3          1.3
## 119          7.7          2.6          6.9          2.3
## 41           5.0          3.5          1.3          0.3
## 27           5.0          3.4          1.6          0.4
## 25           4.8          3.4          1.9          0.2
## 89           5.6          3.0          4.1          1.3
## 100          5.7          2.8          4.1          1.3
## 91           5.5          2.6          4.4          1.2
## 19           5.7          3.8          1.7          0.3
## 137          6.3          3.4          5.6          2.4
## 46           4.8          3.0          1.4          0.3
## 103          7.1          3.0          5.9          2.1
## 85           5.4          3.0          4.5          1.5
```
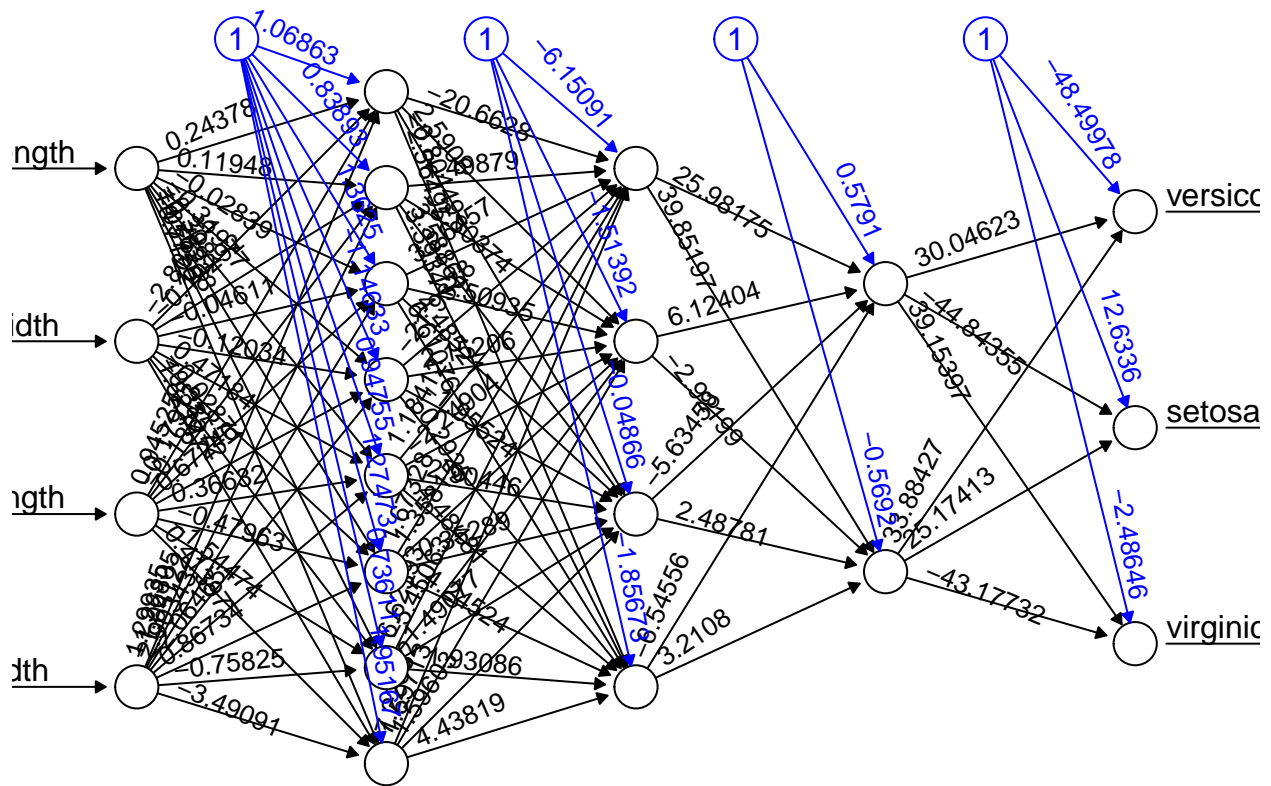
```
## 6        5.4      3.9      1.7      0.4
## 44       5.0      3.5      1.6      0.6
## 86       6.0      3.4      4.5      1.6
## 71       5.9      3.2      4.8      1.8
## 36       5.0      3.2      1.2      0.2
## 104      6.3      2.9      5.6      1.8
## 42       4.5      2.3      1.3      0.3
## 139      6.0      3.0      4.8      1.8
## 118      7.7      3.8      6.7      2.2
## 106      7.6      3.0      6.6      2.1
## 9        4.4      2.9      1.4      0.2
## 43       4.4      3.2      1.3      0.2
## 84       6.0      2.7      5.1      1.6
## 66       6.7      3.1      4.4      1.4
## 39       4.4      3.0      1.3      0.2
## 7        4.6      3.4      1.4      0.3
## 72       6.1      2.8      4.0      1.3
## 117      6.5      3.0      5.5      1.8
## 108      7.3      2.9      6.3      1.8
## 4        4.6      3.1      1.5      0.2
## 38       4.9      3.6      1.4      0.1
## 138      6.4      3.1      5.5      1.8
## 65       5.6      2.9      3.6      1.3
## 5        5.0      3.6      1.4      0.2
## 2        4.9      3.0      1.4      0.2
## 87       6.7      3.1      4.7      1.5
## 82       5.5      2.4      3.7      1.0
## 40       5.1      3.4      1.5      0.2
## 77       6.8      2.8      4.8      1.4
## 128      6.1      3.0      4.9      1.8
## 67       5.6      3.0      4.5      1.5
## 92       6.1      3.0      4.6      1.4
## 131      7.4      2.8      6.1      1.9
## 74       6.1      2.8      4.7      1.2
## 56       5.7      2.8      4.5      1.3
## 59       6.6      2.9      4.6      1.3
## 120      6.0      2.2      5.0      1.5
## 23       4.6      3.6      1.0      0.2
## 13       4.8      3.0      1.4      0.1
## 33       5.2      4.1      1.5      0.1
## 107      4.9      2.5      4.5      1.7
## 127      6.2      2.8      4.8      1.8
## 24       5.1      3.3      1.7      0.5
## 116      6.4      3.2      5.3      2.3
## 34       5.5      4.2      1.4      0.2
## 68       5.8      2.7      4.1      1.0
## 58       4.9      2.4      3.3      1.0
## 73       6.3      2.5      4.9      1.5
## 80       5.7      2.6      3.5      1.0
## 8        5.0      3.4      1.5      0.2
## 99       5.1      2.5      3.0      1.1
## 121      6.9      3.2      5.7      2.3
## 133      6.4      2.8      5.6      2.2
##
```

```
## $model.list
## $model.list$response
## [1] "versicolor" "setosa"      "virginica"
##
## $model.list$variables
## [1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"
##
##
## $err.fct
## function (x, y)
## {
##     1/2 * (y - x)^2
## }
## <bytecode: 0x5bfe53991878>
## <environment: 0x5bfe54f978b0>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5bfe53997cd8>
## <environment: 0x5bfe54f97d48>
## attr(,"type")
## [1] "logistic"
```

```r
plot(model2, rep = 'best')
```

Error: 1.00079   Steps: 666

```r
pred2 <- predict(model2, test_data)
pred2
```

```
##          [,1]          [,2]         [,3]
## 1   9.999998e-01 8.790491e-04 1.486519e-03
## 15  9.999998e-01 8.790488e-04 1.486520e-03
## 16  9.999998e-01 8.790500e-04 1.486518e-03
## 21  9.999998e-01 8.790493e-04 1.486519e-03
## 22  9.999998e-01 8.790539e-04 1.486512e-03
## 26  9.999998e-01 8.790497e-04 1.486519e-03
## 28  9.999998e-01 8.790491e-04 1.486519e-03
## 30  9.999998e-01 8.790500e-04 1.486518e-03
## 31  9.999998e-01 8.790499e-04 1.486518e-03
## 47  9.999998e-01 8.790492e-04 1.486519e-03
## 51  9.798366e-08 1.000000e+00 1.090960e-19
## 52  4.944054e-08 1.000000e+00 2.834624e-19
## 53  3.322452e-09 1.000000e+00 2.235976e-17
## 63  2.720924e-07 1.000000e+00 2.807449e-20
## 78  1.129563e-08 2.223755e-02 9.787111e-01
## 79  4.837272e-09 1.000000e+00 1.120450e-17
## 81  2.408606e-07 1.000000e+00 3.289534e-20
## 90  7.333305e-08 1.000000e+00 1.623310e-19
## 98  1.440887e-07 1.000000e+00 6.478605e-20
## 105 7.265736e-08 7.646931e-14 1.000000e+00
## 110 5.827280e-08 5.665371e-14 1.000000e+00
## 112 1.789452e-07 4.093547e-13 1.000000e+00
## 114 1.200711e-07 1.731450e-13 1.000000e+00
```

```
## 129 8.424443e-08 9.518050e-14 1.000000e+00
## 132 4.144426e-07 1.785009e-11 1.000000e+00
## 135 2.595521e-10 1.000000e+00 1.357644e-14
## 140 1.142640e-07 1.569868e-13 1.000000e+00
## 141 5.678086e-08 5.488341e-14 1.000000e+00
## 142 8.017150e-08 8.785982e-14 1.000000e+00
## 148 1.854539e-07 4.400379e-13 1.000000e+00
```

10 hidden layers with 8, 20, 6, 5, 4, 2, 1, 4, 5, and 30 neurons

```r
model3 <- neuralnet(Species ~ Sepal.Length + Sepal.Width + Petal.Length + Petal.Width, data = train_data
# Print the model summary
head(model3)
```

```
## $call
## neuralnet(formula = Species ~ Sepal.Length + Sepal.Width + Petal.Length +
##     Petal.Width, data = train_data, hidden = c(8, 20, 6, 5, 4,
##     2, 1, 4, 5, 30), linear.output = FALSE)
##
## $response
##     versicolor setosa virginica
## 1        FALSE   TRUE     FALSE
## 2         TRUE  FALSE     FALSE
## 3        FALSE  FALSE      TRUE
## 4        FALSE   TRUE     FALSE
## 5         TRUE  FALSE     FALSE
## 6        FALSE  FALSE      TRUE
## 7         TRUE  FALSE     FALSE
## 8        FALSE   TRUE     FALSE
## 9        FALSE  FALSE      TRUE
## 10        TRUE  FALSE     FALSE
## 11       FALSE   TRUE     FALSE
## 12        TRUE  FALSE     FALSE
## 13       FALSE  FALSE      TRUE
## 14       FALSE  FALSE      TRUE
## 15       FALSE  FALSE      TRUE
## 16       FALSE  FALSE      TRUE
## 17       FALSE   TRUE     FALSE
## 18       FALSE  FALSE      TRUE
## 19       FALSE  FALSE      TRUE
## 20        TRUE  FALSE     FALSE
## 21       FALSE  FALSE      TRUE
## 22       FALSE  FALSE      TRUE
## 23       FALSE   TRUE     FALSE
## 24       FALSE  FALSE      TRUE
## 25       FALSE  FALSE      TRUE
## 26       FALSE  FALSE      TRUE
## 27       FALSE   TRUE     FALSE
## 28       FALSE  FALSE      TRUE
## 29        TRUE  FALSE     FALSE
## 30       FALSE   TRUE     FALSE
## 31       FALSE   TRUE     FALSE
## 32       FALSE   TRUE     FALSE
```

```
## 33        FALSE    TRUE    FALSE
## 34         TRUE   FALSE    FALSE
## 35         TRUE   FALSE    FALSE
## 36        FALSE    TRUE    FALSE
## 37        FALSE   FALSE     TRUE
## 38        FALSE   FALSE     TRUE
## 39        FALSE   FALSE     TRUE
## 40         TRUE   FALSE    FALSE
## 41         TRUE   FALSE    FALSE
## 42        FALSE    TRUE    FALSE
## 43         TRUE   FALSE    FALSE
## 44        FALSE    TRUE    FALSE
## 45         TRUE   FALSE    FALSE
## 46         TRUE   FALSE    FALSE
## 47         TRUE   FALSE    FALSE
## 48        FALSE    TRUE    FALSE
## 49         TRUE   FALSE    FALSE
## 50        FALSE    TRUE    FALSE
## 51        FALSE   FALSE     TRUE
## 52        FALSE   FALSE     TRUE
## 53        FALSE    TRUE    FALSE
## 54        FALSE   FALSE     TRUE
## 55        FALSE    TRUE    FALSE
## 56        FALSE   FALSE     TRUE
## 57         TRUE   FALSE    FALSE
## 58         TRUE   FALSE    FALSE
## 59         TRUE   FALSE    FALSE
## 60        FALSE    TRUE    FALSE
## 61        FALSE    TRUE    FALSE
## 62        FALSE    TRUE    FALSE
## 63         TRUE   FALSE    FALSE
## 64        FALSE   FALSE     TRUE
## 65         TRUE   FALSE    FALSE
## 66        FALSE   FALSE     TRUE
## 67        FALSE    TRUE    FALSE
## 68         TRUE   FALSE    FALSE
## 69         TRUE   FALSE    FALSE
## 70        FALSE    TRUE    FALSE
## 71        FALSE    TRUE    FALSE
## 72         TRUE   FALSE    FALSE
## 73        FALSE   FALSE     TRUE
## 74         TRUE   FALSE    FALSE
## 75        FALSE   FALSE     TRUE
## 76        FALSE   FALSE     TRUE
## 77        FALSE   FALSE     TRUE
## 78         TRUE   FALSE    FALSE
## 79         TRUE   FALSE    FALSE
## 80        FALSE    TRUE    FALSE
## 81        FALSE    TRUE    FALSE
## 82         TRUE   FALSE    FALSE
## 83         TRUE   FALSE    FALSE
## 84        FALSE    TRUE    FALSE
## 85        FALSE   FALSE     TRUE
## 86        FALSE   FALSE     TRUE
```

```
## 87       TRUE  FALSE      FALSE
## 88       TRUE  FALSE      FALSE
## 89      FALSE  FALSE       TRUE
## 90      FALSE   TRUE      FALSE
## 91       TRUE  FALSE      FALSE
## 92       TRUE  FALSE      FALSE
## 93      FALSE   TRUE      FALSE
## 94      FALSE   TRUE      FALSE
## 95       TRUE  FALSE      FALSE
## 96      FALSE   TRUE      FALSE
## 97      FALSE  FALSE       TRUE
## 98      FALSE   TRUE      FALSE
## 99      FALSE   TRUE      FALSE
## 100     FALSE  FALSE       TRUE
## 101     FALSE   TRUE      FALSE
## 102     FALSE   TRUE      FALSE
## 103     FALSE   TRUE      FALSE
## 104     FALSE  FALSE       TRUE
## 105      TRUE  FALSE      FALSE
## 106      TRUE  FALSE      FALSE
## 107      TRUE  FALSE      FALSE
## 108     FALSE  FALSE       TRUE
## 109     FALSE  FALSE       TRUE
## 110      TRUE  FALSE      FALSE
## 111     FALSE  FALSE       TRUE
## 112      TRUE  FALSE      FALSE
## 113     FALSE   TRUE      FALSE
## 114     FALSE   TRUE      FALSE
## 115     FALSE   TRUE      FALSE
## 116     FALSE   TRUE      FALSE
## 117      TRUE  FALSE      FALSE
## 118     FALSE   TRUE      FALSE
## 119     FALSE  FALSE       TRUE
## 120     FALSE  FALSE       TRUE
##
## $covariate
##     Sepal.Length Sepal.Width Petal.Length Petal.Width
## 55           6.5         2.8          4.6         1.5
## 37           5.5         3.5          1.3         0.2
## 146          6.7         3.0          5.2         2.3
## 70           5.6         2.5          3.9         1.1
## 45           5.1         3.8          1.9         0.4
## 124          6.3         2.7          4.9         1.8
## 20           5.1         3.8          1.5         0.3
## 76           6.6         3.0          4.4         1.4
## 144          6.8         3.2          5.9         2.3
## 3            4.7         3.2          1.3         0.2
## 88           6.3         2.3          4.4         1.3
## 10           4.9         3.1          1.5         0.1
## 136          7.7         3.0          6.1         2.3
## 126          7.2         3.2          6.0         1.8
## 102          5.8         2.7          5.1         1.9
## 125          6.7         3.3          5.7         2.1
## 64           6.1         2.9          4.7         1.4
```
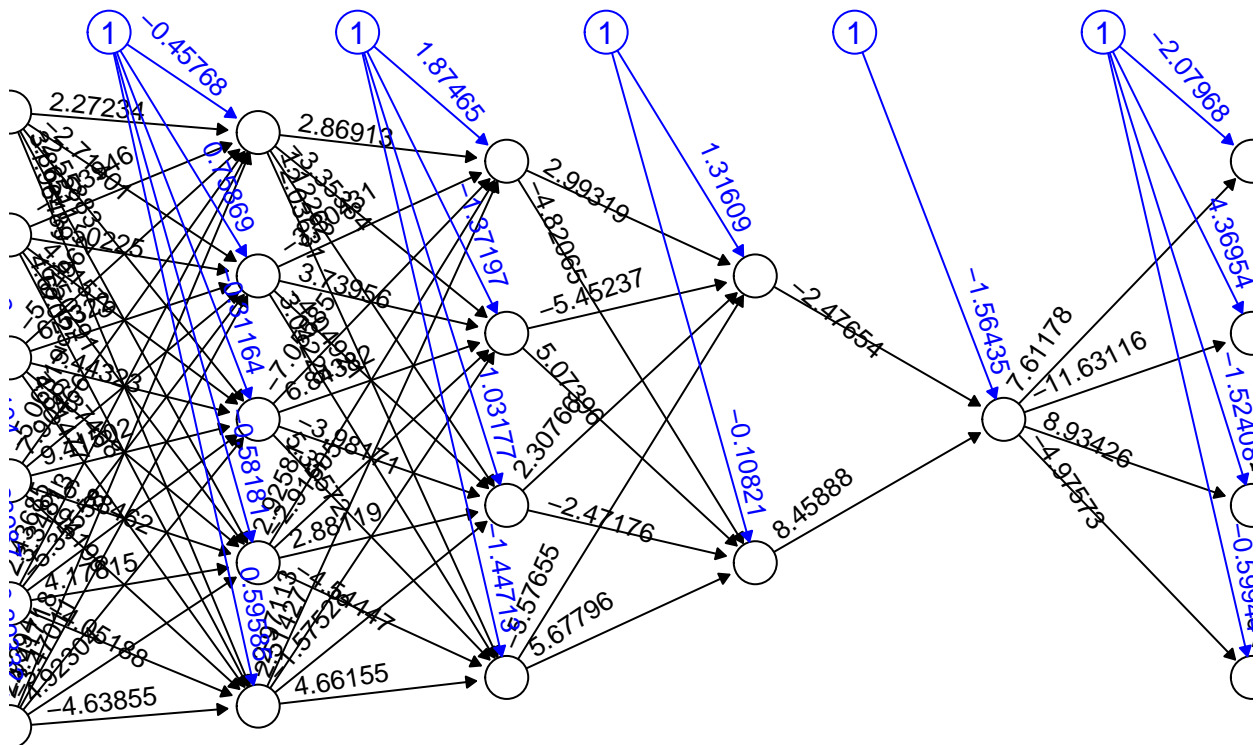
```
## 111          6.5          3.2          5.1          2.0
## 122          5.6          2.8          4.9          2.0
## 32           5.4          3.4          1.5          0.4
## 147          6.3          2.5          5.0          1.9
## 123          7.7          2.8          6.7          2.0
## 95           5.6          2.7          4.2          1.3
## 101          6.3          3.3          6.0          2.5
## 149          6.2          3.4          5.4          2.3
## 143          5.8          2.7          5.1          1.9
## 94           5.0          2.3          3.3          1.0
## 150          5.9          3.0          5.1          1.8
## 11           5.4          3.7          1.5          0.2
## 83           5.8          2.7          3.9          1.2
## 54           5.5          2.3          4.0          1.3
## 57           6.3          3.3          4.7          1.6
## 61           5.0          2.0          3.5          1.0
## 48           4.6          3.2          1.4          0.2
## 29           5.2          3.4          1.4          0.2
## 69           6.2          2.2          4.5          1.5
## 130          7.2          3.0          5.8          1.6
## 115          5.8          2.8          5.1          2.4
## 145          6.7          3.3          5.7          2.5
## 17           5.4          3.9          1.3          0.4
## 50           5.0          3.3          1.4          0.2
## 96           5.7          3.0          4.2          1.2
## 35           4.9          3.1          1.5          0.2
## 93           5.8          2.6          4.0          1.2
## 49           5.3          3.7          1.5          0.2
## 12           4.8          3.4          1.6          0.2
## 14           4.3          3.0          1.1          0.1
## 60           5.2          2.7          3.9          1.4
## 18           5.1          3.5          1.4          0.3
## 97           5.7          2.9          4.2          1.3
## 109          6.7          2.5          5.8          1.8
## 134          6.3          2.8          5.1          1.5
## 62           5.9          3.0          4.2          1.5
## 113          6.8          3.0          5.5          2.1
## 75           6.4          2.9          4.3          1.3
## 119          7.7          2.6          6.9          2.3
## 41           5.0          3.5          1.3          0.3
## 27           5.0          3.4          1.6          0.4
## 25           4.8          3.4          1.9          0.2
## 89           5.6          3.0          4.1          1.3
## 100          5.7          2.8          4.1          1.3
## 91           5.5          2.6          4.4          1.2
## 19           5.7          3.8          1.7          0.3
## 137          6.3          3.4          5.6          2.4
## 46           4.8          3.0          1.4          0.3
## 103          7.1          3.0          5.9          2.1
## 85           5.4          3.0          4.5          1.5
## 6            5.4          3.9          1.7          0.4
## 44           5.0          3.5          1.6          0.6
## 86           6.0          3.4          4.5          1.6
## 71           5.9          3.2          4.8          1.8
```

```
## 36         5.0         3.2         1.2         0.2
## 104        6.3         2.9         5.6         1.8
## 42         4.5         2.3         1.3         0.3
## 139        6.0         3.0         4.8         1.8
## 118        7.7         3.8         6.7         2.2
## 106        7.6         3.0         6.6         2.1
## 9          4.4         2.9         1.4         0.2
## 43         4.4         3.2         1.3         0.2
## 84         6.0         2.7         5.1         1.6
## 66         6.7         3.1         4.4         1.4
## 39         4.4         3.0         1.3         0.2
## 7          4.6         3.4         1.4         0.3
## 72         6.1         2.8         4.0         1.3
## 117        6.5         3.0         5.5         1.8
## 108        7.3         2.9         6.3         1.8
## 4          4.6         3.1         1.5         0.2
## 38         4.9         3.6         1.4         0.1
## 138        6.4         3.1         5.5         1.8
## 65         5.6         2.9         3.6         1.3
## 5          5.0         3.6         1.4         0.2
## 2          4.9         3.0         1.4         0.2
## 87         6.7         3.1         4.7         1.5
## 82         5.5         2.4         3.7         1.0
## 40         5.1         3.4         1.5         0.2
## 77         6.8         2.8         4.8         1.4
## 128        6.1         3.0         4.9         1.8
## 67         5.6         3.0         4.5         1.5
## 92         6.1         3.0         4.6         1.4
## 131        7.4         2.8         6.1         1.9
## 74         6.1         2.8         4.7         1.2
## 56         5.7         2.8         4.5         1.3
## 59         6.6         2.9         4.6         1.3
## 120        6.0         2.2         5.0         1.5
## 23         4.6         3.6         1.0         0.2
## 13         4.8         3.0         1.4         0.1
## 33         5.2         4.1         1.5         0.1
## 107        4.9         2.5         4.5         1.7
## 127        6.2         2.8         4.8         1.8
## 24         5.1         3.3         1.7         0.5
## 116        6.4         3.2         5.3         2.3
## 34         5.5         4.2         1.4         0.2
## 68         5.8         2.7         4.1         1.0
## 58         4.9         2.4         3.3         1.0
## 73         6.3         2.5         4.9         1.5
## 80         5.7         2.6         3.5         1.0
## 8          5.0         3.4         1.5         0.2
## 99         5.1         2.5         3.0         1.1
## 121        6.9         3.2         5.7         2.3
## 133        6.4         2.8         5.6         2.2
##
## $model.list
## $model.list$response
## [1] "versicolor" "setosa"     "virginica"
##
```

```
## $model.list$variables
## [1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"
##
##
## $err.fct
## function (x, y)
## {
##     1/2 * (y - x)^2
## }
## <bytecode: 0x5bfe53991878>
## <environment: 0x5bfe56f96240>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5bfe53997cd8>
## <environment: 0x5bfe56f966d8>
## attr(,"type")
## [1] "logistic"
```

```r
plot(model3, rep = 'best')
```



```r
pred3 <- predict(model3, test_data)
pred3
```

```
##               [,1]         [,2]         [,3]
## 1     9.999036e-01 1.421452e-13 3.158454e-04
```

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```
## 15    9.999036e-01 1.421452e-13 3.158454e-04
## 16    9.999036e-01 1.421452e-13 3.158454e-04
## 21    9.999036e-01 1.421452e-13 3.158454e-04
## 22    9.999036e-01 1.421452e-13 3.158454e-04
## 26    9.999036e-01 1.421452e-13 3.158454e-04
## 28    9.999036e-01 1.421452e-13 3.158454e-04
## 30    9.999036e-01 1.421452e-13 3.158454e-04
## 31    9.999036e-01 1.421452e-13 3.158454e-04
## 47    9.999036e-01 1.421452e-13 3.158454e-04
## 51    8.700491e-109 1.000000e+00 1.336467e-05
## 52    1.297176e-108 1.000000e+00 1.408254e-05
## 53    2.071300e-108 1.000000e+00 1.515804e-05
## 63    7.315655e-109 1.000000e+00 1.311504e-05
## 78    7.205867e-102 9.969511e-01 6.257672e-02
## 79    4.758556e-108 1.000000e+00 1.773884e-05
## 81    7.420057e-109 1.000000e+00 1.313390e-05
## 90    9.760581e-109 1.000000e+00 1.355172e-05
## 98    8.269050e-109 1.000000e+00 1.328727e-05
## 105   3.961383e-04 2.714381e-15 9.990498e-01
## 110   4.266206e-06 1.163679e-15 9.999579e-01
## 112   9.453037e-08 9.148913e-16 9.999839e-01
## 114   1.761865e-02 6.660749e-15 9.761323e-01
## 129   7.258686e-04 3.114619e-15 9.984396e-01
## 132   1.015953e-10 9.434979e-16 9.999723e-01
## 135   3.846955e-06 1.148504e-15 9.999600e-01
## 140   2.117849e-14 1.020414e-15 9.998810e-01
## 141   2.085738e-05 1.486541e-15 9.998942e-01
## 142   2.308972e-15 1.040769e-15 9.998185e-01
## 148   4.906116e-20 1.127430e-15 9.985372e-01
```

17 hidden layers with 10, 20, 30, 40, 40, 20, 10, 40, 50,10, 20, 30, 40, 40, 20, 10, and 40 neurons

```r
model4 <- neuralnet(Species ~ Sepal.Length + Sepal.Width + Petal.Length + Petal.Width, data = train_data
# Print the model summary
head(model4)
```

```
## $call
## neuralnet(formula = Species ~ Sepal.Length + Sepal.Width + Petal.Length +
##     Petal.Width, data = train_data, hidden = c(10, 20, 30, 40,
##     40, 20, 10, 40, 50, 10, 20, 30, 40, 40, 20, 10, 40), linear.output = FALSE)
##
## $response
##     versicolor setosa virginica
## 1       FALSE   TRUE     FALSE
## 2        TRUE  FALSE     FALSE
## 3       FALSE  FALSE      TRUE
## 4       FALSE   TRUE     FALSE
## 5        TRUE  FALSE     FALSE
## 6       FALSE  FALSE      TRUE
## 7        TRUE  FALSE     FALSE
## 8       FALSE   TRUE     FALSE
## 9       FALSE  FALSE      TRUE
```

```
## 10      TRUE FALSE   FALSE
## 11     FALSE  TRUE   FALSE
## 12      TRUE FALSE   FALSE
## 13     FALSE FALSE    TRUE
## 14     FALSE FALSE    TRUE
## 15     FALSE FALSE    TRUE
## 16     FALSE FALSE    TRUE
## 17     FALSE  TRUE   FALSE
## 18     FALSE FALSE    TRUE
## 19     FALSE FALSE    TRUE
## 20      TRUE FALSE   FALSE
## 21     FALSE FALSE    TRUE
## 22     FALSE FALSE    TRUE
## 23     FALSE  TRUE   FALSE
## 24     FALSE FALSE    TRUE
## 25     FALSE FALSE    TRUE
## 26     FALSE FALSE    TRUE
## 27     FALSE  TRUE   FALSE
## 28     FALSE FALSE    TRUE
## 29      TRUE FALSE   FALSE
## 30     FALSE  TRUE   FALSE
## 31     FALSE  TRUE   FALSE
## 32     FALSE  TRUE   FALSE
## 33     FALSE  TRUE   FALSE
## 34      TRUE FALSE   FALSE
## 35      TRUE FALSE   FALSE
## 36     FALSE  TRUE   FALSE
## 37     FALSE FALSE    TRUE
## 38     FALSE FALSE    TRUE
## 39     FALSE FALSE    TRUE
## 40      TRUE FALSE   FALSE
## 41      TRUE FALSE   FALSE
## 42     FALSE  TRUE   FALSE
## 43      TRUE FALSE   FALSE
## 44     FALSE  TRUE   FALSE
## 45      TRUE FALSE   FALSE
## 46      TRUE FALSE   FALSE
## 47      TRUE FALSE   FALSE
## 48     FALSE  TRUE   FALSE
## 49      TRUE FALSE   FALSE
## 50     FALSE  TRUE   FALSE
## 51     FALSE FALSE    TRUE
## 52     FALSE FALSE    TRUE
## 53     FALSE  TRUE   FALSE
## 54     FALSE FALSE    TRUE
## 55     FALSE  TRUE   FALSE
## 56     FALSE FALSE    TRUE
## 57      TRUE FALSE   FALSE
## 58      TRUE FALSE   FALSE
## 59      TRUE FALSE   FALSE
## 60     FALSE  TRUE   FALSE
## 61     FALSE  TRUE   FALSE
## 62     FALSE  TRUE   FALSE
## 63      TRUE FALSE   FALSE
```

```
## 64     FALSE FALSE     TRUE
## 65      TRUE FALSE    FALSE
## 66     FALSE FALSE     TRUE
## 67     FALSE  TRUE    FALSE
## 68      TRUE FALSE    FALSE
## 69      TRUE FALSE    FALSE
## 70     FALSE  TRUE    FALSE
## 71     FALSE  TRUE    FALSE
## 72      TRUE FALSE    FALSE
## 73     FALSE FALSE     TRUE
## 74      TRUE FALSE    FALSE
## 75     FALSE FALSE     TRUE
## 76     FALSE FALSE     TRUE
## 77     FALSE FALSE     TRUE
## 78      TRUE FALSE    FALSE
## 79      TRUE FALSE    FALSE
## 80     FALSE  TRUE    FALSE
## 81     FALSE  TRUE    FALSE
## 82      TRUE FALSE    FALSE
## 83      TRUE FALSE    FALSE
## 84     FALSE  TRUE    FALSE
## 85     FALSE FALSE     TRUE
## 86     FALSE FALSE     TRUE
## 87      TRUE FALSE    FALSE
## 88      TRUE FALSE    FALSE
## 89     FALSE FALSE     TRUE
## 90     FALSE  TRUE    FALSE
## 91      TRUE FALSE    FALSE
## 92      TRUE FALSE    FALSE
## 93     FALSE  TRUE    FALSE
## 94     FALSE  TRUE    FALSE
## 95      TRUE FALSE    FALSE
## 96     FALSE  TRUE    FALSE
## 97     FALSE FALSE     TRUE
## 98     FALSE  TRUE    FALSE
## 99     FALSE  TRUE    FALSE
## 100    FALSE FALSE     TRUE
## 101    FALSE  TRUE    FALSE
## 102    FALSE  TRUE    FALSE
## 103    FALSE  TRUE    FALSE
## 104    FALSE FALSE     TRUE
## 105     TRUE FALSE    FALSE
## 106     TRUE FALSE    FALSE
## 107     TRUE FALSE    FALSE
## 108    FALSE FALSE     TRUE
## 109    FALSE FALSE     TRUE
## 110     TRUE FALSE    FALSE
## 111    FALSE FALSE     TRUE
## 112     TRUE FALSE    FALSE
## 113    FALSE  TRUE    FALSE
## 114    FALSE  TRUE    FALSE
## 115    FALSE  TRUE    FALSE
## 116    FALSE  TRUE    FALSE
## 117     TRUE FALSE    FALSE
```

```
## 118          FALSE     TRUE      FALSE
## 119          FALSE    FALSE       TRUE
## 120          FALSE    FALSE       TRUE
##
## $covariate
##      Sepal.Length Sepal.Width Petal.Length Petal.Width
## 55            6.5         2.8          4.6         1.5
## 37            5.5         3.5          1.3         0.2
## 146           6.7         3.0          5.2         2.3
## 70            5.6         2.5          3.9         1.1
## 45            5.1         3.8          1.9         0.4
## 124           6.3         2.7          4.9         1.8
## 20            5.1         3.8          1.5         0.3
## 76            6.6         3.0          4.4         1.4
## 144           6.8         3.2          5.9         2.3
## 3             4.7         3.2          1.3         0.2
## 88            6.3         2.3          4.4         1.3
## 10            4.9         3.1          1.5         0.1
## 136           7.7         3.0          6.1         2.3
## 126           7.2         3.2          6.0         1.8
## 102           5.8         2.7          5.1         1.9
## 125           6.7         3.3          5.7         2.1
## 64            6.1         2.9          4.7         1.4
## 111           6.5         3.2          5.1         2.0
## 122           5.6         2.8          4.9         2.0
## 32            5.4         3.4          1.5         0.4
## 147           6.3         2.5          5.0         1.9
## 123           7.7         2.8          6.7         2.0
## 95            5.6         2.7          4.2         1.3
## 101           6.3         3.3          6.0         2.5
## 149           6.2         3.4          5.4         2.3
## 143           5.8         2.7          5.1         1.9
## 94            5.0         2.3          3.3         1.0
## 150           5.9         3.0          5.1         1.8
## 11            5.4         3.7          1.5         0.2
## 83            5.8         2.7          3.9         1.2
## 54            5.5         2.3          4.0         1.3
## 57            6.3         3.3          4.7         1.6
## 61            5.0         2.0          3.5         1.0
## 48            4.6         3.2          1.4         0.2
## 29            5.2         3.4          1.4         0.2
## 69            6.2         2.2          4.5         1.5
## 130           7.2         3.0          5.8         1.6
## 115           5.8         2.8          5.1         2.4
## 145           6.7         3.3          5.7         2.5
## 17            5.4         3.9          1.3         0.4
## 50            5.0         3.3          1.4         0.2
## 96            5.7         3.0          4.2         1.2
## 35            4.9         3.1          1.5         0.2
## 93            5.8         2.6          4.0         1.2
## 49            5.3         3.7          1.5         0.2
## 12            4.8         3.4          1.6         0.2
## 14            4.3         3.0          1.1         0.1
## 60            5.2         2.7          3.9         1.4
```
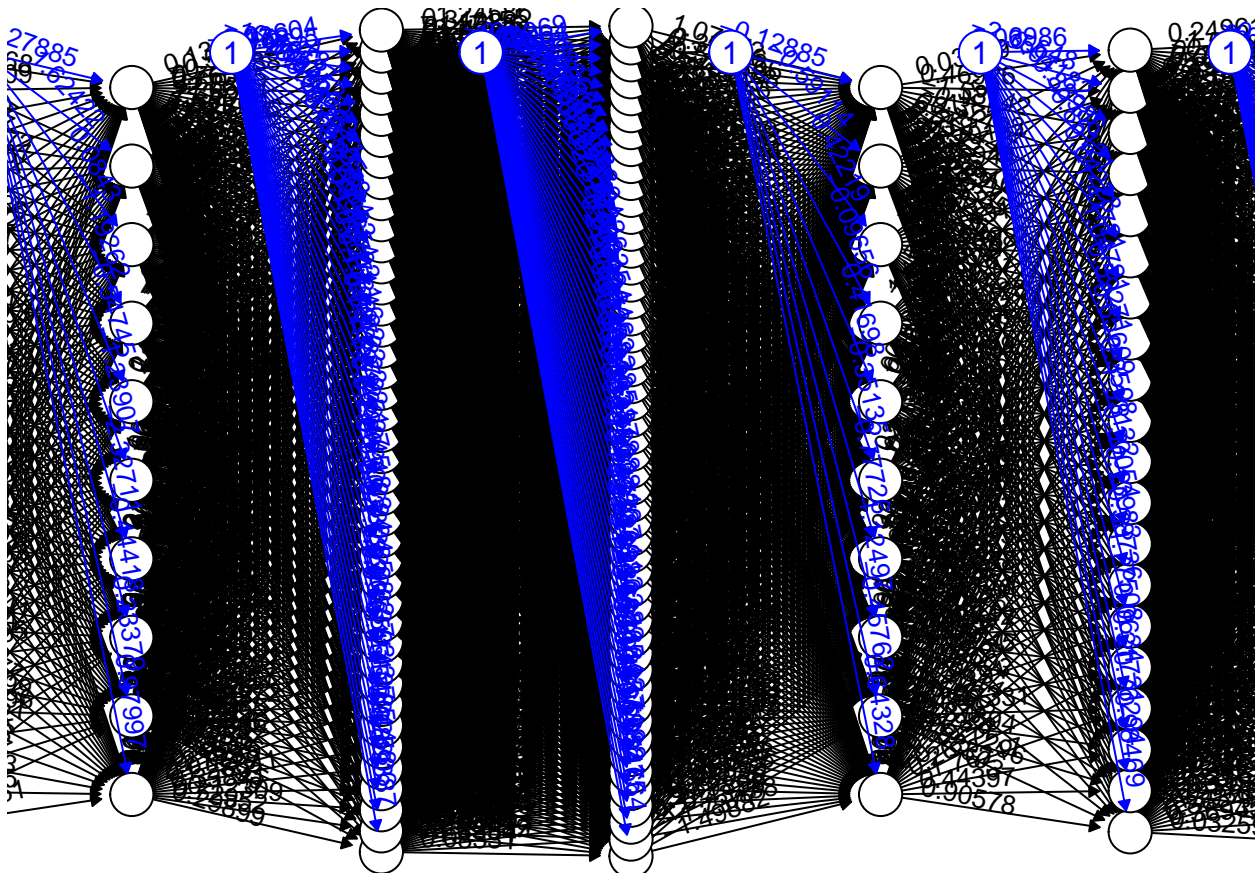
```
## 18           5.1           3.5           1.4           0.3
## 97           5.7           2.9           4.2           1.3
## 109          6.7           2.5           5.8           1.8
## 134          6.3           2.8           5.1           1.5
## 62           5.9           3.0           4.2           1.5
## 113          6.8           3.0           5.5           2.1
## 75           6.4           2.9           4.3           1.3
## 119          7.7           2.6           6.9           2.3
## 41           5.0           3.5           1.3           0.3
## 27           5.0           3.4           1.6           0.4
## 25           4.8           3.4           1.9           0.2
## 89           5.6           3.0           4.1           1.3
## 100          5.7           2.8           4.1           1.3
## 91           5.5           2.6           4.4           1.2
## 19           5.7           3.8           1.7           0.3
## 137          6.3           3.4           5.6           2.4
## 46           4.8           3.0           1.4           0.3
## 103          7.1           3.0           5.9           2.1
## 85           5.4           3.0           4.5           1.5
## 6            5.4           3.9           1.7           0.4
## 44           5.0           3.5           1.6           0.6
## 86           6.0           3.4           4.5           1.6
## 71           5.9           3.2           4.8           1.8
## 36           5.0           3.2           1.2           0.2
## 104          6.3           2.9           5.6           1.8
## 42           4.5           2.3           1.3           0.3
## 139          6.0           3.0           4.8           1.8
## 118          7.7           3.8           6.7           2.2
## 106          7.6           3.0           6.6           2.1
## 9            4.4           2.9           1.4           0.2
## 43           4.4           3.2           1.3           0.2
## 84           6.0           2.7           5.1           1.6
## 66           6.7           3.1           4.4           1.4
## 39           4.4           3.0           1.3           0.2
## 7            4.6           3.4           1.4           0.3
## 72           6.1           2.8           4.0           1.3
## 117          6.5           3.0           5.5           1.8
## 108          7.3           2.9           6.3           1.8
## 4            4.6           3.1           1.5           0.2
## 38           4.9           3.6           1.4           0.1
## 138          6.4           3.1           5.5           1.8
## 65           5.6           2.9           3.6           1.3
## 5            5.0           3.6           1.4           0.2
## 2            4.9           3.0           1.4           0.2
## 87           6.7           3.1           4.7           1.5
## 82           5.5           2.4           3.7           1.0
## 40           5.1           3.4           1.5           0.2
## 77           6.8           2.8           4.8           1.4
## 128          6.1           3.0           4.9           1.8
## 67           5.6           3.0           4.5           1.5
## 92           6.1           3.0           4.6           1.4
## 131          7.4           2.8           6.1           1.9
## 74           6.1           2.8           4.7           1.2
## 56           5.7           2.8           4.5           1.3
```

```
## 59          6.6          2.9          4.6          1.3
## 120         6.0          2.2          5.0          1.5
## 23          4.6          3.6          1.0          0.2
## 13          4.8          3.0          1.4          0.1
## 33          5.2          4.1          1.5          0.1
## 107         4.9          2.5          4.5          1.7
## 127         6.2          2.8          4.8          1.8
## 24          5.1          3.3          1.7          0.5
## 116         6.4          3.2          5.3          2.3
## 34          5.5          4.2          1.4          0.2
## 68          5.8          2.7          4.1          1.0
## 58          4.9          2.4          3.3          1.0
## 73          6.3          2.5          4.9          1.5
## 80          5.7          2.6          3.5          1.0
## 8           5.0          3.4          1.5          0.2
## 99          5.1          2.5          3.0          1.1
## 121         6.9          3.2          5.7          2.3
## 133         6.4          2.8          5.6          2.2
##
## $model.list
## $model.list$response
## [1] "versicolor" "setosa"      "virginica"
##
## $model.list$variables
## [1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"
##
##
## $err.fct
## function (x, y)
## {
##     1/2 * (y - x)^2
## }
## <bytecode: 0x5bfe53991878>
## <environment: 0x5bfe557ee810>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5bfe53997cd8>
## <environment: 0x5bfe557eece0>
## attr(,"type")
## [1] "logistic"
```

```r
plot(model4, rep = 'best')
```

```r
pred4 <- predict(model4, test_data)
pred4
```

```
##              [,1]        [,2]        [,3]
## 1    0.998740896 0.002362521 0.003209156
## 15   0.998749978 0.002366242 0.003214961
## 16   0.998745391 0.002365070 0.003211674
## 21   0.998736578 0.002357736 0.003207876
## 22   0.998734385 0.002353665 0.003208018
## 26   0.998730123 0.002335525 0.003213250
## 28   0.998739772 0.002361558 0.003208685
## 30   0.998730214 0.002300796 0.003230491
## 31   0.998729458 0.002317132 0.003221704
## 47   0.998736261 0.002357223 0.003207859
## 51   0.001152903 0.512633875 0.487269718
## 52   0.001152837 0.512644036 0.487260514
## 53   0.001152912 0.512632525 0.487271073
## 63   0.001152909 0.512633085 0.487270433
## 78   0.001153255 0.512580086 0.487318972
## 79   0.001153021 0.512615803 0.487286376
## 81   0.001152810 0.512648196 0.487256644
## 90   0.001152894 0.512635372 0.487268475
## 98   0.001152823 0.512646172 0.487258511
## 105  0.001153932 0.512476340 0.487413336
## 110  0.001153924 0.512477526 0.487412260
## 112  0.001153811 0.512494822 0.487396552
```

```
## 114 0.001153896 0.512481785 0.487408393
## 129 0.001153915 0.512478841 0.487411065
## 132 0.001153642 0.512520748 0.487372986
## 135 0.001153711 0.512510130 0.487382635
## 140 0.001153743 0.512505219 0.487387105
## 141 0.001153920 0.512478181 0.487411665
## 142 0.001153700 0.512511911 0.487381026
## 148 0.001153738 0.512506054 0.487386345
```

Model Evaluation

predict categories using test data

Create list of category name

prediction dataframe

create a table to display the actual and the predicted

```r
evaluate_model <- function(pred, test_data) {
  labels <- c("setosa", "versicolor", "virginica")
  prediction_label <- data.frame(max.col(pred)) %>%
    mutate(pred = labels[max.col(pred)]) %>%
    select(2) %>%
    unlist()
  confusion_matrix <- table(test_data$Species, prediction_label)
  check <- as.numeric(test_data$Species) == max.col(pred)
  check
  accuracy <- (sum(check) / nrow(test_data)) * 100
  list(confusion_matrix = confusion_matrix, accuracy = accuracy)
}
```

Evaluate the model with two hidden layers

```r
evaluation1 <- evaluate_model(pred, test_data)
print("Evaluation of Model 1:")
```

```
## [1] "Evaluation of Model 1:"
```

```r
print(evaluation1$confusion_matrix)
```

```
##             prediction_label
##              setosa versicolor virginica
##   setosa        10          0         0
##   versicolor     0          9         0
##   virginica      0          0        11
```

```r
print(paste("Accuracy:", evaluation1$accuracy))
```

```
## [1] "Accuracy: 100"
```

Evaluate the model with three hidden layers

```
evaluation2 <- evaluate_model(pred2, test_data)
print("Evaluation of Model 2:")
```

```
## [1] "Evaluation of Model 2:"
```

```
print(evaluation2$confusion_matrix)
```

```
##            prediction_label
##             setosa versicolor virginica
##   setosa        10          0         0
##   versicolor     0          8         1
##   virginica      0          1        10
```

```
print(paste("Accuracy:", evaluation2$accuracy))
```

```
## [1] "Accuracy: 93.3333333333333"
```

Evaluate the model with 10 hidden layers

```
evaluation3 <- evaluate_model(pred3, test_data)
print("Evaluation of Model 3:")
```

```
## [1] "Evaluation of Model 3:"
```

```
print(evaluation3$confusion_matrix)
```

```
##            prediction_label
##             setosa versicolor virginica
##   setosa        10          0         0
##   versicolor     0          9         0
##   virginica      0          0        11
```

```
print(paste("Accuracy:", evaluation3$accuracy))
```

```
## [1] "Accuracy: 100"
```

Evaluate the model with 17 hidden layers

```
evaluation4 <- evaluate_model(pred4, test_data)
print("Evaluation of Model 4:")
```

```
## [1] "Evaluation of Model 4:"
```

```
print(evaluation4$confusion_matrix)
```

```
##            prediction_label
##             setosa versicolor
##   setosa        10          0
##   versicolor     0          9
##   virginica      0         11
```

```
print(paste("Accuracy:", evaluation4$accuracy))
```

```
## [1] "Accuracy: 63.3333333333333"
```

Tabular report

Number of Hidden Layers	Accuracy(%)
2	100
3	93.3333333
10	100
17	63.3333333

Increasing the complexity of a neural network by adding more hidden layers and neurons can enhance model performance, as evidenced by the highest accuracy achieved with a model containing 10 hidden layers. However, this improvement is not always guaranteed and heavily depends on the dataset's specific characteristics and the problem at hand. For instance, in model 4, despite increasing the hidden layers to **17**, the accuracy decreased to **63.33%**, illustrating that a more complex architecture does not necessarily lead to better performance and may even hinder it. Additionally, in terms of RAM consumption, the RAM gauge on the Posit website turned red, indicating that all available memory was consumed, highlighting the increased computational demands and resource constraints associated with overly complex models.