R-project1

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2024-08-01

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)

## Warning in download.file(url, destfile, method, mode = "wb", ...): cannot open
## URL
## 'http://rspm/default/__linux__/focal/latest/src/contrib/keras_2.15.0.tar.gz':
## HTTP status was '504 Gateway Timeout'

## Error in download.file(url, destfile, method, mode = "wb", ...) :
##   cannot open URL 'http://rspm/default/__linux__/focal/latest/src/contrib/keras_2.15.0.tar.gz'

## Warning in download.packages(pkgs, destdir = tmpd, available = available, :
## download of package 'keras' failed
```

```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
```

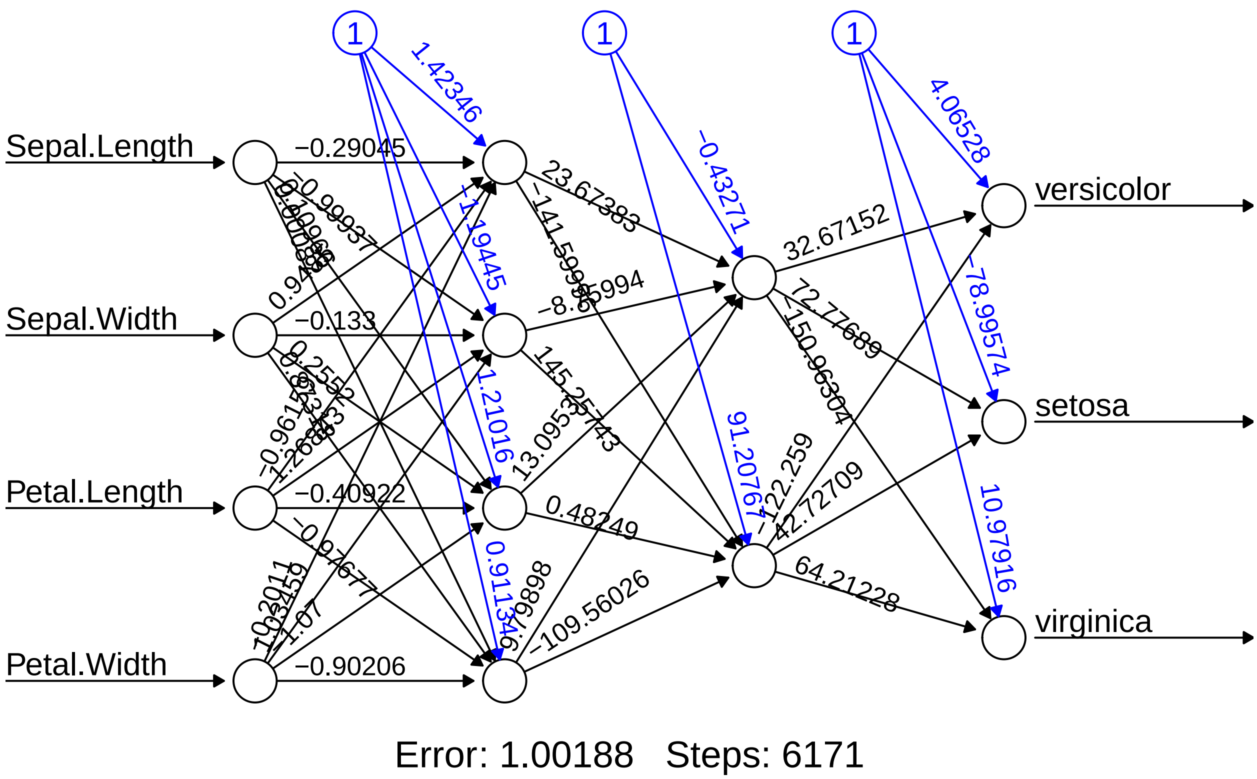
```
## 96       FALSE   TRUE     FALSE
## 97       FALSE  FALSE      TRUE
## 98       FALSE   TRUE     FALSE
## 99       FALSE   TRUE     FALSE
## 100      FALSE  FALSE      TRUE
## 101      FALSE   TRUE     FALSE
## 102      FALSE   TRUE     FALSE
## 103      FALSE   TRUE     FALSE
## 104      FALSE  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: 0x5ff345bcfe58>
## <environment: 0x5ff345bcd720>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5ff345bd4408>
## <environment: 0x5ff345bd0f40>
## attr(,"type")
## [1] "logistic"
```

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




```r
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 5, 6 and 3 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(5, 6, 3), 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
```

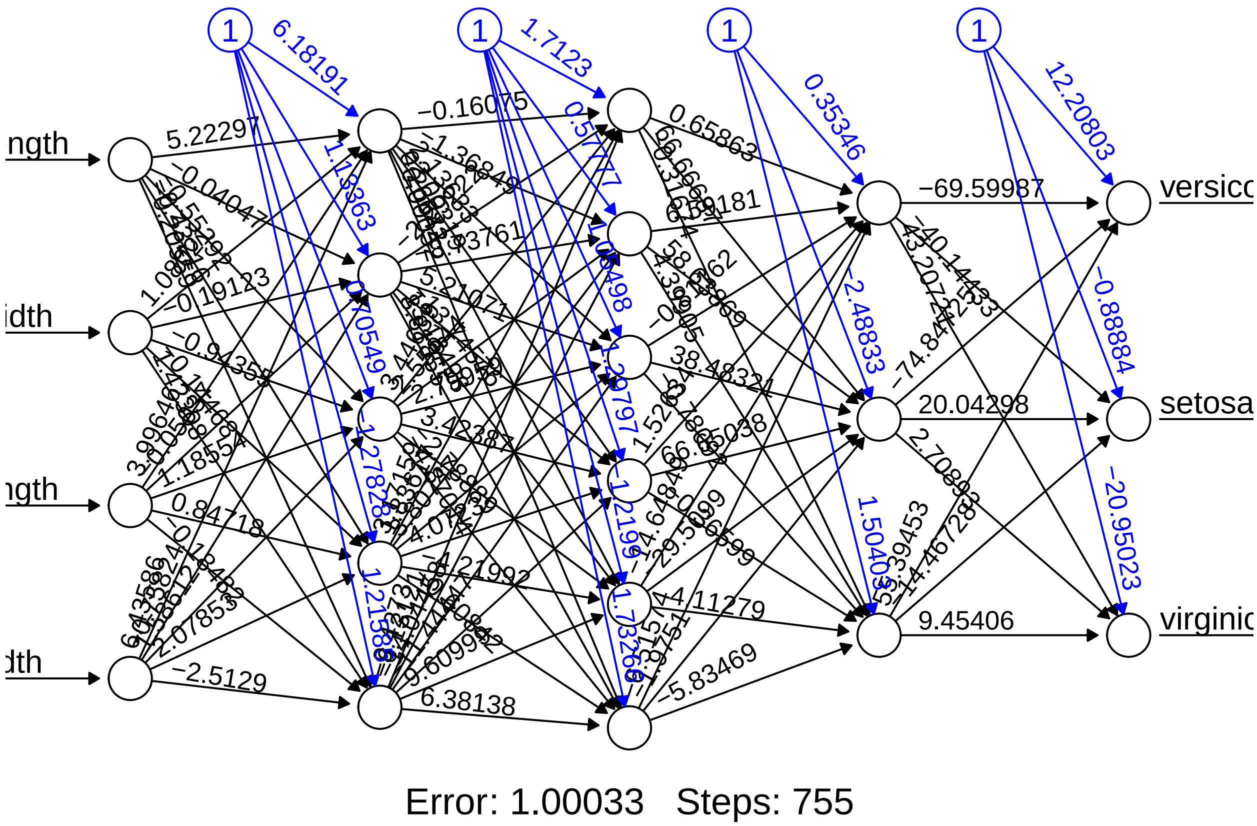
```
## 74          TRUE  FALSE     FALSE
## 75         FALSE  FALSE      TRUE
## 76         FALSE  FALSE      TRUE
## 77         FALSE  FALSE      TRUE
## 78          TRUE  FALSE     FALSE
## 79          TRUE  FALSE     FALSE
## 80         FALSE   TRUE     FALSE
## 81         FALSE   TRUE     FALSE
## 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: 0x5ff345bcfe58>
## <environment: 0x5ff34718e230>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5ff345bd4408>
## <environment: 0x5ff34718e6c8>
## attr(,"type")
## [1] "logistic"
```

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




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

```
##             [,1]         [,2]         [,3]
## 1   1.000000e+00 6.509956e-04 5.385772e-08
## 15  1.000000e+00 6.506519e-04 5.387632e-08
## 16  1.000000e+00 6.504240e-04 5.388867e-08
## 21  1.000000e+00 6.510956e-04 5.385231e-08
## 22  1.000000e+00 6.508797e-04 5.386399e-08
## 26  1.000000e+00 6.515860e-04 5.382580e-08
## 28  1.000000e+00 6.510035e-04 5.385729e-08
## 30  1.000000e+00 6.514384e-04 5.383378e-08
## 31  1.000000e+00 6.515227e-04 5.382923e-08
## 47  1.000000e+00 6.508780e-04 5.386408e-08
## 51  1.504749e-23 9.999999e-01 6.693563e-08
## 52  4.326990e-24 1.000000e+00 5.411274e-08
## 53  1.756766e-24 1.000000e+00 4.665115e-08
## 63  3.673640e-22 9.999998e-01 1.154726e-07
## 78  1.603627e-29 2.902124e-01 7.257712e-01
## 79  2.267233e-24 1.000000e+00 4.862220e-08
## 81  3.948668e-22 9.999998e-01 1.169041e-07
## 90  2.145250e-23 9.999999e-01 7.111211e-08
## 98  8.937235e-23 9.999999e-01 9.072088e-08
## 105 3.066205e-35 8.900533e-16 1.000000e+00
## 110 7.804991e-35 6.578841e-16 1.000000e+00
## 112 5.407094e-37 4.365852e-15 1.000000e+00
## 114 3.033160e-36 2.063718e-15 1.000000e+00
## 129 1.641648e-35 1.101249e-15 1.000000e+00
```

```
## 132 5.574065e-38 1.600095e-14 1.000000e+00
## 135 4.238644e-23 9.999998e-01 1.367487e-07
## 140 7.385844e-36 1.463866e-15 1.000000e+00
## 141 6.528433e-35 6.959737e-16 1.000000e+00
## 142 3.516115e-35 8.496172e-16 1.000000e+00
## 148 7.505262e-37 3.726516e-15 1.000000e+00
```

5 hidden layers with 9, 21, 7, 8, 5, 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(9, 21, 7, 8, 5),
##     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
```

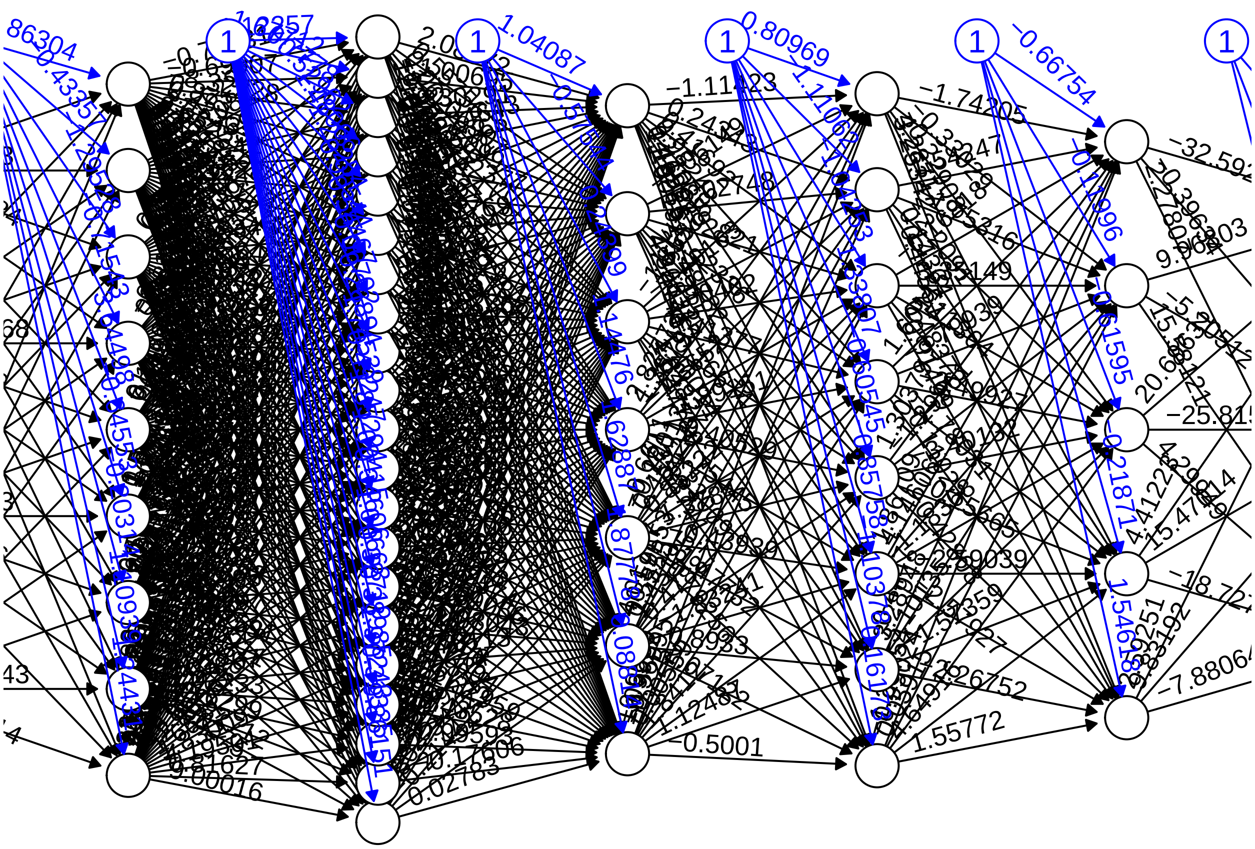
```
## 88        TRUE  FALSE     FALSE
## 89       FALSE  FALSE      TRUE
## 90       FALSE   TRUE     FALSE
## 91        TRUE  FALSE     FALSE
## 92        TRUE  FALSE     FALSE
## 93       FALSE   TRUE     FALSE
## 94       FALSE   TRUE     FALSE
## 95        TRUE  FALSE     FALSE
## 96       FALSE   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: 0x5ff345bcfe58>
## <environment: 0x5ff34978f930>
## attr(,"type")
## [1] "sse"
##
## $act.fct
## function (x)
## {
##     1/(1 + exp(-x))
## }
## <bytecode: 0x5ff345bd4408>
## <environment: 0x5ff34978fdc8>
## attr(,"type")
## [1] "logistic"
```

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



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

```
##             [,1]         [,2]         [,3]
## 1   1.000000e+00 1.028022e-03 1.462620e-03
## 15  1.000000e+00 7.860659e-04 2.017514e-03
## 16  1.000000e+00 1.140339e-03 1.288727e-03
## 21  1.000000e+00 1.014266e-03 1.487406e-03
## 22  1.000000e+00 1.057409e-03 1.413358e-03
## 26  1.000000e+00 1.129845e-03 1.306104e-03
## 28  1.000000e+00 1.025629e-03 1.466899e-03
## 30  1.000000e+00 1.568671e-03 8.730074e-04
## 31  1.000000e+00 1.300101e-03 1.099737e-03
## 47  9.999999e-01 1.843991e-03 7.145405e-04
## 51  1.816741e-09 1.000000e+00 1.858058e-11
## 52  2.675986e-09 1.000000e+00 1.901935e-11
## 53  3.868879e-10 1.000000e+00 3.138251e-11
## 63  1.548027e-09 1.000000e+00 1.893558e-11
## 78  3.149818e-12 9.999999e-01 5.536016e-08
## 79  4.296081e-10 1.000000e+00 4.720082e-11
## 81  2.671509e-09 1.000000e+00 1.761258e-11
## 90  1.892870e-09 1.000000e+00 2.189381e-11
## 98  2.333083e-09 1.000000e+00 1.826905e-11
## 105 4.725142e-08 7.108446e-14 1.000000e+00
## 110 4.278356e-08 8.474517e-14 1.000000e+00
## 112 6.502609e-09 2.064138e-12 1.000000e+00
## 114 2.903561e-08 1.772877e-13 1.000000e+00
## 129 3.804260e-08 1.028013e-13 1.000000e+00
## 132 1.085491e-09 2.696868e-11 1.000000e+00
## 135 6.584627e-09 1.649298e-12 1.000000e+00
## 140 1.351686e-09 3.931129e-11 1.000000e+00
## 141 4.132222e-08 9.921267e-14 1.000000e+00
## 142 2.712914e-10 2.035726e-09 9.999999e-01
## 148 1.371238e-09 5.056537e-11 1.000000e+00
```

Model Evaluation

prediction dataframe

create a table to display the actual and the predicted

```
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

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

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

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

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

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

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

Evaluate the model with 5 hidden layers

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

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

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

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

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

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

Tabular report

Number of Hidden Layers	Accuracy(%)
2	100
3	93.3333333
5	100

analysis is Based on the accuracy scores from your models, the model with three hidden layers achieved an accuracy of 93.33%, indicating that it correctly classified most instances but made a few errors. The confusion matrix shows that this model misclassified one instance of "virginica" as "versicolor." On the other hand, the model with five hidden layers achieved a perfect accuracy of 100%, correctly classifying all instances without any errors. This suggests that the model with five hidden layers was able to capture the patterns in the data more effectively than the one with three hidden layers. This result indicates that for the Iris dataset, increasing the complexity of the model to five hidden layers can enhance performance, eliminating misclassifications present in the simpler model.