ANN in R

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Installing packages

```
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)
```

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

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

```
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 error
```

Data analysis

```
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
```

```
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

```
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
```

```
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
```

```
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

```
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
```

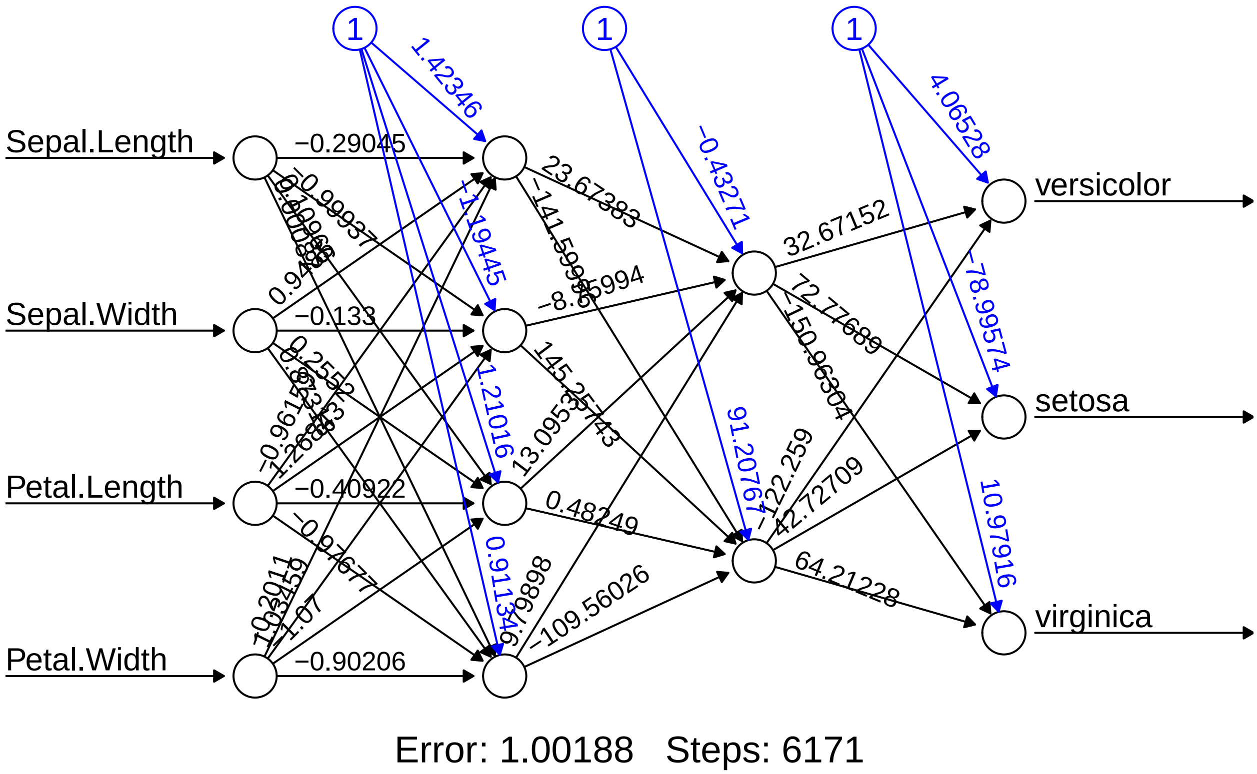
```
## 105       TRUE  FALSE     FALSE
## 106       TRUE  FALSE     FALSE
## 107       TRUE  FALSE     FALSE
## 108      FALSE  FALSE      TRUE
## 109      FALSE  FALSE      TRUE
## 110       TRUE  FALSE     FALSE
## 111      FALSE  FALSE      TRUE
## 112       TRUE  FALSE     FALSE
## 113      FALSE   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"
```

```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 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
```

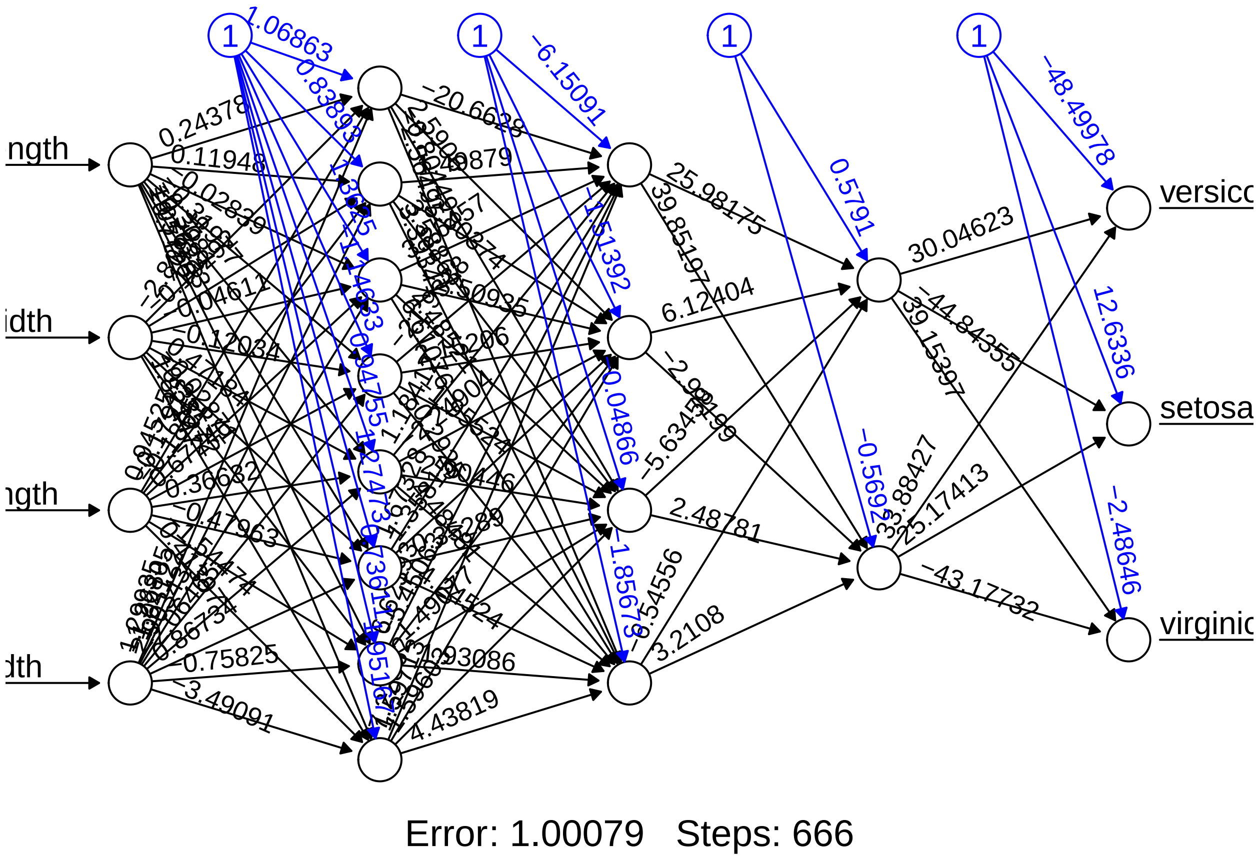
```
## 83        TRUE  FALSE     FALSE
## 84       FALSE   TRUE     FALSE
## 85       FALSE  FALSE      TRUE
## 86       FALSE  FALSE      TRUE
## 87        TRUE  FALSE     FALSE
## 88        TRUE  FALSE     FALSE
## 89       FALSE  FALSE      TRUE
## 90       FALSE   TRUE     FALSE
## 91        TRUE  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
```

```
## 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"
```

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




```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
```

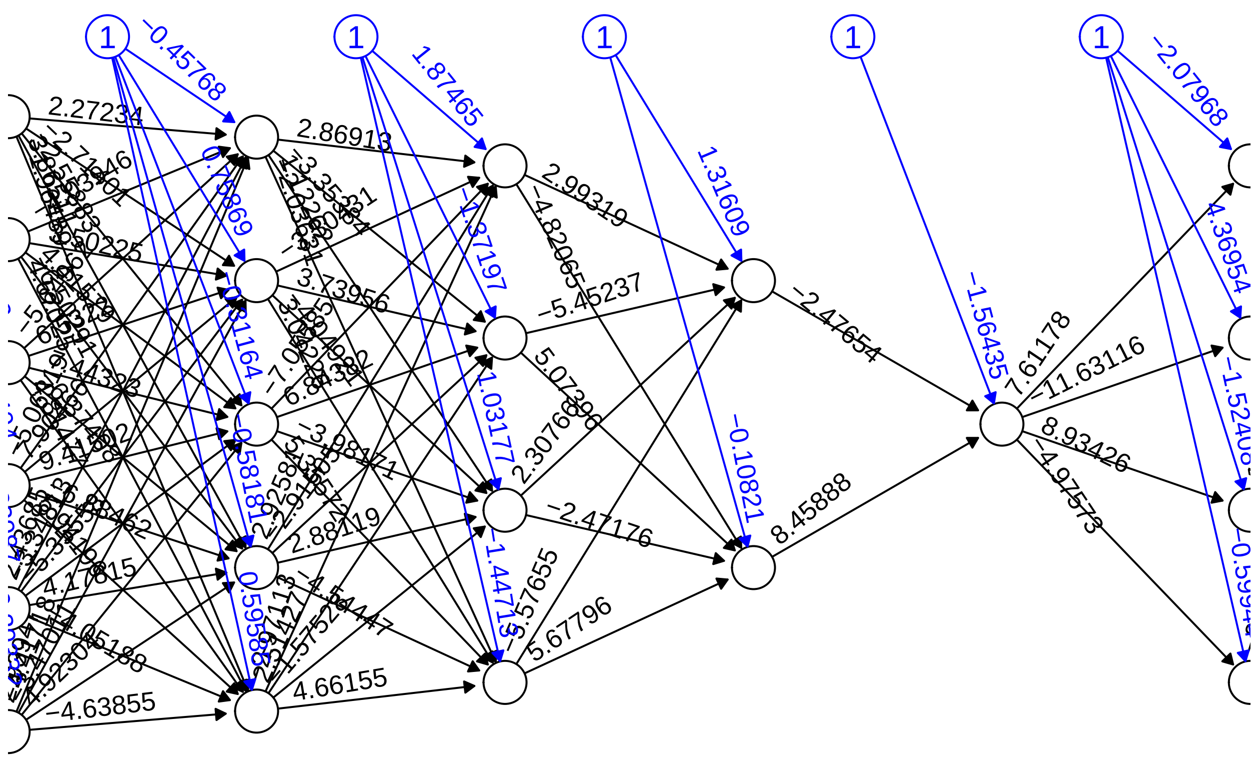
```
## 87         TRUE  FALSE     FALSE
## 88         TRUE  FALSE     FALSE
## 89        FALSE  FALSE      TRUE
## 90        FALSE   TRUE     FALSE
## 91         TRUE  FALSE     FALSE
## 92         TRUE  FALSE     FALSE
## 93        FALSE   TRUE     FALSE
## 94        FALSE   TRUE     FALSE
## 95         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
```

```
## 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
```

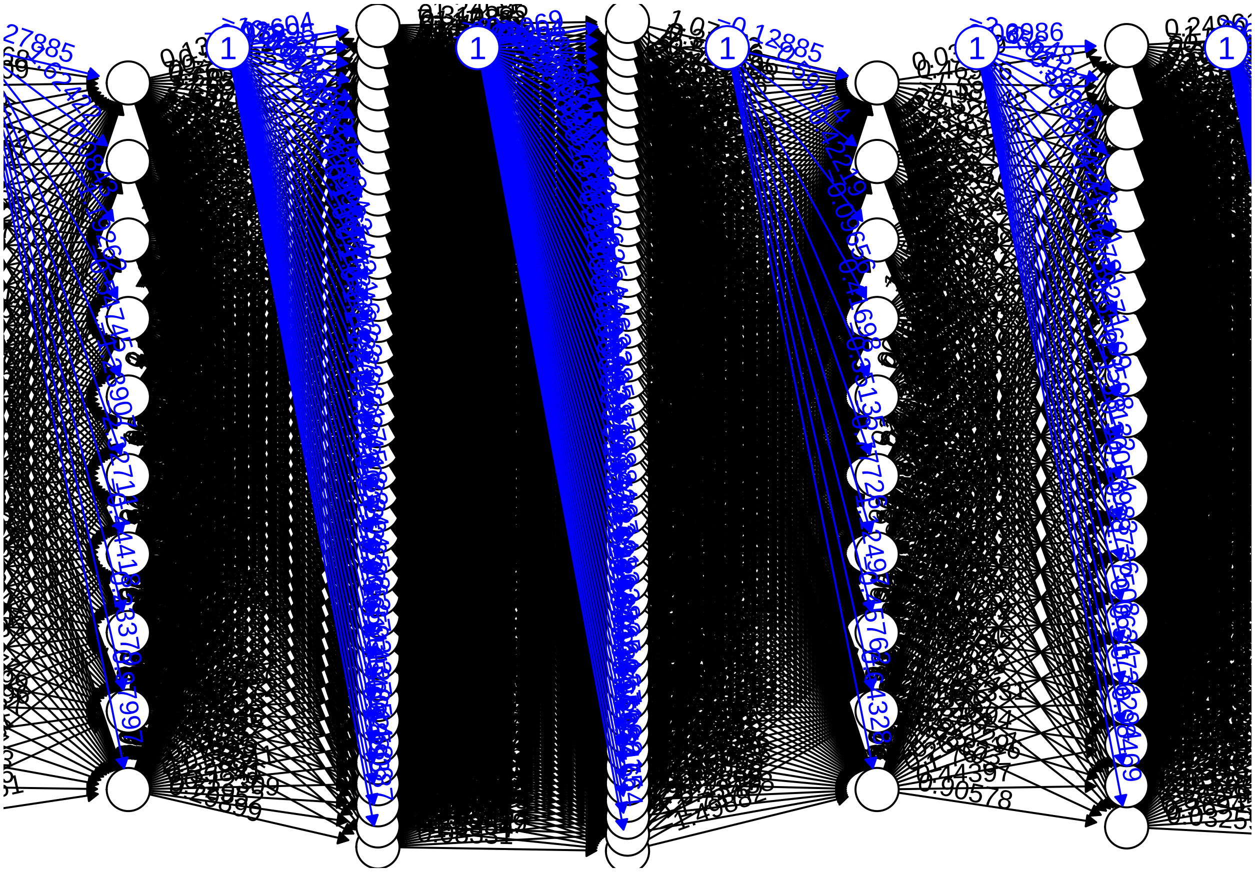
```
## 64        FALSE  FALSE       TRUE
## 65         TRUE  FALSE      FALSE
## 66        FALSE  FALSE       TRUE
## 67        FALSE   TRUE      FALSE
## 68         TRUE  FALSE      FALSE
## 69         TRUE  FALSE      FALSE
## 70        FALSE   TRUE      FALSE
## 71        FALSE   TRUE      FALSE
## 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"
```

```
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

```
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

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

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

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

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

```
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.