Data 609 Module 6 HW

Bryan Persaud

5/2/2021

Ex.1

Use a data set such as the PlantGrowth in R to calculate three different distance metrics and discuss the results.

Solution:

```
plants_euclidean <- dist(PlantGrowth, method = "euclidean")
```

```
## Warning in dist(PlantGrowth, method = "euclidean"): NAs introduced by coercion
```

```
as.matrix(plants_euclidean)
```

```
##           1         2         3         4         5         6         7
## 1  0.0000000 1.99404112 1.42835570 2.74357431 0.46669048 0.6222540 1.41421356
## 2  1.9940411 0.00000000 0.56568542 0.74953319 1.52735065 1.3717872 0.57982756
## 3  1.4283557 0.56568542 0.00000000 1.31521861 0.96166522 0.8061017 0.01414214
## 4  2.7435743 0.74953319 1.31521861 0.00000000 2.27688384 2.1213203 1.32936075
## 5  0.4666905 1.52735065 0.96166522 2.27688384 0.00000000 0.1555635 0.94752309
## 6  0.6222540 1.37178716 0.80610173 2.12132034 0.15556349 0.0000000 0.79195959
## 7  1.4142136 0.57982756 0.01414214 1.32936075 0.94752309 0.7919596 0.00000000
## 8  0.5091169 1.48492424 0.91923882 2.23445743 0.04242641 0.1131371 0.90509668
## 9  1.6404877 0.35355339 0.21213203 1.10308658 1.17379726 1.0182338 0.22627417
## 10 1.3717872 0.62225397 0.05656854 1.37178716 0.90509668 0.7495332 0.04242641
## 11 0.9050967 1.08894444 0.52325902 1.83847763 0.43840620 0.2828427 0.50911688
## 12 0.0000000 1.99404112 1.42835570 2.74357431 0.46669048 0.6222540 1.41421356
## 13 0.3394113 1.65462987 1.08894444 2.40416306 0.12727922 0.2828427 1.07480231
## 14 0.8202439 2.81428499 2.24859956 3.56381818 1.28693434 1.4424978 2.23445743
## 15 2.4041631 0.41012193 0.97580736 0.33941125 1.93747258 1.7819091 0.98994949
## 16 0.4808326 2.47487373 1.90918831 3.22440692 0.94752309 1.1030866 1.89504617
## 17 2.6304372 0.63639610 1.20208153 0.11313708 2.16374675 2.0081833 1.21622366
## 18 1.0182338 0.97580736 0.41012193 1.72534055 0.55154329 0.3959798 0.39597980
## 19 0.2121320 1.78190909 1.21622366 2.53144228 0.25455844 0.4101219 1.20208153
## 20 0.7353911 1.25865007 0.69296465 2.00818326 0.26870058 0.1131371 0.67882251
## 21 3.0264170 1.03237590 1.59806133 0.28284271 2.55972655 2.4041631 1.61220346
## 22 1.3435029 0.65053824 0.08485281 1.40007143 0.87681241 0.7212489 0.07071068
## 23 1.9374726 0.05656854 0.50911688 0.80610173 1.47078210 1.3152186 0.52325902
## 24 1.8809040 0.11313708 0.45254834 0.86267027 1.41421356 1.2586501 0.46669048
## 25 1.6970563 0.29698485 0.26870058 1.04651804 1.23036580 1.0748023 0.28284271
## 26 1.5839192 0.41012193 0.15556349 1.15965512 1.11722871 0.9616652 0.16970563
```

```
## 27 1.0606602 0.93338095 0.36769553 1.68291414 0.59396970 0.4384062 0.35355339
## 28 2.8001429 0.80610173 1.37178716 0.05656854 2.33345238 2.1778889 1.38592929
## 29 2.3051681 0.31112698 0.87681241 0.43840620 1.83847763 1.6829141 0.89095454
## 30 1.5414928 0.45254834 0.11313708 1.20208153 1.07480231 0.9192388 0.12727922
##            8          9         10        11        12        13        14
## 1  0.50911688 1.64048773 1.37178716 0.9050967 0.0000000 0.3394113 0.8202439
## 2  1.48492424 0.35355339 0.62225397 1.0889444 1.9940411 1.6546299 2.8142850
## 3  0.91923882 0.21213203 0.05656854 0.5232590 1.4283557 1.0889444 2.2485996
## 4  2.23445743 1.10308658 1.37178716 1.8384776 2.7435743 2.4041631 3.5638182
## 5  0.04242641 1.17379726 0.90509668 0.4384062 0.4666905 0.1272792 1.2869343
## 6  0.11313708 1.01823376 0.74953319 0.2828427 0.6222540 0.2828427 1.4424978
## 7  0.90509668 0.22627417 0.04242641 0.5091169 1.4142136 1.0748023 2.2344574
## 8  0.00000000 1.13137085 0.86267027 0.3959798 0.5091169 0.1697056 1.3293607
## 9  1.13137085 0.00000000 0.26870058 0.7353911 1.6404877 1.3010765 2.4607316
## 10 0.86267027 0.26870058 0.00000000 0.4666905 1.3717872 1.0323759 2.1920310
## 11 0.39597980 0.73539105 0.46669048 0.0000000 0.9050967 0.5656854 1.7253405
## 12 0.50911688 1.64048773 1.37178716 0.9050967 0.0000000 0.3394113 0.8202439
## 13 0.16970563 1.30107648 1.03237590 0.5656854 0.3394113 0.0000000 1.1596551
## 14 1.32936075 2.46073160 2.19203102 1.7253405 0.8202439 1.1596551 0.0000000
## 15 1.89504617 0.76367532 1.03237590 1.4990664 2.4041631 2.0647518 3.2244069
## 16 0.98994949 2.12132034 1.85261977 1.3859293 0.4808326 0.8202439 0.3394113
## 17 2.12132034 0.98994949 1.25865007 1.7253405 2.6304372 2.2910260 3.4506811
## 18 0.50911688 0.62225397 0.35355339 0.1131371 1.0182338 0.6788225 1.8384776
## 19 0.29698485 1.42835570 1.15965512 0.6929646 0.2121320 0.1272792 1.0323759
## 20 0.22627417 0.90509668 0.63639610 0.1697056 0.7353911 0.3959798 1.5556349
## 21 2.51730014 1.38592929 1.65462987 2.1213203 3.0264170 2.6870058 3.8466609
## 22 0.83438600 0.29698485 0.02828427 0.4384062 1.3435029 1.0040916 2.1637468
## 23 1.42835570 0.29698485 0.56568542 1.0323759 1.9374726 1.5980613 2.7577164
## 24 1.37178716 0.24041631 0.50911688 0.9758074 1.8809040 1.5414928 2.7011479
## 25 1.18793939 0.05656854 0.32526912 0.7919596 1.6970563 1.3576450 2.5173001
## 26 1.07480231 0.05656854 0.21213203 0.6788225 1.5839192 1.2445079 2.4041631
## 27 0.55154329 0.57982756 0.31112698 0.1555635 1.0606602 0.7212489 1.8809040
## 28 2.29102597 1.15965512 1.42835570 1.8950462 2.8001429 2.4607316 3.6203867
## 29 1.79605122 0.66468037 0.93338095 1.4000714 2.3051681 1.9657569 3.1254120
## 30 1.03237590 0.09899495 0.16970563 0.6363961 1.5414928 1.2020815 2.3617366
##           15        16        17         18        19        20        21
## 1  2.40416306 0.4808326 2.6304372 1.01823376 0.2121320 0.7353911 3.0264170
## 2  0.41012193 2.4748737 0.6363961 0.97580736 1.7819091 1.2586501 1.0323759
## 3  0.97580736 1.9091883 1.2020815 0.41012193 1.2162237 0.6929646 1.5980613
## 4  0.33941125 3.2244069 0.1131371 1.72534055 2.5314423 2.0081833 0.2828427
## 5  1.93747258 0.9475231 2.1637468 0.55154329 0.2545584 0.2687006 2.5597265
## 6  1.78190909 1.1030866 2.0081833 0.39597980 0.4101219 0.1131371 2.4041631
## 7  0.98994949 1.8950462 1.2162237 0.39597980 1.2020815 0.6788225 1.6122035
## 8  1.89504617 0.9899495 2.1213203 0.50911688 0.2969848 0.2262742 2.5173001
## 9  0.76367532 2.1213203 0.9899495 0.62225397 1.4283557 0.9050967 1.3859293
## 10 1.03237590 1.8526198 1.2586501 0.35355339 1.1596551 0.6363961 1.6546299
## 11 1.49906638 1.3859293 1.7253405 0.11313708 0.6929646 0.1697056 2.1213203
## 12 2.40416306 0.4808326 2.6304372 1.01823376 0.2121320 0.7353911 3.0264170
## 13 2.06475180 0.8202439 2.2910260 0.67882251 0.1272792 0.3959798 2.6870058
## 14 3.22440692 0.3394113 3.4506811 1.83847763 1.0323759 1.5556349 3.8466609
## 15 0.00000000 2.8849957 0.2262742 1.38592929 2.1920310 1.6687720 0.6222540
## 16 2.88499567 0.0000000 3.1112698 1.49906638 0.6929646 1.2162237 3.5072496
## 17 0.22627417 3.1112698 0.0000000 1.61220346 2.4183052 1.8950462 0.3959798
## 18 1.38592929 1.4990664 1.6122035 0.00000000 0.8061017 0.2828427 2.0081833
```

```
## 19 2.19203102 0.6929646 2.4183052 0.80610173 0.0000000 0.5232590 2.8142850
## 20 1.66877200 1.2162237 1.8950462 0.28284271 0.5232590 0.0000000 2.2910260
## 21 0.62225397 3.5072496 0.3959798 2.00818326 2.8142850 2.2910260 0.0000000
## 22 1.06066017 1.8243355 1.2869343 0.32526912 1.1313708 0.6081118 1.6829141
## 23 0.46669048 2.4183052 0.6929646 0.91923882 1.7253405 1.2020815 1.0889444
## 24 0.52325902 2.3617366 0.7495332 0.86267027 1.6687720 1.1455130 1.1455130
## 25 0.70710678 2.1778889 0.9333810 0.67882251 1.4849242 0.9616652 1.3293607
## 26 0.82024387 2.0647518 1.0465180 0.56568542 1.3717872 0.8485281 1.4424978
## 27 1.34350288 1.5414928 1.5697771 0.04242641 0.8485281 0.3252691 1.9657569
## 28 0.39597980 3.2809755 0.1697056 1.78190909 2.5880108 2.0647518 0.2262742
## 29 0.09899495 2.7860007 0.3252691 1.28693434 2.0930361 1.5697771 0.7212489
## 30 0.86267027 2.0223254 1.0889444 0.52325902 1.3293607 0.8061017 1.4849242
##           22         23         24         25         26         27         28
## 1  1.34350288 1.93747258 1.88090404 1.69705627 1.58391919 1.06066017 2.80014285
## 2  0.65053824 0.05656854 0.11313708 0.29698485 0.41012193 0.93338095 0.80610173
## 3  0.08485281 0.50911688 0.45254834 0.26870058 0.15556349 0.36769553 1.37178716
## 4  1.40007143 0.80610173 0.86267027 1.04651804 1.15965512 1.68291414 0.05656854
## 5  0.87681241 1.47078210 1.41421356 1.23036580 1.11722871 0.59396970 2.33345238
## 6  0.72124892 1.31521861 1.25865007 1.07480231 0.96166522 0.43840620 2.17788889
## 7  0.07071068 0.52325902 0.46669048 0.28284271 0.16970563 0.35355339 1.38592929
## 8  0.83438600 1.42835570 1.37178716 1.18793939 1.07480231 0.55154329 2.29102597
## 9  0.29698485 0.29698485 0.24041631 0.05656854 0.05656854 0.57982756 1.15965512
## 10 0.02828427 0.56568542 0.50911688 0.32526912 0.21213203 0.31112698 1.42835570
## 11 0.43840620 1.03237590 0.97580736 0.79195959 0.67882251 0.15556349 1.89504617
## 12 1.34350288 1.93747258 1.88090404 1.69705627 1.58391919 1.06066017 2.80014285
## 13 1.00409163 1.59806133 1.54149278 1.35764502 1.24450793 0.72124892 2.46073160
## 14 2.16374675 2.75771645 2.70114790 2.51730014 2.40416306 1.88090404 3.62038672
## 15 1.06066017 0.46669048 0.52325902 0.70710678 0.82024387 1.34350288 0.39597980
## 16 1.82433550 2.41830519 2.36173665 2.17788889 2.06475180 1.54149278 3.28097546
## 17 1.28693434 0.69296465 0.74953319 0.93338095 1.04651804 1.56977705 0.16970563
## 18 0.32526912 0.91923882 0.86267027 0.67882251 0.56568542 0.04242641 1.78190909
## 19 1.13137085 1.72534055 1.66877200 1.48492424 1.37178716 0.84852814 2.58801082
## 20 0.60811183 1.20208153 1.14551299 0.96166522 0.84852814 0.32526912 2.06475180
## 21 1.68291414 1.08894444 1.14551299 1.32936075 1.44249783 1.96575685 0.22627417
## 22 0.00000000 0.59396970 0.53740115 0.35355339 0.24041631 0.28284271 1.45663997
## 23 0.59396970 0.00000000 0.05656854 0.24041631 0.35355339 0.87681241 0.86267027
## 24 0.53740115 0.05656854 0.00000000 0.18384776 0.29698485 0.82024387 0.91923882
## 25 0.35355339 0.24041631 0.18384776 0.00000000 0.11313708 0.63639610 1.10308658
## 26 0.24041631 0.35355339 0.29698485 0.11313708 0.00000000 0.52325902 1.21622366
## 27 0.28284271 0.87681241 0.82024387 0.63639610 0.52325902 0.00000000 1.73948268
## 28 1.45663997 0.86267027 0.91923882 1.10308658 1.21622366 1.73948268 0.00000000
## 29 0.96166522 0.36769553 0.42426407 0.60811183 0.72124892 1.24450793 0.49497475
## 30 0.19798990 0.39597980 0.33941125 0.15556349 0.04242641 0.48083261 1.25865007
##           29         30
## 1  2.30516811 1.54149278
## 2  0.31112698 0.45254834
## 3  0.87681241 0.11313708
## 4  0.43840620 1.20208153
## 5  1.83847763 1.07480231
## 6  1.68291414 0.91923882
## 7  0.89095454 0.12727922
## 8  1.79605122 1.03237590
## 9  0.66468037 0.09899495
## 10 0.93338095 0.16970563
```

```
## 11 1.40007143 0.63639610
## 12 2.30516811 1.54149278
## 13 1.96575685 1.20208153
## 14 3.12541197 2.36173665
## 15 0.09899495 0.86267027
## 16 2.78600072 2.02232539
## 17 0.32526912 1.08894444
## 18 1.28693434 0.52325902
## 19 2.09303607 1.32936075
## 20 1.56977705 0.80610173
## 21 0.72124892 1.48492424
## 22 0.96166522 0.19798990
## 23 0.36769553 0.39597980
## 24 0.42426407 0.33941125
## 25 0.60811183 0.15556349
## 26 0.72124892 0.04242641
## 27 1.24450793 0.48083261
## 28 0.49497475 1.25865007
## 29 0.00000000 0.76367532
## 30 0.76367532 0.00000000
```

```
plants_manhattan <- dist(PlantGrowth, method = "manhattan")
```

```
## Warning in dist(PlantGrowth, method = "manhattan"): NAs introduced by coercion
```

```
as.matrix(plants_manhattan)
```

```
##       1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
## 1  0.00 2.82 2.02 3.88 0.66 0.88 2.00 0.72 2.32 1.94 1.28 0.00 0.48 1.16 3.40
## 2  2.82 0.00 0.80 1.06 2.16 1.94 0.82 2.10 0.50 0.88 1.54 2.82 2.34 3.98 0.58
## 3  2.02 0.80 0.00 1.86 1.36 1.14 0.02 1.30 0.30 0.08 0.74 2.02 1.54 3.18 1.38
## 4  3.88 1.06 1.86 0.00 3.22 3.00 1.88 3.16 1.56 1.94 2.60 3.88 3.40 5.04 0.48
## 5  0.66 2.16 1.36 3.22 0.00 0.22 1.34 0.06 1.66 1.28 0.62 0.66 0.18 1.82 2.74
## 6  0.88 1.94 1.14 3.00 0.22 0.00 1.12 0.16 1.44 1.06 0.40 0.88 0.40 2.04 2.52
## 7  2.00 0.82 0.02 1.88 1.34 1.12 0.00 1.28 0.32 0.06 0.72 2.00 1.52 3.16 1.40
## 8  0.72 2.10 1.30 3.16 0.06 0.16 1.28 0.00 1.60 1.22 0.56 0.72 0.24 1.88 2.68
## 9  2.32 0.50 0.30 1.56 1.66 1.44 0.32 1.60 0.00 0.38 1.04 2.32 1.84 3.48 1.08
## 10 1.94 0.88 0.08 1.94 1.28 1.06 0.06 1.22 0.38 0.00 0.66 1.94 1.46 3.10 1.46
## 11 1.28 1.54 0.74 2.60 0.62 0.40 0.72 0.56 1.04 0.66 0.00 1.28 0.80 2.44 2.12
## 12 0.00 2.82 2.02 3.88 0.66 0.88 2.00 0.72 2.32 1.94 1.28 0.00 0.48 1.16 3.40
## 13 0.48 2.34 1.54 3.40 0.18 0.40 1.52 0.24 1.84 1.46 0.80 0.48 0.00 1.64 2.92
## 14 1.16 3.98 3.18 5.04 1.82 2.04 3.16 1.88 3.48 3.10 2.44 1.16 1.64 0.00 4.56
## 15 3.40 0.58 1.38 0.48 2.74 2.52 1.40 2.68 1.08 1.46 2.12 3.40 2.92 4.56 0.00
## 16 0.68 3.50 2.70 4.56 1.34 1.56 2.68 1.40 3.00 2.62 1.96 0.68 1.16 0.48 4.08
## 17 3.72 0.90 1.70 0.16 3.06 2.84 1.72 3.00 1.40 1.78 2.44 3.72 3.24 4.88 0.32
## 18 1.44 1.38 0.58 2.44 0.78 0.56 0.56 0.72 0.88 0.50 0.16 1.44 0.96 2.60 1.96
## 19 0.30 2.52 1.72 3.58 0.36 0.58 1.70 0.42 2.02 1.64 0.98 0.30 0.18 1.46 3.10
## 20 1.04 1.78 0.98 2.84 0.38 0.16 0.96 0.32 1.28 0.90 0.24 1.04 0.56 2.20 2.36
## 21 4.28 1.46 2.26 0.40 3.62 3.40 2.28 3.56 1.96 2.34 3.00 4.28 3.80 5.44 0.88
## 22 1.90 0.92 0.12 1.98 1.24 1.02 0.10 1.18 0.42 0.04 0.62 1.90 1.42 3.06 1.50
## 23 2.74 0.08 0.72 1.14 2.08 1.86 0.74 2.02 0.42 0.80 1.46 2.74 2.26 3.90 0.66
## 24 2.66 0.16 0.64 1.22 2.00 1.78 0.66 1.94 0.34 0.72 1.38 2.66 2.18 3.82 0.74
## 25 2.40 0.42 0.38 1.48 1.74 1.52 0.40 1.68 0.08 0.46 1.12 2.40 1.92 3.56 1.00
```

```
## 26 2.24 0.58 0.22 1.64 1.58 1.36 0.24 1.52 0.08 0.30 0.96 2.24 1.76 3.40 1.16
## 27 1.50 1.32 0.52 2.38 0.84 0.62 0.50 0.78 0.82 0.44 0.22 1.50 1.02 2.66 1.90
## 28 3.96 1.14 1.94 0.08 3.30 3.08 1.96 3.24 1.64 2.02 2.68 3.96 3.48 5.12 0.56
## 29 3.26 0.44 1.24 0.62 2.60 2.38 1.26 2.54 0.94 1.32 1.98 3.26 2.78 4.42 0.14
## 30 2.18 0.64 0.16 1.70 1.52 1.30 0.18 1.46 0.14 0.24 0.90 2.18 1.70 3.34 1.22
##      16   17   18   19   20   21   22   23   24   25   26   27   28   29   30
## 1  0.68 3.72 1.44 0.30 1.04 4.28 1.90 2.74 2.66 2.40 2.24 1.50 3.96 3.26 2.18
## 2  3.50 0.90 1.38 2.52 1.78 1.46 0.92 0.08 0.16 0.42 0.58 1.32 1.14 0.44 0.64
## 3  2.70 1.70 0.58 1.72 0.98 2.26 0.12 0.72 0.64 0.38 0.22 0.52 1.94 1.24 0.16
## 4  4.56 0.16 2.44 3.58 2.84 0.40 1.98 1.14 1.22 1.48 1.64 2.38 0.08 0.62 1.70
## 5  1.34 3.06 0.78 0.36 0.38 3.62 1.24 2.08 2.00 1.74 1.58 0.84 3.30 2.60 1.52
## 6  1.56 2.84 0.56 0.58 0.16 3.40 1.02 1.86 1.78 1.52 1.36 0.62 3.08 2.38 1.30
## 7  2.68 1.72 0.56 1.70 0.96 2.28 0.10 0.74 0.66 0.40 0.24 0.50 1.96 1.26 0.18
## 8  1.40 3.00 0.72 0.42 0.32 3.56 1.18 2.02 1.94 1.68 1.52 0.78 3.24 2.54 1.46
## 9  3.00 1.40 0.88 2.02 1.28 1.96 0.42 0.42 0.34 0.08 0.08 0.82 1.64 0.94 0.14
## 10 2.62 1.78 0.50 1.64 0.90 2.34 0.04 0.80 0.72 0.46 0.30 0.44 2.02 1.32 0.24
## 11 1.96 2.44 0.16 0.98 0.24 3.00 0.62 1.46 1.38 1.12 0.96 0.22 2.68 1.98 0.90
## 12 0.68 3.72 1.44 0.30 1.04 4.28 1.90 2.74 2.66 2.40 2.24 1.50 3.96 3.26 2.18
## 13 1.16 3.24 0.96 0.18 0.56 3.80 1.42 2.26 2.18 1.92 1.76 1.02 3.48 2.78 1.70
## 14 0.48 4.88 2.60 1.46 2.20 5.44 3.06 3.90 3.82 3.56 3.40 2.66 5.12 4.42 3.34
## 15 4.08 0.32 1.96 3.10 2.36 0.88 1.50 0.66 0.74 1.00 1.16 1.90 0.56 0.14 1.22
## 16 0.00 4.40 2.12 0.98 1.72 4.96 2.58 3.42 3.34 3.08 2.92 2.18 4.64 3.94 2.86
## 17 4.40 0.00 2.28 3.42 2.68 0.56 1.82 0.98 1.06 1.32 1.48 2.22 0.24 0.46 1.54
## 18 2.12 2.28 0.00 1.14 0.40 2.84 0.46 1.30 1.22 0.96 0.80 0.06 2.52 1.82 0.74
## 19 0.98 3.42 1.14 0.00 0.74 3.98 1.60 2.44 2.36 2.10 1.94 1.20 3.66 2.96 1.88
## 20 1.72 2.68 0.40 0.74 0.00 3.24 0.86 1.70 1.62 1.36 1.20 0.46 2.92 2.22 1.14
## 21 4.96 0.56 2.84 3.98 3.24 0.00 2.38 1.54 1.62 1.88 2.04 2.78 0.32 1.02 2.10
## 22 2.58 1.82 0.46 1.60 0.86 2.38 0.00 0.84 0.76 0.50 0.34 0.40 2.06 1.36 0.28
## 23 3.42 0.98 1.30 2.44 1.70 1.54 0.84 0.00 0.08 0.34 0.50 1.24 1.22 0.52 0.56
## 24 3.34 1.06 1.22 2.36 1.62 1.62 0.76 0.08 0.00 0.26 0.42 1.16 1.30 0.60 0.48
## 25 3.08 1.32 0.96 2.10 1.36 1.88 0.50 0.34 0.26 0.00 0.16 0.90 1.56 0.86 0.22
## 26 2.92 1.48 0.80 1.94 1.20 2.04 0.34 0.50 0.42 0.16 0.00 0.74 1.72 1.02 0.06
## 27 2.18 2.22 0.06 1.20 0.46 2.78 0.40 1.24 1.16 0.90 0.74 0.00 2.46 1.76 0.68
## 28 4.64 0.24 2.52 3.66 2.92 0.32 2.06 1.22 1.30 1.56 1.72 2.46 0.00 0.70 1.78
## 29 3.94 0.46 1.82 2.96 2.22 1.02 1.36 0.52 0.60 0.86 1.02 1.76 0.70 0.00 1.08
## 30 2.86 1.54 0.74 1.88 1.14 2.10 0.28 0.56 0.48 0.22 0.06 0.68 1.78 1.08 0.00
```

```
plants_minkowski <- dist(PlantGrowth, method = "minkowski")
```

```
## Warning in dist(PlantGrowth, method = "minkowski"): NAs introduced by coercion
```

```
as.matrix(plants_minkowski)
```

```
##           1         2         3         4         5         6         7
## 1  0.0000000 1.99404112 1.42835570 2.74357431 0.46669048 0.6222540 1.41421356
## 2  1.9940411 0.00000000 0.56568542 0.74953319 1.52735065 1.3717872 0.57982756
## 3  1.4283557 0.56568542 0.00000000 1.31521861 0.96166522 0.8061017 0.01414214
## 4  2.7435743 0.74953319 1.31521861 0.00000000 2.27688384 2.1213203 1.32936075
## 5  0.4666905 1.52735065 0.96166522 2.27688384 0.00000000 0.1555635 0.94752309
## 6  0.6222540 1.37178716 0.80610173 2.12132034 0.15556349 0.0000000 0.79195959
## 7  1.4142136 0.57982756 0.01414214 1.32936075 0.94752309 0.7919596 0.00000000
## 8  0.5091169 1.48492424 0.91923882 2.23445743 0.04242641 0.1131371 0.90509668
## 9  1.6404877 0.35355339 0.21213203 1.10308658 1.17379726 1.0182338 0.22627417
```

```
## 10 1.3717872 0.62225397 0.05656854 1.37178716 0.90509668 0.7495332 0.04242641
## 11 0.9050967 1.08894444 0.52325902 1.83847763 0.43840620 0.2828427 0.50911688
## 12 0.0000000 1.99404112 1.42835570 2.74357431 0.46669048 0.6222540 1.41421356
## 13 0.3394113 1.65462987 1.08894444 2.40416306 0.12727922 0.2828427 1.07480231
## 14 0.8202439 2.81428499 2.24859956 3.56381818 1.28693434 1.4424978 2.23445743
## 15 2.4041631 0.41012193 0.97580736 0.33941125 1.93747258 1.7819091 0.98994949
## 16 0.4808326 2.47487373 1.90918831 3.22440692 0.94752309 1.1030866 1.89504617
## 17 2.6304372 0.63639610 1.20208153 0.11313708 2.16374675 2.0081833 1.21622366
## 18 1.0182338 0.97580736 0.41012193 1.72534055 0.55154329 0.3959798 0.39597980
## 19 0.2121320 1.78190909 1.21622366 2.53144228 0.25455844 0.4101219 1.20208153
## 20 0.7353911 1.25865007 0.69296465 2.00818326 0.26870058 0.1131371 0.67882251
## 21 3.0264170 1.03237590 1.59806133 0.28284271 2.55972655 2.4041631 1.61220346
## 22 1.3435029 0.65053824 0.08485281 1.40007143 0.87681241 0.7212489 0.07071068
## 23 1.9374726 0.05656854 0.50911688 0.80610173 1.47078210 1.3152186 0.52325902
## 24 1.8809040 0.11313708 0.45254834 0.86267027 1.41421356 1.2586501 0.46669048
## 25 1.6970563 0.29698485 0.26870058 1.04651804 1.23036580 1.0748023 0.28284271
## 26 1.5839192 0.41012193 0.15556349 1.15965512 1.11722871 0.9616652 0.16970563
## 27 1.0606602 0.93338095 0.36769553 1.68291414 0.59396970 0.4384062 0.35355339
## 28 2.8001429 0.80610173 1.37178716 0.05656854 2.33345238 2.1778889 1.38592929
## 29 2.3051681 0.31112698 0.87681241 0.43840620 1.83847763 1.6829141 0.89095454
## 30 1.5414928 0.45254834 0.11313708 1.20208153 1.07480231 0.9192388 0.12727922
##            8          9         10        11        12        13        14
## 1  0.50911688 1.64048773 1.37178716 0.9050967 0.0000000 0.3394113 0.8202439
## 2  1.48492424 0.35355339 0.62225397 1.0889444 1.9940411 1.6546299 2.8142850
## 3  0.91923882 0.21213203 0.05656854 0.5232590 1.4283557 1.0889444 2.2485996
## 4  2.23445743 1.10308658 1.37178716 1.8384776 2.7435743 2.4041631 3.5638182
## 5  0.04242641 1.17379726 0.90509668 0.4384062 0.4666905 0.1272792 1.2869343
## 6  0.11313708 1.01823376 0.74953319 0.2828427 0.6222540 0.2828427 1.4424978
## 7  0.90509668 0.22627417 0.04242641 0.5091169 1.4142136 1.0748023 2.2344574
## 8  0.00000000 1.13137085 0.86267027 0.3959798 0.5091169 0.1697056 1.3293607
## 9  1.13137085 0.00000000 0.26870058 0.7353911 1.6404877 1.3010765 2.4607316
## 10 0.86267027 0.26870058 0.00000000 0.4666905 1.3717872 1.0323759 2.1920310
## 11 0.39597980 0.73539105 0.46669048 0.0000000 0.9050967 0.5656854 1.7253405
## 12 0.50911688 1.64048773 1.37178716 0.9050967 0.0000000 0.3394113 0.8202439
## 13 0.16970563 1.30107648 1.03237590 0.5656854 0.3394113 0.0000000 1.1596551
## 14 1.32936075 2.46073160 2.19203102 1.7253405 0.8202439 1.1596551 0.0000000
## 15 1.89504617 0.76367532 1.03237590 1.4990664 2.4041631 2.0647518 3.2244069
## 16 0.98994949 2.12132034 1.85261977 1.3859293 0.4808326 0.8202439 0.3394113
## 17 2.12132034 0.98994949 1.25865007 1.7253405 2.6304372 2.2910260 3.4506811
## 18 0.50911688 0.62225397 0.35355339 0.1131371 1.0182338 0.6788225 1.8384776
## 19 0.29698485 1.42835570 1.15965512 0.6929646 0.2121320 0.1272792 1.0323759
## 20 0.22627417 0.90509668 0.63639610 0.1697056 0.7353911 0.3959798 1.5556349
## 21 2.51730014 1.38592929 1.65462987 2.1213203 3.0264170 2.6870058 3.8466609
## 22 0.83438600 0.29698485 0.02828427 0.4384062 1.3435029 1.0040916 2.1637468
## 23 1.42835570 0.29698485 0.56568542 1.0323759 1.9374726 1.5980613 2.7577164
## 24 1.37178716 0.24041631 0.50911688 0.9758074 1.8809040 1.5414928 2.7011479
## 25 1.18793939 0.05656854 0.32526912 0.7919596 1.6970563 1.3576450 2.5173001
## 26 1.07480231 0.05656854 0.21213203 0.6788225 1.5839192 1.2445079 2.4041631
## 27 0.55154329 0.57982756 0.31112698 0.1555635 1.0606602 0.7212489 1.8809040
## 28 2.29102597 1.15965512 1.42835570 1.8950462 2.8001429 2.4607316 3.6203867
## 29 1.79605122 0.66468037 0.93338095 1.4000714 2.3051681 1.9657569 3.1254120
## 30 1.03237590 0.09899495 0.16970563 0.6363961 1.5414928 1.2020815 2.3617366
##           15        16        17         18        19        20        21
## 1  2.40416306 0.4808326 2.6304372 1.01823376 0.2121320 0.7353911 3.0264170
```

```
## 2  0.41012193 2.4748737 0.6363961 0.97580736 1.7819091 1.2586501 1.0323759
## 3  0.97580736 1.9091883 1.2020815 0.41012193 1.2162237 0.6929646 1.5980613
## 4  0.33941125 3.2244069 0.1131371 1.72534055 2.5314423 2.0081833 0.2828427
## 5  1.93747258 0.9475231 2.1637468 0.55154329 0.2545584 0.2687006 2.5597265
## 6  1.78190909 1.1030866 2.0081833 0.39597980 0.4101219 0.1131371 2.4041631
## 7  0.98994949 1.8950462 1.2162237 0.39597980 1.2020815 0.6788225 1.6122035
## 8  1.89504617 0.9899495 2.1213203 0.50911688 0.2969848 0.2262742 2.5173001
## 9  0.76367532 2.1213203 0.9899495 0.62225397 1.4283557 0.9050967 1.3859293
## 10 1.03237590 1.8526198 1.2586501 0.35355339 1.1596551 0.6363961 1.6546299
## 11 1.49906638 1.3859293 1.7253405 0.11313708 0.6929646 0.1697056 2.1213203
## 12 2.40416306 0.4808326 2.6304372 1.01823376 0.2121320 0.7353911 3.0264170
## 13 2.06475180 0.8202439 2.2910260 0.67882251 0.1272792 0.3959798 2.6870058
## 14 3.22440692 0.3394113 3.4506811 1.83847763 1.0323759 1.5556349 3.8466609
## 15 0.00000000 2.8849957 0.2262742 1.38592929 2.1920310 1.6687720 0.6222540
## 16 2.88499567 0.0000000 3.1112698 1.49906638 0.6929646 1.2162237 3.5072496
## 17 0.22627417 3.1112698 0.0000000 1.61220346 2.4183052 1.8950462 0.3959798
## 18 1.38592929 1.4990664 1.6122035 0.00000000 0.8061017 0.2828427 2.0081833
## 19 2.19203102 0.6929646 2.4183052 0.80610173 0.0000000 0.5232590 2.8142850
## 20 1.66877200 1.2162237 1.8950462 0.28284271 0.5232590 0.0000000 2.2910260
## 21 0.62225397 3.5072496 0.3959798 2.00818326 2.8142850 2.2910260 0.0000000
## 22 1.06066017 1.8243355 1.2869343 0.32526912 1.1313708 0.6081118 1.6829141
## 23 0.46669048 2.4183052 0.6929646 0.91923882 1.7253405 1.2020815 1.0889444
## 24 0.52325902 2.3617366 0.7495332 0.86267027 1.6687720 1.1455130 1.1455130
## 25 0.70710678 2.1778889 0.9333810 0.67882251 1.4849242 0.9616652 1.3293607
## 26 0.82024387 2.0647518 1.0465180 0.56568542 1.3717872 0.8485281 1.4424978
## 27 1.34350288 1.5414928 1.5697771 0.04242641 0.8485281 0.3252691 1.9657569
## 28 0.39597980 3.2809755 0.1697056 1.78190909 2.5880108 2.0647518 0.2262742
## 29 0.09899495 2.7860007 0.3252691 1.28693434 2.0930361 1.5697771 0.7212489
## 30 0.86267027 2.0223254 1.0889444 0.52325902 1.3293607 0.8061017 1.4849242
##           22         23         24         25         26         27         28
## 1  1.34350288 1.93747258 1.88090404 1.69705627 1.58391919 1.06066017 2.80014285
## 2  0.65053824 0.05656854 0.11313708 0.29698485 0.41012193 0.93338095 0.80610173
## 3  0.08485281 0.50911688 0.45254834 0.26870058 0.15556349 0.36769553 1.37178716
## 4  1.40007143 0.80610173 0.86267027 1.04651804 1.15965512 1.68291414 0.05656854
## 5  0.87681241 1.47078210 1.41421356 1.23036580 1.11722871 0.59396970 2.33345238
## 6  0.72124892 1.31521861 1.25865007 1.07480231 0.96166522 0.43840620 2.17788889
## 7  0.07071068 0.52325902 0.46669048 0.28284271 0.16970563 0.35355339 1.38592929
## 8  0.83438600 1.42835570 1.37178716 1.18793939 1.07480231 0.55154329 2.29102597
## 9  0.29698485 0.29698485 0.24041631 0.05656854 0.05656854 0.57982756 1.15965512
## 10 0.02828427 0.56568542 0.50911688 0.32526912 0.21213203 0.31112698 1.42835570
## 11 0.43840620 1.03237590 0.97580736 0.79195959 0.67882251 0.15556349 1.89504617
## 12 1.34350288 1.93747258 1.88090404 1.69705627 1.58391919 1.06066017 2.80014285
## 13 1.00409163 1.59806133 1.54149278 1.35764502 1.24450793 0.72124892 2.46073160
## 14 2.16374675 2.75771645 2.70114790 2.51730014 2.40416306 1.88090404 3.62038672
## 15 1.06066017 0.46669048 0.52325902 0.70710678 0.82024387 1.34350288 0.39597980
## 16 1.82433550 2.41830519 2.36173665 2.17788889 2.06475180 1.54149278 3.28097546
## 17 1.28693434 0.69296465 0.74953319 0.93338095 1.04651804 1.56977705 0.16970563
## 18 0.32526912 0.91923882 0.86267027 0.67882251 0.56568542 0.04242641 1.78190909
## 19 1.13137085 1.72534055 1.66877200 1.48492424 1.37178716 0.84852814 2.58801082
## 20 0.60811183 1.20208153 1.14551299 0.96166522 0.84852814 0.32526912 2.06475180
## 21 1.68291414 1.08894444 1.14551299 1.32936075 1.44249783 1.96575685 0.22627417
## 22 0.00000000 0.59396970 0.53740115 0.35355339 0.24041631 0.28284271 1.45663997
## 23 0.59396970 0.00000000 0.05656854 0.24041631 0.35355339 0.87681241 0.86267027
## 24 0.53740115 0.05656854 0.00000000 0.18384776 0.29698485 0.82024387 0.91923882
```

```
## 25 0.35355339 0.24041631 0.18384776 0.00000000 0.11313708 0.63639610 1.10308658
## 26 0.24041631 0.35355339 0.29698485 0.11313708 0.00000000 0.52325902 1.21622366
## 27 0.28284271 0.87681241 0.82024387 0.63639610 0.52325902 0.00000000 1.73948268
## 28 1.45663997 0.86267027 0.91923882 1.10308658 1.21622366 1.73948268 0.00000000
## 29 0.96166522 0.36769553 0.42426407 0.60811183 0.72124892 1.24450793 0.49497475
## 30 0.19798990 0.39597980 0.33941125 0.15556349 0.04242641 0.48083261 1.25865007
##            29         30
## 1  2.30516811 1.54149278
## 2  0.31112698 0.45254834
## 3  0.87681241 0.11313708
## 4  0.43840620 1.20208153
## 5  1.83847763 1.07480231
## 6  1.68291414 0.91923882
## 7  0.89095454 0.12727922
## 8  1.79605122 1.03237590
## 9  0.66468037 0.09899495
## 10 0.93338095 0.16970563
## 11 1.40007143 0.63639610
## 12 2.30516811 1.54149278
## 13 1.96575685 1.20208153
## 14 3.12541197 2.36173665
## 15 0.09899495 0.86267027
## 16 2.78600072 2.02232539
## 17 0.32526912 1.08894444
## 18 1.28693434 0.52325902
## 19 2.09303607 1.32936075
## 20 1.56977705 0.80610173
## 21 0.72124892 1.48492424
## 22 0.96166522 0.19798990
## 23 0.36769553 0.39597980
## 24 0.42426407 0.33941125
## 25 0.60811183 0.15556349
## 26 0.72124892 0.04242641
## 27 1.24450793 0.48083261
## 28 0.49497475 1.25865007
## 29 0.00000000 0.76367532
## 30 0.76367532 0.00000000
```

Three distance metrics were used, Euclidean, Manhattan, and Minkowski. The results can be seen above in the form of a matrix. Euclidean and Minkowski have similar results, while Manhattan gives different results than the other two.

Ex.2

Now use a higher-dimension data set mtcars, try the same three distance metrics in the previous question and discuss the results.

Solution:

```
cars_euclidean <- dist(mtcars, method = "euclidean")
as.matrix(cars_euclidean)
```

```
##                           Mazda RX4 Mazda RX4 Wag Datsun 710 Hornet 4 Drive
```

```
## Mazda RX4             0.0000000     0.6153251   54.90861       98.11252
## Mazda RX4 Wag         0.6153251     0.0000000   54.89152       98.09589
## Datsun 710           54.9086059    54.8915169    0.00000      150.99352
## Hornet 4 Drive       98.1125212    98.0958939  150.99352        0.00000
## Hornet Sportabout   210.3374396   210.3358546  265.08316      121.02976
## Valiant              65.4717710    65.4392224  117.75470       33.55087
## Duster 360          241.4076490   241.4088680  294.47902      169.42996
## Merc 240D            50.1532711    50.1146059   49.65848      121.27397
## Merc 230             25.4683117    25.3284509   33.18038      118.24331
## Merc 280             15.3641921    15.2956865   66.93635       91.42240
## Merc 280C            15.6724727    15.5837744   67.02614       91.46129
## Merc 450SE          135.4307018   135.4254826  189.19549       72.49643
## Merc 450SL          135.4014424   135.3960351  189.16317       72.43135
## Merc 450SLC         135.4794674   135.4723157  189.23454       72.57185
## Cadillac Fleetwood  326.3395903   326.3355070  381.09262      234.44039
## Lincoln Continental 318.0469808   318.0429333  372.80121      227.97261
## Chrysler Imperial   304.7203408   304.7169175  359.30149      218.15483
## Fiat 128             93.2679950    93.2530993   40.99338      184.96897
## Honda Civic         102.8307567   102.8238713   52.77046      191.55187
## Toyota Corolla      100.6040368   100.5887588   47.65350      192.67142
## Toyota Corona        42.3075233    42.2659224   12.96547      138.53047
## Dodge Challenger    163.1150750   163.1134210  217.77958       72.44039
## AMC Javelin         149.6047203   149.6014522  204.31889       61.36019
## Camaro Z28          233.2228758   233.2248748  286.00492      163.66326
## Pontiac Firebird    248.6780270   248.6762035  303.35839      156.22403
## Fiat X1-9            92.5048389    92.4940020   39.88151      184.44712
## Porsche 914-2        44.4033659    44.4073589   13.13571      139.15795
## Lotus Europa         65.7328377    65.7362635   25.09486      163.23674
## Ford Pantera L      245.4247064   245.4293785  297.29405      180.11403
## Ferrari Dino         66.7661029    66.7764167   90.24155      130.55230
## Maserati Bora       265.6454248   265.6491465  309.77182      229.34194
## Volvo 142E           39.1894029    39.1626037   20.69394      137.03633
##                    Hornet Sportabout   Valiant Duster 360 Merc 240D  Merc 230
## Mazda RX4                 210.33744  65.47177  241.40765  50.15327  25.46831
## Mazda RX4 Wag             210.33585  65.43922  241.40887  50.11461  25.32845
## Datsun 710                265.08316 117.75470  294.47902  49.65848  33.18038
## Hornet 4 Drive            121.02976  33.55087  169.42996 121.27397 118.24331
## Hornet Sportabout           0.00000 152.12414   70.17673 241.50697 233.49240
## Valiant                   152.12414   0.00000  194.60945  89.59111  85.00796
## Duster 360                 70.17673 194.60945    0.00000 281.29625 265.88233
## Merc 240D                 241.50697  89.59111  281.29625   0.00000  33.68730
## Merc 230                  233.49240  85.00796  265.88233  33.68730   0.00000
## Merc 280                  199.33450  60.29098  227.89985  64.77542  39.29942
## Merc 280C                 199.34066  60.26557  227.88132  64.88987  39.38685
## Merc 450SE                 84.38885  90.69703  106.40843 175.16201 159.81796
## Merc 450SL                 84.36840  90.67697  106.43206 175.11898 159.77609
## Merc 450SLC                84.43324  90.70930  106.40103 175.21182 159.84958
## Cadillac Fleetwood        116.28042 266.62809  119.02391 355.66275 349.28326
## Lincoln Continental       108.06243 259.63044  104.51130 348.99013 341.31543
## Chrysler Imperial          97.20491 248.77133   81.42977 338.19594 328.43352
## Fiat 128                  302.03772 152.11533  333.97921  68.61059  69.31279
## Honda Civic               310.03246 158.96158  344.05183  72.00145  78.53872
## Toyota Corolla            309.55818 159.83030  341.02182  76.28065  76.77317
## Toyota Corona             252.33320 105.28764  282.05088  44.08510  21.09620
```

```
## Dodge Challenger             48.98389 103.43107  103.90239 192.86179 185.83319
## AMC Javelin                  61.42742  91.04443  110.30849 180.54798 172.53126
## Camaro Z28                   70.96653 187.84638   10.07612 273.83680 257.74697
## Pontiac Firebird             40.00525 188.52721   80.80573 277.46069 271.38720
## Fiat X1-9                   301.56695 151.43794  333.48432  67.91640  68.55649
## Porsche 914-2               254.14526 106.05858  285.19862  39.44693  22.11810
## Lotus Europa                272.35824 130.82482  296.45723  72.89711  50.10940
## Ford Pantera L               89.59340 203.01779   21.26560 287.52388 269.97720
## Ferrari Dino                215.06739 106.56948  226.20363 113.30230  80.65510
## Maserati Bora               170.70945 242.43930  107.72250 313.86331 288.87556
## Volvo 142E                  248.00634 104.18637  275.13535  53.68235  24.69135
##                          Merc 280  Merc 280C  Merc 450SE  Merc 450SL Merc 450SLC
## Mazda RX4                15.364192  15.672473 135.4307018 135.4014424  135.479467
## Mazda RX4 Wag            15.295686  15.583774 135.4254826 135.3960351  135.472316
## Datsun 710               66.936353  67.026140 189.1954941 189.1631745  189.234543
## Hornet 4 Drive           91.422403  91.461291  72.4964325  72.4313532   72.571847
## Hornet Sportabout       199.334496 199.340656  84.3888482  84.3683999   84.433242
## Valiant                  60.290981  60.265566  90.6970264  90.6769728   90.709299
## Duster 360              227.899852 227.881317 106.4084264 106.4320572  106.401031
## Merc 240D                64.775423  64.889871 175.1620073 175.1189767  175.211822
## Merc 230                 39.299416  39.386852 159.8179555 159.7760899  159.849584
## Merc 280                  0.000000   1.523155 122.3642489 122.3443771  122.393497
## Merc 280C                 1.523155   0.000000 122.3461050 122.3355492  122.358686
## Merc 450SE              122.364249 122.346105   0.0000000   0.9826495    1.372625
## Merc 450SL              122.344377 122.335549   0.9826495   0.0000000    2.138340
## Merc 450SLC             122.393497 122.358686   1.3726252   2.1383405    0.000000
## Cadillac Fleetwood      315.390486 315.355708 197.8842803 197.9154476  197.852624
## Lincoln Continental     306.676072 306.640619 187.5997191 187.6330806  187.567108
## Chrysler Imperial       292.714690 292.698933 171.6600758 171.6743028  171.655764
## Fiat 128                106.505315 106.682979 228.3247948 228.2592340  228.405183
## Honda Civic             116.728099 116.871148 238.0141824 237.9588183  238.082900
## Toyota Corolla          113.629072 113.811801 235.5183809 235.4481971  235.602410
## Toyota Corona            54.364171  54.425831 176.6020527 176.5727477  176.630536
## Dodge Challenger        152.892926 152.872244  51.8008639  51.8242520   51.801261
## AMC Javelin             139.145797 139.118198  41.2080044  41.2411618   41.192905
## Camaro Z28              219.552085 219.527643  98.7203049  98.7566899   98.703583
## Pontiac Firebird        238.172610 238.180629 124.3368538 124.3204160  124.372613
## Fiat X1-9               105.741291 105.856037 227.7627676 227.7173075  227.817655
## Porsche 914-2            57.645816  57.847386 179.5034108 179.4550855  179.572045
## Lotus Europa             74.144358  74.382430 193.3074449 193.2407697  193.396922
## Ford Pantera L          231.408131 231.402426 112.8181834 112.8296774  112.833260
## Ferrari Dino             56.836510  56.898760 131.0272205 131.0077635  131.070449
## Maserati Bora           250.587412 250.577436 157.1633256 157.1768956  157.168397
## Volvo 142E               48.805345  48.888462 170.4500681 170.4225164  170.484373
##                         Cadillac Fleetwood Lincoln Continental Chrysler Imperial
## Mazda RX4                         326.33959           318.04698         304.72034
## Mazda RX4 Wag                     326.33551           318.04293         304.71692
## Datsun 710                        381.09262           372.80121         359.30149
## Hornet 4 Drive                    234.44039           227.97261         218.15483
## Hornet Sportabout                 116.28042           108.06243          97.20491
## Valiant                           266.62809           259.63044         248.77133
## Duster 360                        119.02391           104.51130          81.42977
## Merc 240D                         355.66275           348.99013         338.19594
## Merc 230                          349.28326           341.31543         328.43352
```

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## Merc 280                   315.39049          306.67607         292.71469
## Merc 280C                  315.35571          306.64062         292.69893
## Merc 450SE                 197.88428          187.59972         171.66008
## Merc 450SL                 197.91545          187.63308         171.67430
## Merc 450SLC                197.85262          187.56711         171.65576
## Cadillac Fleetwood           0.00000           15.62244          40.83996
## Lincoln Continental         15.62244            0.00000          25.37142
## Chrysler Imperial           40.83996           25.37142           0.00000
## Fiat 128                   417.76876          410.02070         397.22764
## Honda Civic                425.32716          417.96796         405.81522
## Toyota Corolla             425.34465          417.54300         404.63354
## Toyota Corona              368.31955          360.02675         346.57246
## Dodge Challenger           163.63149          156.28050         145.91948
## AMC Javelin                176.86109          169.09255         157.80976
## Camaro Z28                 128.45872          114.09321          91.28809
## Pontiac Firebird            78.53853           72.69479          68.20307
## Fiat X1-9                  417.24905          409.49984         396.75975
## Porsche 914-2              370.09568          362.01455         348.84669
## Lotus Europa               388.53500          379.47167         364.59943
## Ford Pantera L             134.81195          119.72365          95.38054
## Ferrari Dino               328.54416          317.70631         300.16407
## Maserati Bora              214.93669          199.34206         174.29369
## Volvo 142E                 364.10009          355.40094         341.28967
##                      Fiat 128 Honda Civic Toyota Corolla Toyota Corona
## Mazda RX4            93.267995   102.83076     100.604037      42.30752
## Mazda RX4 Wag        93.253099   102.82387     100.588759      42.26592
## Datsun 710           40.993376    52.77046      47.653502      12.96547
## Hornet 4 Drive      184.968973   191.55187     192.671419     138.53047
## Hornet Sportabout   302.037721   310.03246     309.558178     252.33320
## Valiant             152.115326   158.96158     159.830299     105.28764
## Duster 360          333.979207   344.05183     341.021823     282.05088
## Merc 240D            68.610590    72.00145      76.280646      44.08510
## Merc 230             69.312791    78.53872      76.773167      21.09620
## Merc 280            106.505315   116.72810     113.629072      54.36417
## Merc 280C           106.682979   116.87115     113.811801      54.42583
## Merc 450SE          228.324795   238.01418     235.518381     176.60205
## Merc 450SL          228.259234   237.95882     235.448197     176.57275
## Merc 450SLC         228.405183   238.08290     235.602410     176.63054
## Cadillac Fleetwood  417.768758   425.32716     425.344652     368.31955
## Lincoln Continental 410.020698   417.96796     417.542999     360.02675
## Chrysler Imperial   397.227638   405.81522     404.633539     346.57246
## Fiat 128              0.000000    14.55909       7.832479      52.87983
## Honda Civic          14.559094     0.00000      14.348063      63.89856
## Toyota Corolla        7.832479    14.34806       0.000000      59.84513
## Toyota Corona        52.879828    63.89856      59.845128       0.00000
## Dodge Challenger    254.236789   261.84988     261.834531     205.03479
## AMC Javelin         241.120362   248.96365     248.691707     191.55805
## Camaro Z28          325.663624   335.88832     332.658970     273.63169
## Pontiac Firebird    339.585766   347.06554     347.166764     290.62407
## Fiat X1-9             5.147342    14.78071      10.392286      51.84117
## Porsche 914-2        49.064437    59.45888      56.324303       8.65359
## Lotus Europa         49.911251    64.04952      53.884656      31.25369
## Ford Pantera L      337.163924   347.83377     343.992096     285.12879
## Ferrari Dino        128.395005   141.70445     133.470762      82.23557
```

```
## Maserati Bora       349.533883   362.16208     355.260162     299.18652
## Volvo 142E           61.330125    73.37660      67.718942      12.25053
##                    Dodge Challenger AMC Javelin Camaro Z28 Pontiac Firebird
## Mazda RX4                  163.11508   149.60472  233.22288        248.67803
## Mazda RX4 Wag              163.11342   149.60145  233.22487        248.67620
## Datsun 710                 217.77958   204.31889  286.00492        303.35839
## Hornet 4 Drive              72.44039    61.36019  163.66326        156.22403
## Hornet Sportabout           48.98389    61.42742   70.96653         40.00525
## Valiant                    103.43107    91.04443  187.84638        188.52721
## Duster 360                 103.90239   110.30849   10.07612         80.80573
## Merc 240D                  192.86179   180.54798  273.83680        277.46069
## Merc 230                   185.83319   172.53126  257.74697        271.38720
## Merc 280                   152.89293   139.14580  219.55209        238.17261
## Merc 280C                  152.87224   139.11820  219.52764        238.18063
## Merc 450SE                  51.80086    41.20800   98.72030        124.33685
## Merc 450SL                  51.82425    41.24116   98.75669        124.32042
## Merc 450SLC                 51.80126    41.19291   98.70358        124.37261
## Cadillac Fleetwood         163.63149   176.86109  128.45872         78.53853
## Lincoln Continental        156.28050   169.09255  114.09321         72.69479
## Chrysler Imperial          145.91948   157.80976   91.28809         68.20307
## Fiat 128                   254.23679   241.12036  325.66362        339.58577
## Honda Civic                261.84988   248.96365  335.88832        347.06554
## Toyota Corolla             261.83453   248.69171  332.65897        347.16676
## Toyota Corona              205.03479   191.55805  273.63169        290.62407
## Dodge Challenger             0.00000    14.01550  100.30461         85.80752
## AMC Javelin                 14.01550     0.00000  105.60626         99.28361
## Camaro Z28                 100.30461   105.60626    0.00000         86.26658
## Pontiac Firebird            85.80752    99.28361   86.26658          0.00000
## Fiat X1-9                  253.66240   240.52668  325.14909        339.13962
## Porsche 914-2              206.64526   193.30806  276.89244        292.16465
## Lotus Europa               226.50048   212.75688  287.61790        311.38623
## Ford Pantera L             118.75168   123.38320   19.35890        101.73897
## Ferrari Dino               174.92804   161.10603  216.74899        255.05705
## Maserati Bora              185.90593   185.15534  102.59462        188.32400
## Volvo 142E                 201.36825   187.69784  266.52777        286.74978
##                     Fiat X1-9 Porsche 914-2 Lotus Europa Ford Pantera L
## Mazda RX4            92.504839     44.40337     65.73284      245.42471
## Mazda RX4 Wag        92.494002     44.40736     65.73626      245.42938
## Datsun 710           39.881515     13.13571     25.09486      297.29405
## Hornet 4 Drive      184.447120    139.15795    163.23674      180.11403
## Hornet Sportabout   301.566948    254.14526    272.35824       89.59340
## Valiant             151.437942    106.05858    130.82482      203.01779
## Duster 360          333.484323    285.19862    296.45723       21.26560
## Merc 240D            67.916398     39.44693     72.89711      287.52388
## Merc 230             68.556486     22.11810     50.10940      269.97720
## Merc 280            105.741291     57.64582     74.14436      231.40813
## Merc 280C           105.856037     57.84739     74.38243      231.40243
## Merc 450SE          227.762768    179.50341    193.30744      112.81818
## Merc 450SL          227.717307    179.45509    193.24077      112.82968
## Merc 450SLC         227.817655    179.57204    193.39692      112.83326
## Cadillac Fleetwood  417.249048    370.09568    388.53500      134.81195
## Lincoln Continental 409.499836    362.01455    379.47167      119.72365
## Chrysler Imperial   396.759752    348.84669    364.59943       95.38054
## Fiat 128              5.147342     49.06444     49.91125      337.16392
```

```
## Honda Civic          14.780707      59.45888     64.04952      347.83377
## Toyota Corolla       10.392286      56.32430     53.88466      343.99210
## Toyota Corona        51.841175       8.65359     31.25369      285.12879
## Dodge Challenger    253.662405     206.64526    226.50048      118.75168
## AMC Javelin         240.526682     193.30806    212.75688      123.38320
## Camaro Z28          325.149091     276.89244    287.61790       19.35890
## Pontiac Firebird    339.139618     292.16465    311.38623      101.73897
## Fiat X1-9             0.000000      48.37752     49.84069      336.70188
## Porsche 914-2        48.377521       0.00000     33.76787      288.58530
## Lotus Europa         49.840688      33.76787      0.00000      297.53769
## Ford Pantera L      336.701878     288.58530    297.53769        0.00000
## Ferrari Dino        127.821081      87.91060     80.45535      224.45875
## Maserati Bora       349.119958     303.92225    303.27965       86.93833
## Volvo 142E           60.412043      18.75559     27.81045      277.48033
##                    Ferrari Dino Maserati Bora Volvo 142E
## Mazda RX4             66.76610     265.64542   39.18940
## Mazda RX4 Wag         66.77642     265.64915   39.16260
## Datsun 710            90.24155     309.77182   20.69394
## Hornet 4 Drive       130.55230     229.34194  137.03633
## Hornet Sportabout    215.06739     170.70945  248.00634
## Valiant              106.56948     242.43930  104.18637
## Duster 360           226.20363     107.72250  275.13535
## Merc 240D            113.30230     313.86331   53.68235
## Merc 230              80.65510     288.87556   24.69135
## Merc 280              56.83651     250.58741   48.80534
## Merc 280C             56.89876     250.57744   48.88846
## Merc 450SE           131.02722     157.16333  170.45007
## Merc 450SL           131.00776     157.17690  170.42252
## Merc 450SLC          131.07045     157.16840  170.48437
## Cadillac Fleetwood   328.54416     214.93669  364.10009
## Lincoln Continental  317.70631     199.34206  355.40094
## Chrysler Imperial    300.16407     174.29369  341.28967
## Fiat 128             128.39501     349.53388   61.33012
## Honda Civic          141.70445     362.16208   73.37660
## Toyota Corolla       133.47076     355.26016   67.71894
## Toyota Corona         82.23557     299.18652   12.25053
## Dodge Challenger     174.92804     185.90593  201.36825
## AMC Javelin          161.10603     185.15534  187.69784
## Camaro Z28           216.74899     102.59462  266.52777
## Pontiac Firebird     255.05705     188.32400  286.74978
## Fiat X1-9            127.82108     349.11996   60.41204
## Porsche 914-2         87.91060     303.92225   18.75559
## Lotus Europa          80.45535     303.27965   27.81045
## Ford Pantera L       224.45875      86.93833  277.48033
## Ferrari Dino           0.00000     223.53422   70.47510
## Maserati Bora        223.53422       0.00000  289.11574
## Volvo 142E            70.47510     289.11574    0.00000
```

```
cars_manhattan <- dist(mtcars, method = "manhattan")
as.matrix(cars_manhattan)
```

```
##                   Mazda RX4 Mazda RX4 Wag Datsun 710 Hornet 4 Drive
## Mazda RX4             0.000         0.815     79.300        108.795
## Mazda RX4 Wag         0.815         0.000     78.995        107.980
```

```
## Datsun 710             79.300        78.995      0.000        174.895
## Hornet 4 Drive        108.795       107.980    174.895          0.000
## Hornet Sportabout     275.430       274.615    349.510        176.415
## Valiant                84.640        83.825    141.540         42.645
## Duster 360            347.960       348.265    427.160        254.185
## Merc 240D              75.020        74.205     75.720        167.495
## Merc 230               48.990        48.175     41.990        141.965
## Merc 280               27.080        26.265    100.700        111.805
## Merc 280C              29.080        28.265    102.080        112.605
## Merc 450SE            198.620       197.805    273.940        100.705
## Merc 450SL            197.580       196.765    272.500         99.265
## Merc 450SLC           200.130       199.315    274.250        101.015
## Cadillac Fleetwood    426.720       425.905    502.880        329.645
## Lincoln Continental   424.664       423.849    501.144        327.909
## Chrysler Imperial     414.655       413.840    491.935        319.000
## Fiat 128              146.310       146.005     67.110        240.345
## Honda Civic           160.795       160.490     83.775        258.670
## Toyota Corolla        157.345       157.040     78.145        251.380
## Toyota Corona          65.305        65.000     21.095        154.940
## Dodge Challenger      211.950       211.435    286.330        113.095
## AMC Javelin           198.205       197.390    271.725         98.630
## Camaro Z28            339.140       339.445    418.340        246.405
## Pontiac Firebird      315.435       314.620    389.455        216.220
## Fiat X1-9             140.605       140.300     61.405        235.720
## Porsche 914-2          69.950        70.285     23.170        173.465
## Lotus Europa           84.977        84.912     45.097        185.832
## Ford Pantera L        356.030       356.335    435.330        267.725
## Ferrari Dino           85.690        86.205    134.890        193.625
## Maserati Bora         382.170       382.475    461.370        293.055
## Volvo 142E             47.910        47.285     32.130        145.305
##                    Hornet Sportabout Valiant Duster 360 Merc 240D Merc 230
## Mazda RX4                    275.430  84.640    347.960    75.020   48.990
## Mazda RX4 Wag                274.615  83.825    348.265    74.205   48.175
## Datsun 710                   349.510 141.540    427.160    75.720   41.990
## Hornet 4 Drive               176.415  42.645    254.185   167.495  141.965
## Hornet Sportabout              0.000 213.210     77.770   341.770  316.240
## Valiant                      213.210   0.000    289.740   133.020  107.050
## Duster 360                    77.770 289.740      0.000   419.420  393.890
## Merc 240D                    341.770 133.020    419.420     0.000   43.670
## Merc 230                     316.240 107.050    393.890    43.670    0.000
## Merc 280                     252.950  83.600    326.600    93.280   67.290
## Merc 280C                    253.950  82.200    325.800    94.080   68.090
## Merc 450SE                    93.590 136.240    154.500   266.200  240.670
## Merc 450SL                    92.550 134.800    155.260   264.760  239.230
## Merc 450SLC                   95.100 136.550    153.610   266.510  240.980
## Cadillac Fleetwood           155.290 364.900    160.000   495.140  469.610
## Lincoln Continental          153.234 363.304    137.944   493.404  467.874
## Chrysler Imperial            143.385 354.555     98.775   484.195  458.665
## Fiat 128                     416.620 206.930    494.270    83.910  107.240
## Honda Civic                  431.105 225.315    508.755    92.295  123.625
## Toyota Corolla               427.655 217.105    505.305    92.085  117.415
## Toyota Corona                331.215 120.445    408.865    67.245   29.795
## Dodge Challenger              70.820 148.010    141.730   278.590  253.060
## AMC Javelin                   84.785 134.235    155.555   263.985  238.455
```

```
## Camaro Z28                  89.990 281.960     12.220   410.680  385.070
## Pontiac Firebird            41.005 253.975    118.515   381.715  356.185
## Fiat X1-9                  410.915 202.365    488.565    79.345  102.675
## Porsche 914-2              340.900 140.110    417.910    65.090   38.420
## Lotus Europa               349.267 162.477    426.677   115.457   81.087
## Ford Pantera L             109.760 303.770     35.250   429.950  403.920
## Ferrari Dino               227.660 166.870    298.950   133.390  104.380
## Maserati Bora              234.640 328.610    158.270   455.630  430.100
## Volvo 142E                 317.900 119.950    395.550    78.930   41.060
##                    Merc 280 Merc 280C Merc 450SE Merc 450SL Merc 450SLC
## Mazda RX4            27.080    29.080    198.620    197.580     200.130
## Mazda RX4 Wag        26.265    28.265    197.805    196.765     199.315
## Datsun 710          100.700   102.080    273.940    272.500     274.250
## Hornet 4 Drive      111.805   112.605    100.705     99.265     101.015
## Hornet Sportabout   252.950   253.950     93.590     92.550      95.100
## Valiant              83.600    82.200    136.240    134.800     136.550
## Duster 360          326.600   325.800    154.500    155.260     153.610
## Merc 240D            93.280    94.080    266.200    264.760     266.510
## Merc 230             67.290    68.090    240.670    239.230     240.980
## Merc 280              0.000     2.000    175.380    173.940     175.690
## Merc 280C             2.000     0.000    174.580    173.140     174.890
## Merc 450SE          175.380   174.580      0.000      1.440       2.090
## Merc 450SL          173.940   173.140      1.440      0.000       2.550
## Merc 450SLC         175.690   174.890      2.090      2.550       0.000
## Cadillac Fleetwood  402.320   401.520    230.100    231.140     228.630
## Lincoln Continental 400.584   399.784    228.044    229.084     226.894
## Chrysler Imperial   391.375   390.575    218.355    219.755     218.005
## Fiat 128            167.670   168.470    341.050    339.610     341.360
## Honda Civic         182.155   183.715    355.535    354.095     355.845
## Toyota Corolla      178.705   179.505    352.085    350.645     352.395
## Toyota Corona        84.705    85.505    255.645    254.205     255.955
## Dodge Challenger    189.770   188.970     75.490     76.250      75.200
## AMC Javelin         175.175   174.375     61.215     61.975      60.325
## Camaro Z28          317.780   316.980    146.180    147.160     145.410
## Pontiac Firebird    292.895   294.895    133.585    132.775     135.225
## Fiat X1-9           161.965   162.765    335.345    333.905     335.655
## Porsche 914-2        96.510    98.510    266.090    265.050     267.600
## Lotus Europa        103.177   105.177    274.457    273.417     275.967
## Ford Pantera L      337.170   336.370    168.750    169.510     169.060
## Ferrari Dino         83.870    85.870    150.850    149.810     152.360
## Maserati Bora       362.810   362.010    193.370    194.130     192.480
## Volvo 142E           68.950    70.350    242.330    240.890     242.640
##                    Cadillac Fleetwood Lincoln Continental Chrysler Imperial
## Mazda RX4                      426.720             424.664           414.655
## Mazda RX4 Wag                  425.905             423.849           413.840
## Datsun 710                     502.880             501.144           491.935
## Hornet 4 Drive                 329.645             327.909           319.000
## Hornet Sportabout              155.290             153.234           143.385
## Valiant                        364.900             363.304           354.555
## Duster 360                     160.000             137.944            98.775
## Merc 240D                      495.140             493.404           484.195
## Merc 230                       469.610             467.874           458.665
## Merc 280                       402.320             400.584           391.375
## Merc 280C                      401.520             399.784           390.575
```

```
## Merc 450SE                    230.100             228.044          218.355
## Merc 450SL                    231.140             229.084          219.755
## Merc 450SLC                   228.630             226.894          218.005
## Cadillac Fleetwood              0.000              22.404           62.255
## Lincoln Continental            22.404               0.000           40.009
## Chrysler Imperial              62.255              40.009            0.000
## Fiat 128                      569.990             568.254          559.045
## Honda Civic                   584.475             582.739          573.530
## Toyota Corolla                581.025             579.289          570.080
## Toyota Corona                 484.585             482.849          473.640
## Dodge Challenger              219.110             217.194          207.645
## AMC Javelin                   232.515             230.459          220.610
## Camaro Z28                    169.680             147.624          110.415
## Pontiac Firebird              115.285             113.229          103.520
## Fiat X1-9                     564.285             562.549          553.340
## Porsche 914-2                 496.190             494.134          484.125
## Lotus Europa                  504.557             502.501          492.492
## Ford Pantera L                195.250             173.194          133.185
## Ferrari Dino                  378.950             376.894          366.885
## Maserati Bora                 318.270             296.214          256.205
## Volvo 142E                    471.270             469.534          460.325
##                     Fiat 128 Honda Civic Toyota Corolla Toyota Corona
## Mazda RX4            146.310     160.795        157.345        65.305
## Mazda RX4 Wag        146.005     160.490        157.040        65.000
## Datsun 710            67.110      83.775         78.145        21.095
## Hornet 4 Drive       240.345     258.670        251.380       154.940
## Hornet Sportabout    416.620     431.105        427.655       331.215
## Valiant              206.930     225.315        217.105       120.445
## Duster 360           494.270     508.755        505.305       408.865
## Merc 240D             83.910      92.295         92.085        67.245
## Merc 230             107.240     123.625        117.415        29.795
## Merc 280             167.670     182.155        178.705        84.705
## Merc 280C            168.470     183.715        179.505        85.505
## Merc 450SE           341.050     355.535        352.085       255.645
## Merc 450SL           339.610     354.095        350.645       254.205
## Merc 450SLC          341.360     355.845        352.395       255.955
## Cadillac Fleetwood   569.990     584.475        581.025       484.585
## Lincoln Continental  568.254     582.739        579.289       482.849
## Chrysler Imperial    559.045     573.530        570.080       473.640
## Fiat 128               0.000      22.385         11.035        86.485
## Honda Civic           22.385       0.000         24.410       104.870
## Toyota Corolla        11.035      24.410          0.000        96.660
## Toyota Corona         86.485     104.870         96.660         0.000
## Dodge Challenger     353.440     367.925        364.475       268.035
## AMC Javelin          338.835     353.320        349.870       253.430
## Camaro Z28           485.450     499.935        496.485       400.105
## Pontiac Firebird     456.565     471.050        467.600       371.160
## Fiat X1-9              6.235      22.950         16.740        81.920
## Porsche 914-2         79.180      92.845         89.815        20.065
## Lotus Europa          70.967      84.282         81.272        58.032
## Ford Pantera L       501.980     516.185        512.735       421.335
## Ferrari Dino         202.000     216.485        213.035       120.595
## Maserati Bora        528.480     542.965        539.515       447.075
## Volvo 142E            98.780     113.365        109.755        18.135
```

```
##                     Dodge Challenger AMC Javelin Camaro Z28 Pontiac Firebird
## Mazda RX4                    211.950     198.205    339.140          315.435
## Mazda RX4 Wag                211.435     197.390    339.445          314.620
## Datsun 710                   286.330     271.725    418.340          389.455
## Hornet 4 Drive               113.095      98.630    246.405          216.220
## Hornet Sportabout             70.820      84.785     89.990           41.005
## Valiant                      148.010     134.235    281.960          253.975
## Duster 360                   141.730     155.555     12.220          118.515
## Merc 240D                    278.590     263.985    410.680          381.715
## Merc 230                     253.060     238.455    385.070          356.185
## Merc 280                     189.770     175.175    317.780          292.895
## Merc 280C                    188.970     174.375    316.980          294.895
## Merc 450SE                    75.490      61.215    146.180          133.585
## Merc 450SL                    76.250      61.975    147.160          132.775
## Merc 450SLC                   75.200      60.325    145.410          135.225
## Cadillac Fleetwood           219.110     232.515    169.680          115.285
## Lincoln Continental          217.194     230.459    147.624          113.229
## Chrysler Imperial            207.645     220.610    110.415          103.520
## Fiat 128                     353.440     338.835    485.450          456.565
## Honda Civic                  367.925     353.320    499.935          471.050
## Toyota Corolla               364.475     349.870    496.485          467.600
## Toyota Corona                268.035     253.430    400.105          371.160
## Dodge Challenger               0.000      15.205    133.950          111.525
## AMC Javelin                   15.205       0.000    147.775          125.730
## Camaro Z28                   133.950     147.775      0.000          130.195
## Pontiac Firebird             111.525     125.730    130.195            0.000
## Fiat X1-9                    347.735     333.130    479.745          450.860
## Porsche 914-2                277.420     263.675    409.090          380.905
## Lotus Europa                 285.847     272.042    417.857          389.272
## Ford Pantera L               156.480     170.735     27.570          150.765
## Ferrari Dino                 214.180     200.435    289.670          267.665
## Maserati Bora                214.600     200.425    148.970          275.385
## Volvo 142E                   254.720     240.115    386.730          357.845
##                     Fiat X1-9 Porsche 914-2 Lotus Europa Ford Pantera L
## Mazda RX4             140.605        69.950       84.977        356.030
## Mazda RX4 Wag         140.300        70.285       84.912        356.335
## Datsun 710             61.405        23.170       45.097        435.330
## Hornet 4 Drive        235.720       173.465      185.832        267.725
## Hornet Sportabout     410.915       340.900      349.267        109.760
## Valiant               202.365       140.110      162.477        303.770
## Duster 360            488.565       417.910      426.677         35.250
## Merc 240D              79.345        65.090      115.457        429.950
## Merc 230              102.675        38.420       81.087        403.920
## Merc 280              161.965        96.510      103.177        337.170
## Merc 280C             162.765        98.510      105.177        336.370
## Merc 450SE            335.345       266.090      274.457        168.750
## Merc 450SL            333.905       265.050      273.417        169.510
## Merc 450SLC           335.655       267.600      275.967        169.060
## Cadillac Fleetwood    564.285       496.190      504.557        195.250
## Lincoln Continental   562.549       494.134      502.501        173.194
## Chrysler Imperial     553.340       484.125      492.492        133.185
## Fiat 128                6.235        79.180       70.967        501.980
## Honda Civic            22.950        92.845       84.282        516.185
## Toyota Corolla         16.740        89.815       81.272        512.735
```

```
## Toyota Corona          81.920       20.065       58.032       421.335
## Dodge Challenger      347.735      277.420      285.847       156.480
## AMC Javelin           333.130      263.675      272.042       170.735
## Camaro Z28            479.745      409.090      417.857        27.570
## Pontiac Firebird      450.860      380.905      389.272       150.765
## Fiat X1-9               0.000       73.355       70.932       496.275
## Porsche 914-2          73.355        0.000       54.087       423.340
## Lotus Europa           70.932       54.087        0.000       433.007
## Ford Pantera L        496.275      423.340      433.007         0.000
## Ferrari Dino          196.295      123.640      132.407       304.900
## Maserati Bora         522.775      450.120      458.887       126.980
## Volvo 142E             93.075       28.160       43.207       403.200
##                    Ferrari Dino Maserati Bora Volvo 142E
## Mazda RX4                85.690       382.170     47.910
## Mazda RX4 Wag            86.205       382.475     47.285
## Datsun 710              134.890       461.370     32.130
## Hornet 4 Drive          193.625       293.055    145.305
## Hornet Sportabout       227.660       234.640    317.900
## Valiant                 166.870       328.610    119.950
## Duster 360              298.950       158.270    395.550
## Merc 240D               133.390       455.630     78.930
## Merc 230                104.380       430.100     41.060
## Merc 280                 83.870       362.810     68.950
## Merc 280C                85.870       362.010     70.350
## Merc 450SE              150.850       193.370    242.330
## Merc 450SL              149.810       194.130    240.890
## Merc 450SLC             152.360       192.480    242.640
## Cadillac Fleetwood      378.950       318.270    471.270
## Lincoln Continental     376.894       296.214    469.534
## Chrysler Imperial       366.885       256.205    460.325
## Fiat 128                202.000       528.480     98.780
## Honda Civic             216.485       542.965    113.365
## Toyota Corolla          213.035       539.515    109.755
## Toyota Corona           120.595       447.075     18.135
## Dodge Challenger        214.180       214.600    254.720
## AMC Javelin             200.435       200.425    240.115
## Camaro Z28              289.670       148.970    386.730
## Pontiac Firebird        267.665       275.385    357.845
## Fiat X1-9               196.295       522.775     93.075
## Porsche 914-2           123.640       450.120     28.160
## Lotus Europa            132.407       458.887     43.207
## Ford Pantera L          304.900       126.980    403.200
## Ferrari Dino              0.000       326.480    103.300
## Maserati Bora           326.480         0.000    429.760
## Volvo 142E              103.300       429.760      0.000
```

```
cars_minkowski <- dist(mtcars, method = "minkowski")
as.matrix(cars_minkowski)
```

```
##                    Mazda RX4 Mazda RX4 Wag Datsun 710 Hornet 4 Drive
## Mazda RX4          0.0000000     0.6153251   54.90861       98.11252
## Mazda RX4 Wag      0.6153251     0.0000000   54.89152       98.09589
## Datsun 710        54.9086059    54.8915169    0.00000      150.99352
## Hornet 4 Drive    98.1125212    98.0958939  150.99352        0.00000
```

```
## Hornet Sportabout   210.3374396   210.3358546  265.08316      121.02976
## Valiant              65.4717710    65.4392224  117.75470       33.55087
## Duster 360          241.4076490   241.4088680  294.47902      169.42996
## Merc 240D            50.1532711    50.1146059   49.65848      121.27397
## Merc 230             25.4683117    25.3284509   33.18038      118.24331
## Merc 280             15.3641921    15.2956865   66.93635       91.42240
## Merc 280C            15.6724727    15.5837744   67.02614       91.46129
## Merc 450SE          135.4307018   135.4254826  189.19549       72.49643
## Merc 450SL          135.4014424   135.3960351  189.16317       72.43135
## Merc 450SLC         135.4794674   135.4723157  189.23454       72.57185
## Cadillac Fleetwood  326.3395903   326.3355070  381.09262      234.44039
## Lincoln Continental 318.0469808   318.0429333  372.80121      227.97261
## Chrysler Imperial   304.7203408   304.7169175  359.30149      218.15483
## Fiat 128             93.2679950    93.2530993   40.99338      184.96897
## Honda Civic         102.8307567   102.8238713   52.77046      191.55187
## Toyota Corolla      100.6040368   100.5887588   47.65350      192.67142
## Toyota Corona        42.3075233    42.2659224   12.96547      138.53047
## Dodge Challenger    163.1150750   163.1134210  217.77958       72.44039
## AMC Javelin         149.6047203   149.6014522  204.31889       61.36019
## Camaro Z28          233.2228758   233.2248748  286.00492      163.66326
## Pontiac Firebird    248.6780270   248.6762035  303.35839      156.22403
## Fiat X1-9            92.5048389    92.4940020   39.88151      184.44712
## Porsche 914-2        44.4033659    44.4073589   13.13571      139.15795
## Lotus Europa         65.7328377    65.7362635   25.09486      163.23674
## Ford Pantera L      245.4247064   245.4293785  297.29405      180.11403
## Ferrari Dino         66.7661029    66.7764167   90.24155      130.55230
## Maserati Bora       265.6454248   265.6491465  309.77182      229.34194
## Volvo 142E           39.1894029    39.1626037   20.69394      137.03633
##                    Hornet Sportabout   Valiant Duster 360 Merc 240D  Merc 230
## Mazda RX4                  210.33744  65.47177  241.40765  50.15327  25.46831
## Mazda RX4 Wag              210.33585  65.43922  241.40887  50.11461  25.32845
## Datsun 710                 265.08316 117.75470  294.47902  49.65848  33.18038
## Hornet 4 Drive             121.02976  33.55087  169.42996 121.27397 118.24331
## Hornet Sportabout            0.00000 152.12414   70.17673 241.50697 233.49240
## Valiant                    152.12414   0.00000  194.60945  89.59111  85.00796
## Duster 360                  70.17673 194.60945    0.00000 281.29625 265.88233
## Merc 240D                  241.50697  89.59111  281.29625   0.00000  33.68730
## Merc 230                   233.49240  85.00796  265.88233  33.68730   0.00000
## Merc 280                   199.33450  60.29098  227.89985  64.77542  39.29942
## Merc 280C                  199.34066  60.26557  227.88132  64.88987  39.38685
## Merc 450SE                  84.38885  90.69703  106.40843 175.16201 159.81796
## Merc 450SL                  84.36840  90.67697  106.43206 175.11898 159.77609
## Merc 450SLC                 84.43324  90.70930  106.40103 175.21182 159.84958
## Cadillac Fleetwood         116.28042 266.62809  119.02391 355.66275 349.28326
## Lincoln Continental        108.06243 259.63044  104.51130 348.99013 341.31543
## Chrysler Imperial           97.20491 248.77133   81.42977 338.19594 328.43352
## Fiat 128                   302.03772 152.11533  333.97921  68.61059  69.31279
## Honda Civic                310.03246 158.96158  344.05183  72.00145  78.53872
## Toyota Corolla             309.55818 159.83030  341.02182  76.28065  76.77317
## Toyota Corona              252.33320 105.28764  282.05088  44.08510  21.09620
## Dodge Challenger            48.98389 103.43107  103.90239 192.86179 185.83319
## AMC Javelin                 61.42742  91.04443  110.30849 180.54798 172.53126
## Camaro Z28                  70.96653 187.84638   10.07612 273.83680 257.74697
## Pontiac Firebird            40.00525 188.52721   80.80573 277.46069 271.38720
```

```
## Fiat X1-9                  301.56695 151.43794  333.48432  67.91640  68.55649
## Porsche 914-2              254.14526 106.05858  285.19862  39.44693  22.11810
## Lotus Europa               272.35824 130.82482  296.45723  72.89711  50.10940
## Ford Pantera L              89.59340 203.01779   21.26560 287.52388 269.97720
## Ferrari Dino               215.06739 106.56948  226.20363 113.30230  80.65510
## Maserati Bora              170.70945 242.43930  107.72250 313.86331 288.87556
## Volvo 142E                 248.00634 104.18637  275.13535  53.68235  24.69135
##                          Merc 280  Merc 280C  Merc 450SE  Merc 450SL Merc 450SLC
## Mazda RX4                15.364192  15.672473 135.4307018 135.4014424  135.479467
## Mazda RX4 Wag            15.295686  15.583774 135.4254826 135.3960351  135.472316
## Datsun 710               66.936353  67.026140 189.1954941 189.1631745  189.234543
## Hornet 4 Drive           91.422403  91.461291  72.4964325  72.4313532   72.571847
## Hornet Sportabout       199.334496 199.340656  84.3888482  84.3683999   84.433242
## Valiant                  60.290981  60.265566  90.6970264  90.6769728   90.709299
## Duster 360              227.899852 227.881317 106.4084264 106.4320572  106.401031
## Merc 240D                64.775423  64.889871 175.1620073 175.1189767  175.211822
## Merc 230                 39.299416  39.386852 159.8179555 159.7760899  159.849584
## Merc 280                  0.000000   1.523155 122.3642489 122.3443771  122.393497
## Merc 280C                 1.523155   0.000000 122.3461050 122.3355492  122.358686
## Merc 450SE              122.364249 122.346105   0.0000000   0.9826495    1.372625
## Merc 450SL              122.344377 122.335549   0.9826495   0.0000000    2.138340
## Merc 450SLC             122.393497 122.358686   1.3726252   2.1383405    0.000000
## Cadillac Fleetwood      315.390486 315.355708 197.8842803 197.9154476  197.852624
## Lincoln Continental     306.676072 306.640619 187.5997191 187.6330806  187.567108
## Chrysler Imperial       292.714690 292.698933 171.6600758 171.6743028  171.655764
## Fiat 128                106.505315 106.682979 228.3247948 228.2592340  228.405183
## Honda Civic             116.728099 116.871148 238.0141824 237.9588183  238.082900
## Toyota Corolla          113.629072 113.811801 235.5183809 235.4481971  235.602410
## Toyota Corona            54.364171  54.425831 176.6020527 176.5727477  176.630536
## Dodge Challenger        152.892926 152.872244  51.8008639  51.8242520   51.801261
## AMC Javelin             139.145797 139.118198  41.2080044  41.2411618   41.192905
## Camaro Z28              219.552085 219.527643  98.7203049  98.7566899   98.703583
## Pontiac Firebird        238.172610 238.180629 124.3368538 124.3204160  124.372613
## Fiat X1-9               105.741291 105.856037 227.7627676 227.7173075  227.817655
## Porsche 914-2            57.645816  57.847386 179.5034108 179.4550855  179.572045
## Lotus Europa             74.144358  74.382430 193.3074449 193.2407697  193.396922
## Ford Pantera L          231.408131 231.402426 112.8181834 112.8296774  112.833260
## Ferrari Dino             56.836510  56.898760 131.0272205 131.0077635  131.070449
## Maserati Bora           250.587412 250.577436 157.1633256 157.1768956  157.168397
## Volvo 142E               48.805345  48.888462 170.4500681 170.4225164  170.484373
##                         Cadillac Fleetwood Lincoln Continental Chrysler Imperial
## Mazda RX4                         326.33959           318.04698         304.72034
## Mazda RX4 Wag                     326.33551           318.04293         304.71692
## Datsun 710                        381.09262           372.80121         359.30149
## Hornet 4 Drive                    234.44039           227.97261         218.15483
## Hornet Sportabout                 116.28042           108.06243          97.20491
## Valiant                           266.62809           259.63044         248.77133
## Duster 360                        119.02391           104.51130          81.42977
## Merc 240D                         355.66275           348.99013         338.19594
## Merc 230                          349.28326           341.31543         328.43352
## Merc 280                          315.39049           306.67607         292.71469
## Merc 280C                         315.35571           306.64062         292.69893
## Merc 450SE                        197.88428           187.59972         171.66008
## Merc 450SL                        197.91545           187.63308         171.67430
```

```
## Merc 450SLC                197.85262          187.56711         171.65576
## Cadillac Fleetwood           0.00000           15.62244          40.83996
## Lincoln Continental         15.62244            0.00000          25.37142
## Chrysler Imperial           40.83996           25.37142           0.00000
## Fiat 128                   417.76876          410.02070         397.22764
## Honda Civic                425.32716          417.96796         405.81522
## Toyota Corolla             425.34465          417.54300         404.63354
## Toyota Corona              368.31955          360.02675         346.57246
## Dodge Challenger           163.63149          156.28050         145.91948
## AMC Javelin                176.86109          169.09255         157.80976
## Camaro Z28                 128.45872          114.09321          91.28809
## Pontiac Firebird            78.53853           72.69479          68.20307
## Fiat X1-9                  417.24905          409.49984         396.75975
## Porsche 914-2              370.09568          362.01455         348.84669
## Lotus Europa               388.53500          379.47167         364.59943
## Ford Pantera L             134.81195          119.72365          95.38054
## Ferrari Dino               328.54416          317.70631         300.16407
## Maserati Bora              214.93669          199.34206         174.29369
## Volvo 142E                 364.10009          355.40094         341.28967
##                      Fiat 128 Honda Civic Toyota Corolla Toyota Corona
## Mazda RX4            93.267995   102.83076     100.604037      42.30752
## Mazda RX4 Wag        93.253099   102.82387     100.588759      42.26592
## Datsun 710           40.993376    52.77046      47.653502      12.96547
## Hornet 4 Drive      184.968973   191.55187     192.671419     138.53047
## Hornet Sportabout   302.037721   310.03246     309.558178     252.33320
## Valiant             152.115326   158.96158     159.830299     105.28764
## Duster 360          333.979207   344.05183     341.021823     282.05088
## Merc 240D            68.610590    72.00145      76.280646      44.08510
## Merc 230             69.312791    78.53872      76.773167      21.09620
## Merc 280            106.505315   116.72810     113.629072      54.36417
## Merc 280C           106.682979   116.87115     113.811801      54.42583
## Merc 450SE          228.324795   238.01418     235.518381     176.60205
## Merc 450SL          228.259234   237.95882     235.448197     176.57275
## Merc 450SLC         228.405183   238.08290     235.602410     176.63054
## Cadillac Fleetwood  417.768758   425.32716     425.344652     368.31955
## Lincoln Continental 410.020698   417.96796     417.542999     360.02675
## Chrysler Imperial   397.227638   405.81522     404.633539     346.57246
## Fiat 128              0.000000    14.55909       7.832479      52.87983
## Honda Civic          14.559094     0.00000      14.348063      63.89856
## Toyota Corolla        7.832479    14.34806       0.000000      59.84513
## Toyota Corona        52.879828    63.89856      59.845128       0.00000
## Dodge Challenger    254.236789   261.84988     261.834531     205.03479
## AMC Javelin         241.120362   248.96365     248.691707     191.55805
## Camaro Z28          325.663624   335.88832     332.658970     273.63169
## Pontiac Firebird    339.585766   347.06554     347.166764     290.62407
## Fiat X1-9             5.147342    14.78071      10.392286      51.84117
## Porsche 914-2        49.064437    59.45888      56.324303       8.65359
## Lotus Europa         49.911251    64.04952      53.884656      31.25369
## Ford Pantera L      337.163924   347.83377     343.992096     285.12879
## Ferrari Dino        128.395005   141.70445     133.470762      82.23557
## Maserati Bora       349.533883   362.16208     355.260162     299.18652
## Volvo 142E           61.330125    73.37660      67.718942      12.25053
##                    Dodge Challenger AMC Javelin Camaro Z28 Pontiac Firebird
## Mazda RX4                163.11508   149.60472  233.22288        248.67803
```

```
## Mazda RX4 Wag             163.11342   149.60145  233.22487        248.67620
## Datsun 710                217.77958   204.31889  286.00492        303.35839
## Hornet 4 Drive             72.44039    61.36019  163.66326        156.22403
## Hornet Sportabout          48.98389    61.42742   70.96653         40.00525
## Valiant                   103.43107    91.04443  187.84638        188.52721
## Duster 360                103.90239   110.30849   10.07612         80.80573
## Merc 240D                 192.86179   180.54798  273.83680        277.46069
## Merc 230                  185.83319   172.53126  257.74697        271.38720
## Merc 280                  152.89293   139.14580  219.55209        238.17261
## Merc 280C                 152.87224   139.11820  219.52764        238.18063
## Merc 450SE                 51.80086    41.20800   98.72030        124.33685
## Merc 450SL                 51.82425    41.24116   98.75669        124.32042
## Merc 450SLC                51.80126    41.19291   98.70358        124.37261
## Cadillac Fleetwood        163.63149   176.86109  128.45872         78.53853
## Lincoln Continental       156.28050   169.09255  114.09321         72.69479
## Chrysler Imperial         145.91948   157.80976   91.28809         68.20307
## Fiat 128                  254.23679   241.12036  325.66362        339.58577
## Honda Civic               261.84988   248.96365  335.88832        347.06554
## Toyota Corolla            261.83453   248.69171  332.65897        347.16676
## Toyota Corona             205.03479   191.55805  273.63169        290.62407
## Dodge Challenger            0.00000    14.01550  100.30461         85.80752
## AMC Javelin                14.01550     0.00000  105.60626         99.28361
## Camaro Z28                100.30461   105.60626    0.00000         86.26658
## Pontiac Firebird           85.80752    99.28361   86.26658          0.00000
## Fiat X1-9                 253.66240   240.52668  325.14909        339.13962
## Porsche 914-2             206.64526   193.30806  276.89244        292.16465
## Lotus Europa              226.50048   212.75688  287.61790        311.38623
## Ford Pantera L            118.75168   123.38320   19.35890        101.73897
## Ferrari Dino              174.92804   161.10603  216.74899        255.05705
## Maserati Bora             185.90593   185.15534  102.59462        188.32400
## Volvo 142E                201.36825   187.69784  266.52777        286.74978
##                      Fiat X1-9 Porsche 914-2 Lotus Europa Ford Pantera L
## Mazda RX4            92.504839      44.40337     65.73284      245.42471
## Mazda RX4 Wag        92.494002      44.40736     65.73626      245.42938
## Datsun 710           39.881515      13.13571     25.09486      297.29405
## Hornet 4 Drive      184.447120     139.15795    163.23674      180.11403
## Hornet Sportabout   301.566948     254.14526    272.35824       89.59340
## Valiant             151.437942     106.05858    130.82482      203.01779
## Duster 360          333.484323     285.19862    296.45723       21.26560
## Merc 240D            67.916398      39.44693     72.89711      287.52388
## Merc 230             68.556486      22.11810     50.10940      269.97720
## Merc 280            105.741291      57.64582     74.14436      231.40813
## Merc 280C           105.856037      57.84739     74.38243      231.40243
## Merc 450SE          227.762768     179.50341    193.30744      112.81818
## Merc 450SL          227.717307     179.45509    193.24077      112.82968
## Merc 450SLC         227.817655     179.57204    193.39692      112.83326
## Cadillac Fleetwood  417.249048     370.09568    388.53500      134.81195
## Lincoln Continental 409.499836     362.01455    379.47167      119.72365
## Chrysler Imperial   396.759752     348.84669    364.59943       95.38054
## Fiat 128              5.147342      49.06444     49.91125      337.16392
## Honda Civic          14.780707      59.45888     64.04952      347.83377
## Toyota Corolla       10.392286      56.32430     53.88466      343.99210
## Toyota Corona        51.841175       8.65359     31.25369      285.12879
## Dodge Challenger    253.662405     206.64526    226.50048      118.75168
```

```
## AMC Javelin         240.526682     193.30806    212.75688      123.38320
## Camaro Z28          325.149091     276.89244    287.61790       19.35890
## Pontiac Firebird    339.139618     292.16465    311.38623      101.73897
## Fiat X1-9             0.000000      48.37752     49.84069      336.70188
## Porsche 914-2        48.377521       0.00000     33.76787      288.58530
## Lotus Europa         49.840688      33.76787      0.00000      297.53769
## Ford Pantera L      336.701878     288.58530    297.53769        0.00000
## Ferrari Dino        127.821081      87.91060     80.45535      224.45875
## Maserati Bora       349.119958     303.92225    303.27965       86.93833
## Volvo 142E           60.412043      18.75559     27.81045      277.48033
##                     Ferrari Dino Maserati Bora Volvo 142E
## Mazda RX4              66.76610     265.64542   39.18940
## Mazda RX4 Wag          66.77642     265.64915   39.16260
## Datsun 710             90.24155     309.77182   20.69394
## Hornet 4 Drive        130.55230     229.34194  137.03633
## Hornet Sportabout     215.06739     170.70945  248.00634
## Valiant               106.56948     242.43930  104.18637
## Duster 360            226.20363     107.72250  275.13535
## Merc 240D             113.30230     313.86331   53.68235
## Merc 230               80.65510     288.87556   24.69135
## Merc 280               56.83651     250.58741   48.80534
## Merc 280C              56.89876     250.57744   48.88846
## Merc 450SE            131.02722     157.16333  170.45007
## Merc 450SL            131.00776     157.17690  170.42252
## Merc 450SLC           131.07045     157.16840  170.48437
## Cadillac Fleetwood    328.54416     214.93669  364.10009
## Lincoln Continental   317.70631     199.34206  355.40094
## Chrysler Imperial     300.16407     174.29369  341.28967
## Fiat 128              128.39501     349.53388   61.33012
## Honda Civic           141.70445     362.16208   73.37660
## Toyota Corolla        133.47076     355.26016   67.71894
## Toyota Corona          82.23557     299.18652   12.25053
## Dodge Challenger      174.92804     185.90593  201.36825
## AMC Javelin           161.10603     185.15534  187.69784
## Camaro Z28            216.74899     102.59462  266.52777
## Pontiac Firebird      255.05705     188.32400  286.74978
## Fiat X1-9             127.82108     349.11996   60.41204
## Porsche 914-2          87.91060     303.92225   18.75559
## Lotus Europa           80.45535     303.27965   27.81045
## Ford Pantera L        224.45875      86.93833  277.48033
## Ferrari Dino            0.00000     223.53422   70.47510
## Maserati Bora         223.53422       0.00000  289.11574
## Volvo 142E             70.47510     289.11574    0.00000
```

The same three distance metrics, Euclidean, Manhattan, and Minkowski from the previous question were used. The results were the same as Euclidean and Minkowski gave similar results and the results from Manhattan differed.

Ex.3

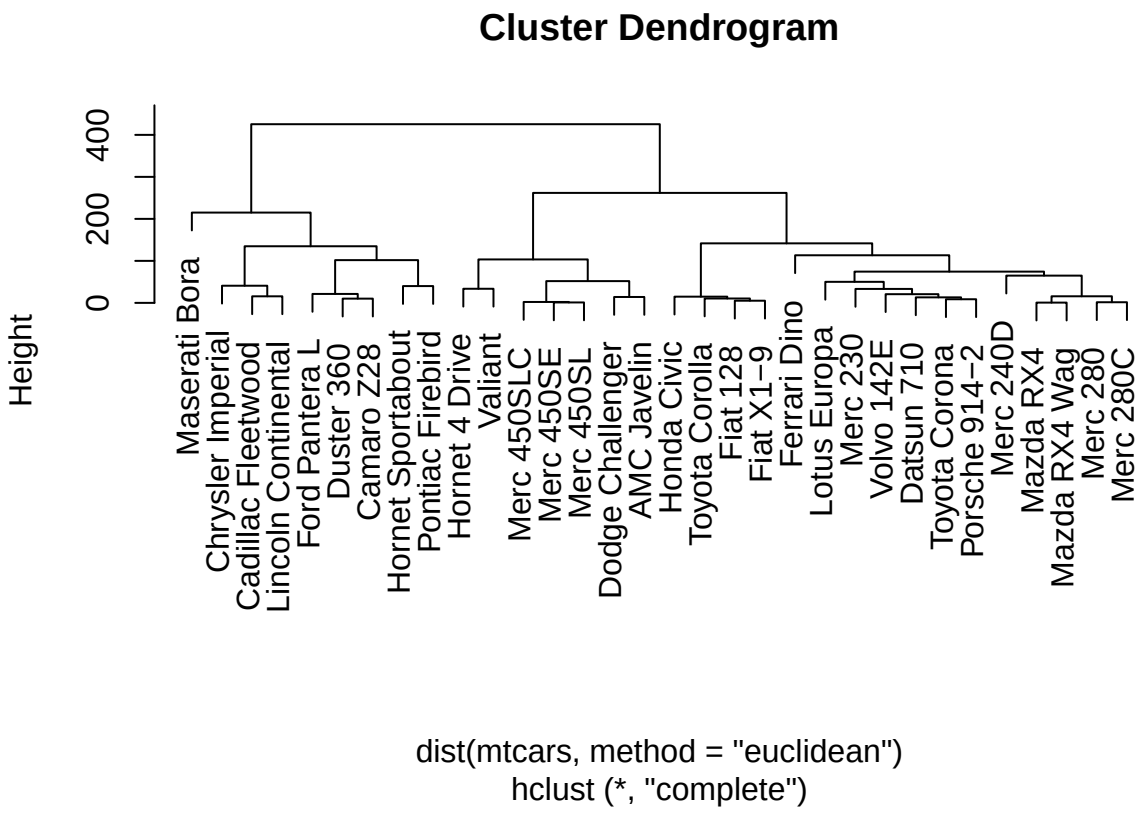
Use the built-in data set mtcars to carry out hierarchy clustering using two different distance metrics and compare if they get the same results. Discuss the results.

Solution:

```
clusters <- hclust(dist(mtcars, method = "euclidean"))
summary(clusters)
```

```
##              Length Class  Mode
## merge        62     -none- numeric
## height       31     -none- numeric
## order        32     -none- numeric
## labels       32     -none- character
## method        1     -none- character
## call          2     -none- call
## dist.method   1     -none- character
```

```
plot(clusters)
```

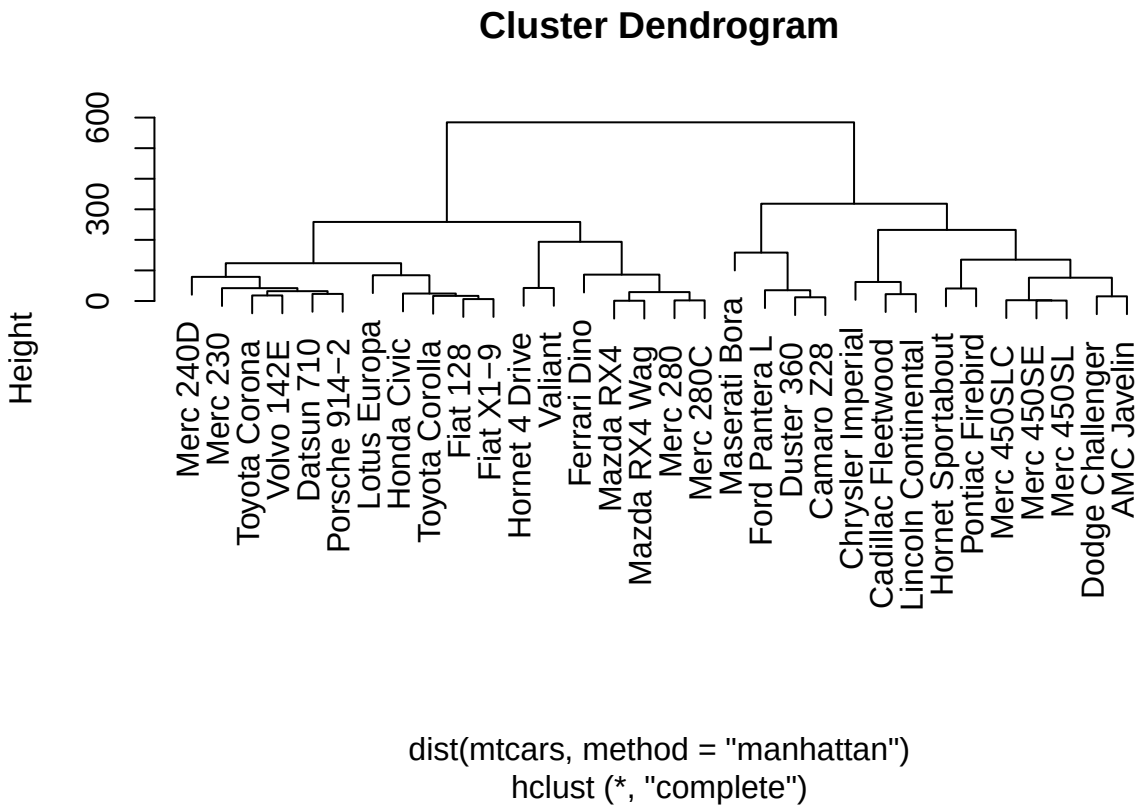



```
clusters2 <- hclust(dist(mtcars, method = "manhattan"))
summary(clusters2)
```

```
##              Length Class  Mode
## merge        62     -none- numeric
## height       31     -none- numeric
## order        32     -none- numeric
## labels       32     -none- character
```

```
## method       1     -none- character
## call         2     -none- call
## dist.method  1     -none- character
```

```
plot(clusters2)
```



Euclidean and Manhattan were both used to do hierarchy clustering. Above you can see the results look to be the same, but both have different plots.

Ex.4

Load the well-known Fisher's iris flower data set that consists of 150 samples for three 3 species (50 samples each species). The four measures or features are the lengths and widths of sepal and petals. Use the kNN clustering to analyze this iris data set by selecting 120 samples for training and 30 samples for testing.

Solution:

```
library(class)
set.seed(123)
iris_split <- sort(sample(nrow(iris), nrow(iris) * 0.8))
train <- iris[iris_split, -5]
test <- iris[-iris_split, -5]
train_category <- iris[iris_split, 5]
test_category <- iris[-iris_split, 5]
iris_knn <- knn(train, test, cl = train_category, k = 5)
```

```
knn_table <- table(iris_knn, test_category)
knn_accuracy <- sum(diag(knn_table)) / sum(knn_table)
knn_accuracy
```

```
## [1] 0.9666667
```

The accuracy for knn clustering can be seen above.

Ex.5

Use the iris data set to carry out k-means clustering. Compare the results to the actual classes and estimate the clustering accuracy.

Solution:

```
set.seed(123)
iris_kmeans <- kmeans(iris[, -5], centers = 3)
iris_kmeans
```

```
## K-means clustering with 3 clusters of sizes 50, 62, 38
##
## Cluster means:
##   Sepal.Length Sepal.Width Petal.Length Petal.Width
## 1     5.006000    3.428000     1.462000    0.246000
## 2     5.901613    2.748387     4.393548    1.433871
## 3     6.850000    3.073684     5.742105    2.071053
##
## Clustering vector:
##   [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##  [38] 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [75] 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 3 3 3 2 3 3 3 3
## [112] 3 3 2 2 3 3 3 3 2 3 2 3 2 3 3 2 2 3 3 3 3 3 2 3 3 3 3 2 3 3 3 2 3 3 3 2 3
## [149] 3 2
##
## Within cluster sum of squares by cluster:
## [1] 15.15100 39.82097 23.87947
##  (between_SS / total_SS =  88.4 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

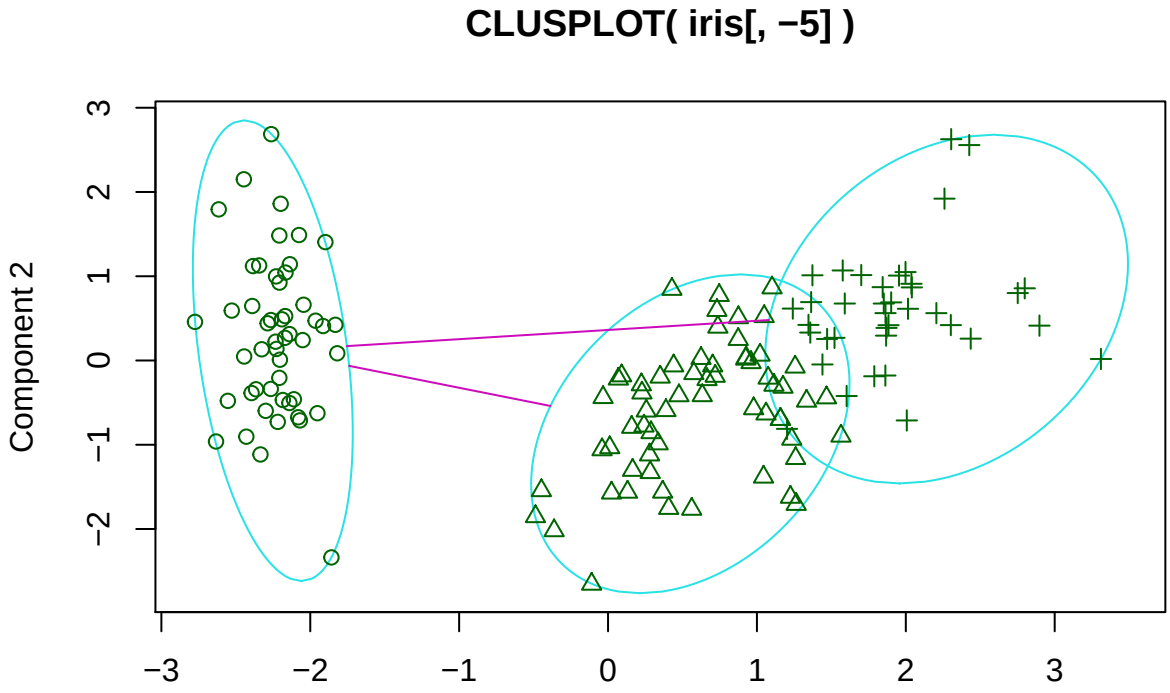
```
iris_clusters <- iris_kmeans$cluster
table(iris_clusters)
```

```
## iris_clusters
##  1  2  3
## 50 62 38
```

```
library(cluster)
```

```
## Warning: package 'cluster' was built under R version 4.0.5
```

```
clusplot(iris[, -5], iris_clusters)
```




```
iris$cluster.kmeans <- iris_clusters
cluster_table <- table(iris$Species, iris$cluster.kmeans)
cluster_table
```

```
##
##                1  2  3
##   setosa      50  0  0
##   versicolor   0 48  2
##   virginica    0 14 36
```

```
kmeans_accuracy <- sum(diag(cluster_table)) / sum(cluster_table)
kmeans_accuracy
```

```
## [1] 0.8933333
```

The accuracy for kmeans clustering can be seen above.

Ex.6

Please set up Python environment on your computer (recommended installation would be ANACONDA), then go through the following codes: https://github.com/ageron/handson-ml2/blob/master/09_unsupervised_learning.ipynb

Provide a summary on what you have learned and give several screenshots to show that you have gone through the code.

Solution:

The codes helped me to learn how to do k-means using sklearn. Sklearn has different functions to use for k-means, such as kmeans() and it can also be used to show k-means algorithms. There is also functions to show mini-batch k-means. There was also some interesting code on clustering where you can find the optimal number of clusters or use clustering to do image segmentation or preprocessing. Also code on clustering algorithms.

Screenshots can be found here: https://github.com/bpersaud104/Data609/blob/main/Module%206%20Screenshots.docx

Ex.7

Go through the following codes: https://github.com/ageron/handson-ml2/blob/master/07_ensemble_learning_and_random_forests.ipynb

Provide a summary on what you have learned and give several screenshots to show that you have gone through the code.

Solution:

The codes helped me to learn about voting classifiers and random forests by coding using sklearn. The functions baggingclassifiers() and randomforestclassifiers() from sklearn wee helpful and the codes helped to show how to use them. The code on gradient boosting was also good and it was nice to see how to code it.

Screenshots can be found here: https://github.com/bpersaud104/Data609/blob/main/Module%206%20Screenshots.docx