Abhishek_Pandit_hw2

Abhishek Pandit

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You fielded a survey and collected some wildly descriptive feature vectors. Use the following vectors to address questions 1-3: p{1, 2} q{3, 4} 1. Calculate Manahattan, Canberra, and Euclidean distances "by hand" (i.e., create the data, program each line, and make the calculations). What are the values for each measure? 2. Use the dist() function in R to check your work. Were you right or wrong? (be honest in your reporting). If wrong, after debugging, where and why did you go wrong? 3. What are the key differences between these measures, and why does it matter? How might you see these differences "in action" with these fictitious data?

```
p<-c(1,2)
q<-c(3,4)
dist_data<-data.frame(p,q)
```

Now we try to calculate the 3 distance metrics.

```
manhattan <-function(p,q){
  distance<-abs(p-q)
  total_distance<-sum(distance)
  return(total_distance)
  }

euclid <-function(p,q){
  distance<-(p-q)^2
  total_distance<-sum(distance)
  final<-sqrt(total_distance)
  return(final)
}


canberra <-function(p,q){
  total_dist <-0
  for (i in length(p)){
    distance<-abs(p[i]-q[i])/(abs(p[i])+abs(q[i]))
    total_dist <-total_dist + distance}
  return(total_dist)}
```

2. Use the dist() function in R to check your work. Were you right or wrong? (be honest in your reporting). If wrong, after debugging, where and why did you go wrong?

Now we apply them to our fictitious data

```
manhattan(p,q)
```

```
## [1] 4
```

```
euclid(p,q)
```

```
## [1] 2.828427
```

```
canberra(p,q)
```

```
## [1] 0.3333333
```

Now we check against the pre-existing function

```
euc = dist(dist_data, method="euclidean")
manh = dist(dist_data, method="manhattan")
canb = dist(dist_data, method="canberra")
all_dist<-c(euc, manh, canb)
all_dist
```

```
## [1] 1.4142136 2.0000000 0.4761905
```

The expected values as per the dist function were 1.4142136 2.0000000 0.4761905 respectively. I initially got all three wrong- with 4, 2.82, 0.33. On further inspecton, my mistakes were to do with how I indexed the variables

3. What are the key differences between these measures, and why does it matter? How might you see these differences "in action" with these fictitious data?

Euclidean distance considers the geometric distance as the shortest line between two data points, while Manhattan distance finds the shortest distance specifically along the feature axes. Canberra distance considers the absolute value of the distances in each dimensions (feature) after normalizing for the sum of the absolute value of each feature individually. This ensures that the distance for each feature always lies between 0 and 1 (though the sum can be greater than 1).

The choice of these measures becomes crucial in deciding the 'nearness' of data points, and thus in their allocation to clusters. The results of clustering process could vary greatly simply by changing the metric.

For these specific data, we could see these measures in action by plotting the individual vectors (since we are still operating in 2 dimensions). The Euclidean distance would be the straight line connecting them, while the Manhattan would be equivalent to dropping a vertical and horizontal perpendicular from the first and second points, noting their intersection and then adding the 2 resulting lines. The Euclidean measure would thus be akin to the hypotenuse of a right triangle, of which the other two sides can be summed to derive the Manhattan distance.

```
faith<-faithful
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 3.5.3
```

```
## -- Attaching packages ---------------------------------------------------------------------------
```

```
## v ggplot2 3.1.0     v purrr   0.2.5
## v tibble  2.0.1     v dplyr   0.7.8
## v tidyr   0.8.2     v stringr 1.3.1
## v readr   1.3.1     v forcats 0.3.0
```

```
## Warning: package 'ggplot2' was built under R version 3.5.2
```

```
## Warning: package 'tibble' was built under R version 3.5.2
```

```
## Warning: package 'tidyr' was built under R version 3.5.2
```

```
## Warning: package 'readr' was built under R version 3.5.2
```

```
## Warning: package 'purrr' was built under R version 3.5.2
```

```
## Warning: package 'dplyr' was built under R version 3.5.2
```

```
## Warning: package 'stringr' was built under R version 3.5.2
```

```
## Warning: package 'forcats' was built under R version 3.5.2
```

```
## -- Conflicts ------------------------------------------------------------------------------------
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(skimr)
```

```
## Warning: package 'skimr' was built under R version 3.5.3
```

```
##
## Attaching package: 'skimr'
```

```
## The following object is masked from 'package:stats':
##
##     filter
```

```
library(seriation)
```

```
## Warning: package 'seriation' was built under R version 3.5.3
```

```
summary(faith)
```

```
##    eruptions        waiting
##  Min.   :1.600   Min.   :43.0
##  1st Qu.:2.163   1st Qu.:58.0
##  Median :4.000   Median :76.0
##  Mean   :3.488   Mean   :70.9
##  3rd Qu.:4.454   3rd Qu.:82.0
##  Max.   :5.100   Max.   :96.0
```

```
skim(faith)
```

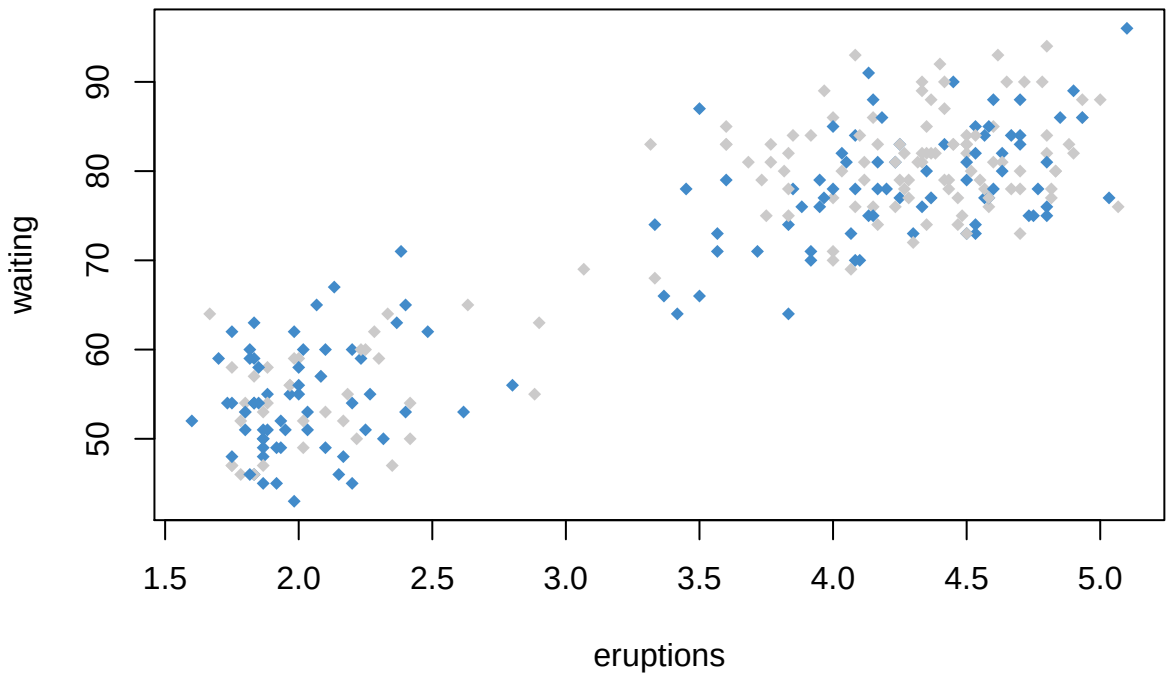
```
## Skim summary statistics
##  n obs: 272
##  n variables: 2
```

```
## Warning: package 'bindrcpp' was built under R version 3.5.2
```

```
##
## -- Variable type:numeric ------------------------------------------------------------------------
##   variable missing complete   n  mean    sd   p0   p25 p50   p75 p100
##  eruptions       0      272 272  3.49  1.14  1.6  2.16   4  4.45  5.1
##    waiting       0      272 272 70.9  13.59 43   58     76 82    96
##      hist
##  <U+2587><U+2583><U+2581><U+2581><U+2582><U+2585><U+2587><U+2583>
##  <U+2582><U+2585><U+2583><U+2582><U+2585><U+2587><U+2586><U+2582>
```

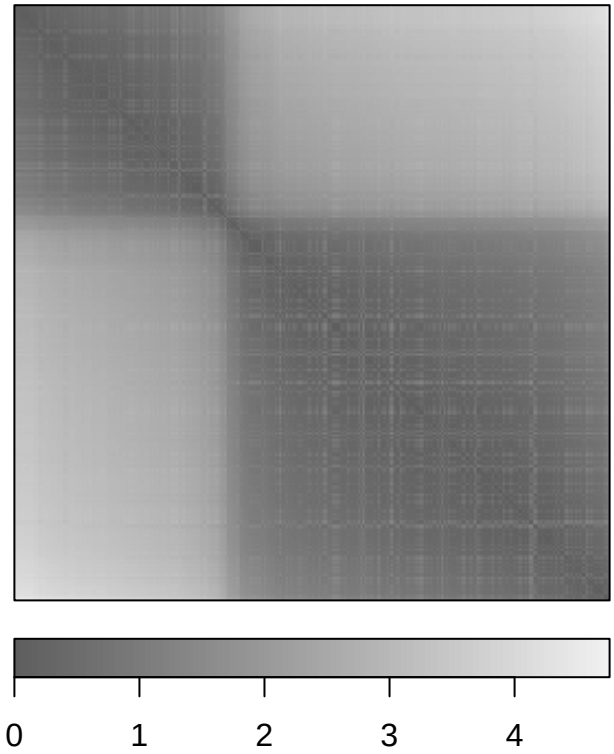
We thus see that the data consists of 2 variables. Both variables appear to be bimodal

```
plot(faith,
     col = c("#428bca", "#cbcaca"),
     pch = 18,
     cex = 0.9)
```



We can discern two clusters in this data, as were suggested by the bimodal summary statistics We now visualize the ODI.

```
faith_scaled <- scale(faith)
faith_dist <- dist(faith_scaled,
                   method = "euclidean")
dissplot(faith_dist)
```



The dark shading in two distinct squae sections of the plot indicates that we most likely have two clusters in the data.

7. Using any munging tools you'd like (e.g., dplyr from the Tidyverse), create a subset of the data excluding the species feature, scaling the features, and calculating a dissimilarity matrix (think "pipe" for stacking functions to do this quickly, e.g.)

```
skim(iris)
```

```
## Skim summary statistics
##  n obs: 150
##  n variables: 5
##
## -- Variable type:factor ---------------------------------------------------------------------------
##  variable missing complete   n n_unique                       top_counts
##   Species       0      150 150        3 set: 50, ver: 50, vir: 50, NA: 0
##  ordered
##    FALSE
##
## -- Variable type:numeric --------------------------------------------------------------------------
##      variable missing complete   n mean   sd  p0 p25  p50 p75 p100
##  Petal.Length       0      150 150 3.76 1.77 1   1.6 4.35 5.1  6.9
##   Petal.Width       0      150 150 1.2  0.76 0.1 0.3 1.3  1.8  2.5
##  Sepal.Length       0      150 150 5.84 0.83 4.3 5.1 5.8  6.4  7.9
##   Sepal.Width       0      150 150 3.06 0.44 2   2.8 3    3.3  4.4
##      hist
##  <U+2587><U+2581><U+2581><U+2582><U+2585><U+2585><U+2583><U+2581>
```

```
##  <U+2587><U+2581><U+2581><U+2585><U+2583><U+2583><U+2582><U+2582>
##  <U+2582><U+2587><U+2585><U+2587><U+2586><U+2585><U+2582><U+2582>
##  <U+2581><U+2582><U+2585><U+2587><U+2583><U+2582><U+2581><U+2581>
```

```
iris_sub<-iris %>%
  dplyr::select(Sepal.Length, Sepal.Width) %>%
  scale() %>%
  dist()
iris_sub
```

```
##            1         2         3         4         5         6         7
## 2   1.1722914
## 3   0.8408781 0.5185405
## 4   1.0985403 0.4288254 0.2592702
## 5   0.2592702 1.3818560 0.9866359 1.2446977
## 6   0.9866359 2.1513285 1.8148917 2.0741619 0.8408781
## 7   0.6459347 0.9866359 0.4744817 0.6882845 0.6662503 1.4997645
## 8   0.2592702 0.9256243 0.5846393 0.8408781 0.4588563 1.2446977 0.4830532
## 9   1.6154093 0.6459347 0.7778107 0.5185405 1.7618861 2.5927024 1.1722914
## 10  0.9489634 0.2294282 0.3331252 0.3622899 1.1534799 1.9321957 0.7778107
## 11  0.5846393 1.7157567 1.4249691 1.6817561 0.5347688 0.4588563 1.1862113
## 12  0.4288254 0.9256243 0.4744817 0.7294317 0.5185405 1.3568154 0.2415266
## 13  1.2029904 0.1207633 0.4744817 0.3331252 1.3975969 2.1882951 0.9489634
## 14  1.4997645 0.7245798 0.6662503 0.4288254 1.6154093 2.4552508 0.9866359
## 15  1.4249691 2.5387032 2.2657058 2.5226342 1.3325007 0.5347688 1.9987510
## 16  2.1882951 3.3541420 3.0063509 3.2650172 2.0207402 1.2029904 2.6511063
## 17  0.9866359 2.1513285 1.8148917 2.0741619 0.8408781 0.0000000 1.4997645
## 18  0.0000000 1.1722914 0.8408781 1.0985403 0.2592702 0.9866359 0.6459347
## 19  0.9993755 2.0741619 1.8312071 2.0841937 0.9618493 0.4288254 1.6145691
## 20  0.6882845 1.8512485 1.4588634 1.7157567 0.4744817 0.4288254 1.0985403
## 21  0.4288254 1.0985403 0.9618493 1.1862113 0.6662503 1.1471408 0.9661064
## 22  0.4588563 1.6240572 1.2446977 1.5031755 0.2592702 0.5846393 0.9156036
## 23  0.6459347 1.4234451 0.9256243 1.1471408 0.4830532 1.1862113 0.4588563
## 24  0.4588563 0.7294317 0.5347688 0.7583822 0.6987985 1.4234451 0.6459347
## 25  0.4288254 0.9256243 0.4744817 0.7294317 0.5185405 1.3568154 0.2415266
## 26  1.1534799 0.1207633 0.5846393 0.5347688 1.3765690 2.1206037 1.0370809
## 27  0.2592702 0.9256243 0.5846393 0.8408781 0.4588563 1.2446977 0.4830532
## 28  0.1207633 1.2029904 0.9156036 1.1692786 0.3331252 0.9489634 0.7600350
## 29  0.2592702 0.9866359 0.7583822 0.9993755 0.5185405 1.1722914 0.7245798
## 30  0.8408781 0.5185405 0.0000000 0.2592702 0.9866359 1.8148917 0.4744817
## 31  0.9866359 0.2592702 0.2592702 0.2415266 1.1722914 1.9732719 0.7294317
## 32  0.4288254 1.0985403 0.9618493 1.1862113 0.6662503 1.1471408 0.9661064
## 33  1.3818560 2.5495813 2.1513285 2.4059809 1.1722914 0.5185405 1.7618861
## 34  1.6770710 2.8468903 2.4893954 2.7477985 1.5031755 0.6987985 2.1330897
## 35  0.9489634 0.2294282 0.3331252 0.3622899 1.1534799 1.9321957 0.7778107
## 36  0.6987985 0.4744817 0.3622899 0.5347688 0.9177126 1.6770710 0.6662503
## 37  0.4830532 1.3568154 1.1862113 1.4224916 0.6459347 0.9256243 1.1108209
## 38  0.3331252 1.3765690 0.9489634 1.2029904 0.1207633 0.9156036 0.5846393
## 39  1.4249691 0.6038165 0.5846393 0.3331252 1.5556214 2.3920697 0.9489634
## 40  0.2294282 0.9489634 0.6662503 0.9156036 0.4744817 1.2029904 0.6038165
## 41  0.1207633 1.1534799 0.7778107 1.0370809 0.2294282 1.0370809 0.5347688
## 42  2.8468903 1.6770710 2.0789312 1.8393939 3.0430733 3.8283717 2.5265975
## 43  1.0901103 0.7583822 0.3622899 0.3331252 1.1692786 2.0093791 0.5185405
## 44  0.1207633 1.1534799 0.7778107 1.0370809 0.2294282 1.0370809 0.5347688
## 45  0.6882845 1.8512485 1.4588634 1.7157567 0.4744817 0.4288254 1.0985403
```

```
## 46  1.2029904 0.1207633 0.4744817 0.3331252 1.3975969 2.1882951 0.9489634
## 47  0.6882845 1.8512485 1.4588634 1.7157567 0.4744817 0.4288254 1.0985403
## 48  0.9156036 0.5846393 0.1207633 0.2294282 1.0370809 1.8741901 0.4588563
## 49  0.5185405 1.6770710 1.3568154 1.6154093 0.4288254 0.4744817 1.0901103
## 50  0.4744817 0.6987985 0.4288254 0.6662503 0.6882845 1.4588634 0.5347688
## 51  2.3955121 2.5772066 2.7775559 2.9073857 2.5837389 2.5125034 2.9344171
## 52  1.7141743 1.8686622 2.0529761 2.1858134 1.9236986 2.0093791 2.2216418
## 53  2.3595211 2.4261384 2.6666804 2.7775559 2.5652826 2.5787856 2.8615647
## 54  2.7951939 1.7618861 2.2796889 2.1330897 3.0430733 3.6728365 2.7477985
## 55  2.3318762 1.9859495 2.3595211 2.3955121 2.5787856 2.8519726 2.6757588
## 56  1.7618861 1.0695376 1.5167643 1.4961191 2.0207402 2.5495813 1.9130026
## 57  1.5200700 1.8254193 1.9457861 2.1036302 1.7141743 1.7539179 2.0657561
## 58  2.5352408 1.3765690 1.8512485 1.6463538 2.7557852 3.4939924 2.3227101
## 59  2.2751465 2.0657561 2.3955121 2.4584668 2.5125034 2.7136307 2.6738441
## 60  1.8393939 0.7778107 1.2963512 1.1692786 2.0789312 2.7637119 1.7618861
## 61  3.4435406 2.2974577 2.7768728 2.5695236 3.6708506 4.3858179 3.2481144
## 62  1.4997645 1.2076330 1.5200700 1.5865987 1.7539179 2.1513285 1.8184759
## 63  3.1744269 2.2657058 2.7799975 2.6687150 3.4315135 3.9670127 3.2308185
## 64  1.8312071 1.4672085 1.8254193 1.8686622 2.0841937 2.4450630 2.1441272
## 65  1.5031755 0.8759237 1.2864763 1.2918694 1.7618861 2.3069597 1.6656259
## 66  2.1390753 2.1858134 2.4261384 2.5360293 2.3517319 2.4152524 2.6277710
## 67  1.2963512 0.8453431 1.1797605 1.2292334 1.5556214 2.0789312 1.5167643
## 68  2.0207402 1.2864763 1.7551549 1.7153018 2.2796889 2.7951939 2.1631667
## 69  3.2650172 2.4152524 2.9231965 2.8279084 3.5237722 4.0181508 3.3635123
## 70  2.3724086 1.4249691 1.9392041 1.8312071 2.6256669 3.2210623 2.3920697
## 71  1.1862113 1.2918694 1.4491596 1.5865987 1.4224916 1.7157567 1.6356060
## 72  2.0093791 1.5200700 1.9236986 1.9378042 2.2657058 2.6615251 2.2751465
## 73  2.7136307 2.0431231 2.5125034 2.4717713 2.9721657 3.3908985 2.9117573
## 74  2.0093791 1.5200700 1.9236986 1.9378042 2.2657058 2.6615251 2.2751465
## 75  2.0879655 1.8259208 2.1652821 2.2216418 2.3318762 2.5927024 2.4578599
## 76  2.1441272 2.0529761 2.3399342 2.4261384 2.3724225 2.5226342 2.5837389
## 77  2.6065183 2.3399342 2.6969689 2.7445004 2.8449831 3.0376851 2.9922382
## 78  2.2470822 2.1737394 2.4584668 2.5463861 2.4717713 2.5938924 2.6969689
## 79  1.7539179 1.3480631 1.7141743 1.7518473 2.0093791 2.4059809 2.0431231
## 80  2.1882951 1.3325007 1.8312071 1.7551549 2.4450630 3.0044890 2.2657058
## 81  2.5695236 1.5556214 2.0741619 1.9392041 2.8185746 3.4435406 2.5387032
## 82  2.5695236 1.5556214 2.0741619 1.9392041 2.8185746 3.4435406 2.5387032
## 83  2.0207402 1.2864763 1.7551549 1.7153018 2.2796889 2.7951939 2.1631667
## 84  2.1330897 1.4961191 1.9443739 1.9236986 2.3920697 2.8468903 2.3318762
## 85  1.2029904 0.6038165 0.9618493 0.9929748 1.4588634 2.0648534 1.3325007
## 86  1.1108209 1.6145691 1.6356060 1.8254193 1.2918694 1.3568154 1.6906862
## 87  2.1390753 2.1858134 2.4261384 2.5360293 2.3517319 2.4152524 2.6277710
## 88  3.1112428 2.3318762 2.8279084 2.7538150 3.3705131 3.8283717 3.2532787
## 89  1.2963512 0.8453431 1.1797605 1.2292334 1.5556214 2.0789312 1.5167643
## 90  2.3445828 1.3568154 1.8741901 1.7539179 2.5949384 3.2142637 2.3334321
## 91  2.1206037 1.1692786 1.6817561 1.5802588 2.3724086 2.9850099 2.1330897
## 92  1.6656259 1.4491596 1.7518473 1.8259208 1.9130026 2.2311936 2.0306516
## 93  2.2311936 1.4224916 1.9130026 1.8482412 2.4893954 3.0214303 2.3385572
## 94  2.7557852 1.6105311 2.0963954 1.8979269 2.9825661 3.7024970 2.5695236
## 95  1.9321957 1.0901103 1.5802588 1.5167643 2.1882951 2.7637119 2.0093791
## 96  1.3568154 0.9661064 1.2918694 1.3480631 1.6154093 2.0963954 1.6145691
## 97  1.5556214 0.9929748 1.3900047 1.4054131 1.8148917 2.3227101 1.7551549
## 98  1.9130026 1.5865987 1.9378042 1.9859495 2.1631667 2.4893954 2.2470822
## 99  2.2942816 1.1722914 1.6770710 1.5031755 2.5265975 3.2323615 2.1513285
```

```
## 100 1.7618861 1.0695376 1.5167643 1.4961191 2.0207402 2.5495813 1.9130026
## 101 1.5200700 1.8254193 1.9457861 2.1036302 1.7141743 1.7539179 2.0657561
## 102 2.0207402 1.2864763 1.7551549 1.7153018 2.2796889 2.7951939 2.1631667
## 103 2.6738441 2.6567926 2.9344171 3.0277874 2.8855479 2.9117573 3.1554803
## 104 1.9987510 1.7061821 2.0511416 2.1036302 2.2458595 2.5387032 2.3517319
## 105 2.0431231 1.9322128 2.2216418 2.3059445 2.2751465 2.4552508 2.4712222
## 106 3.2296736 3.2606092 3.5320680 3.6301563 3.4283486 3.3648428 3.7373245
## 107 2.3069597 1.1471408 1.6240572 1.4234451 2.5265975 3.2682566 2.0963954
## 108 2.9922382 2.9073857 3.2144000 3.2927376 3.2084332 3.2447605 3.4565162
## 109 2.9995291 2.4578599 2.9004718 2.8855479 3.2532787 3.5751315 3.2703310
## 110 2.5463861 3.0999612 3.1554803 3.3428377 2.6567926 2.2801050 3.1731973
## 111 1.8254193 1.9859495 2.1737394 2.3059445 2.0306516 2.0841937 2.3399342
## 112 2.4152524 1.9378042 2.3517319 2.3595211 2.6687150 3.0063509 2.7026598
## 113 2.3517319 2.2945027 2.5772066 2.6666804 2.5729526 2.6687150 2.8108262
## 114 2.4059809 1.4997645 2.0093791 1.9130026 2.6615251 3.2323615 2.4552508
## 115 1.8148917 1.1797605 1.6145691 1.6043064 2.0741619 2.5695236 1.9987510
## 116 1.7141743 1.8686622 2.0529761 2.1858134 1.9236986 2.0093791 2.2216418
## 117 2.0431231 1.9322128 2.2216418 2.3059445 2.2751465 2.4552508 2.4712222
## 118 3.2144000 3.8473973 3.8756083 4.0736022 3.2927376 2.7870153 3.8545044
## 119 3.7579585 3.5036947 3.8756083 3.9154744 3.9868910 4.0756003 4.1693877
## 120 3.1744269 2.2657058 2.7799975 2.6687150 3.4315135 3.9670127 3.2308185
## 121 2.2801050 2.4584668 2.6567926 2.7870153 2.4712222 2.4208627 2.8152027
## 122 1.7157567 0.9618493 1.4224916 1.3900047 1.9732719 2.5352408 1.8312071
## 123 3.5267349 3.4123641 3.7373245 3.8064082 3.7417052 3.7528560 3.9887279
## 124 2.3385572 1.8254193 2.2470822 2.2487569 2.5938924 2.9599078 2.6065183
## 125 1.9859495 2.2801050 2.4261384 2.5772066 2.1652821 2.0879655 2.5463861
## 126 2.6277710 2.8152027 3.0190826 3.1482168 2.8108262 2.7026598 3.1731973
## 127 2.0841937 1.6356060 2.0306516 2.0511416 2.3385572 2.7023088 2.3724225
## 128 1.6656259 1.4491596 1.7518473 1.8259208 1.9130026 2.2311936 2.0306516
## 129 2.2458595 1.8686622 2.2487569 2.2801050 2.4954370 2.7977649 2.5729526
## 130 2.7834110 2.7775559 3.0537532 3.1482168 2.9922382 2.9981266 3.2712121
## 131 3.2084332 3.0537532 3.3872952 3.4507123 3.4306035 3.4932250 3.6508385
## 132 3.4507123 4.0613032 4.1022832 4.2966217 3.5320680 3.0277874 4.0894899
## 133 2.2458595 1.8686622 2.2487569 2.2801050 2.4954370 2.7977649 2.5729526
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## 136 3.3428377 3.3813725 3.6518416 3.7506860 3.5392816 3.4609878 3.8545044
## 137 1.4672085 1.9236986 1.9859495 2.1652821 1.6356060 1.5802588 2.0529761
## 138 1.8184759 1.8259208 2.0657561 2.1737394 2.0431231 2.1970807 2.2801050
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## 142 2.3595211 2.4261384 2.6666804 2.7775559 2.5652826 2.5787856 2.8615647
## 143 2.0207402 1.2864763 1.7551549 1.7153018 2.2796889 2.7951939 2.1631667
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## 146 2.2470822 2.1737394 2.4584668 2.5463861 2.4717713 2.5938924 2.6969689
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## 150 1.4997645 1.2076330 1.5200700 1.5865987 1.7539179 2.1513285 1.8184759
##             8         9        10        11        12        13        14
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## 9   1.3568154
## 10  0.6987985 0.7583822
## 11  0.8408781 2.1970807 1.5031755
## 12  0.2415266 1.2446977 0.6987985 0.9993755
## 13  0.9489634 0.5347688 0.2592702 1.7618861 0.9177126
## 14  1.2477185 0.2592702 0.7600350 2.0841937 1.0985403 0.6038165
## 15  1.6817561 3.0376851 2.3334321 0.8408781 1.8312071 2.5927024 2.9231965
## 16  2.4450630 3.7825978 3.1351335 1.6463538 2.5387032 3.3908985 3.6297833
## 17  1.2446977 2.5927024 1.9321957 0.4588563 1.3568154 2.1882951 2.4552508
## 18  0.2592702 1.6154093 0.9489634 0.5846393 0.4288254 1.2029904 1.4997645
## 19  1.2477185 2.5938924 1.8741901 0.4288254 1.4224916 2.1330897 2.4954370
## 20  0.9256243 2.2311936 1.6240572 0.4288254 0.9866359 1.8708394 2.0741619
## 21  0.4830532 1.6656259 0.9156036 0.6882845 0.7245798 1.1692786 1.6145691
## 22  0.6987985 2.0207402 1.3975969 0.3622899 0.7778107 1.6463538 1.8741901
## 23  0.6662503 1.6240572 1.2029904 0.9929748 0.5185405 1.3975969 1.4234451
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## 27  0.0000000 1.3568154 0.6987985 0.8408781 0.2415266 0.9489634 1.2477185
## 28  0.3331252 1.6817561 0.9866359 0.5185405 0.5347688 1.2446977 1.5802588
## 29  0.2415266 1.4997645 0.7778107 0.7294317 0.4830532 1.0370809 1.4224916
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## 32  0.4830532 1.6656259 0.9156036 0.6882845 0.7245798 1.1692786 1.6145691
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## 43  0.8576509 0.6882845 0.6459347 1.6656259 0.6662503 0.6662503 0.4744817
## 44  0.2294282 1.5556214 0.9256243 0.6662503 0.3331252 1.1722914 1.4249691
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## 55  2.2751465 2.5463861 2.0511416 2.4552508 2.4717713 2.1036302 2.6961262
## 56  1.6154093 1.5865987 1.1862113 2.0963954 1.7539179 1.1797605 1.7518473
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## 73  2.5938924 2.4712222 2.1802206 2.9599078 2.7468107 2.1441272 2.6738441
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##            15        16        17        18        19        20        21
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## 22  1.0901103 1.7618861 0.5846393 0.4588563 0.7600350 0.2294282 0.7778107
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## 61  4.6891656 5.5707880 4.3858179 3.4435406 4.2153391 4.1314722 3.2481144
## 62  2.2974577 3.2210623 2.1513285 1.4997645 1.8512485 2.0741619 1.0985403
## 63  4.1367637 5.0604049 3.9670127 3.1744269 3.6886851 3.8283717 2.8468903
## 64  2.5495813 3.4751588 2.4450630 1.8312071 2.1206037 2.3920697 1.4249691
## 65  2.5352408 3.4435406 2.3069597 1.5031755 2.0683819 2.1513285 1.1722914
## 66  2.3334321 3.2177753 2.4152524 2.1390753 2.0093791 2.5125034 1.7141743
## 67  2.3069597 3.2142637 2.0789312 1.2963512 1.8393939 1.9321957 0.9489634
## 68  2.9825661 3.9021479 2.7951939 2.0207402 2.5265975 2.6615251 1.6770710
## 69  4.1578624 5.0834081 4.0181508 3.2650172 3.7201799 3.9038162 2.9177269
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## 70  3.4498874 4.3608075 3.2210623 2.3724086 2.9850099 3.0430733 2.0789312
## 71  1.8393939 2.7637119 1.7157567 1.1862113 1.3975969 1.6817561 0.7583822
## 72  2.7768728 3.7024970 2.6615251 2.0093791 2.3445828 2.5927024 1.6154093
## 73  3.4939924 4.4189449 3.3908985 2.7136307 3.0693186 3.3159861 2.3334321
## 74  2.7768728 3.7024970 2.6615251 2.0093791 2.3445828 2.5927024 1.6154093
## 75  2.6256669 3.5437259 2.5927024 2.0879655 2.2311936 2.5938924 1.6656259
## 76  2.4893954 3.3908985 2.5226342 2.1441272 2.1330897 2.5787856 1.7153018
## 77  3.0063509 3.9038162 3.0376851 2.6065183 2.6511063 3.0787074 2.1802206
## 78  2.5387032 3.4315135 2.5938924 2.2470822 2.1970807 2.6650014 1.8184759
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## 80  3.2142637 4.1297069 3.0044890 2.1882951 2.7531379 2.8468903 1.8708394
## 81  3.6886851 4.5949154 3.4435406 2.5695236 3.2210623 3.2481144 2.2974577
## 82  3.6886851 4.5949154 3.4435406 2.5695236 3.2210623 3.2481144 2.2974577
## 83  2.9825661 3.9021479 2.7951939 2.0207402 2.5265975 2.6615251 1.6770710
## 84  2.9923295 3.9170688 2.8468903 2.1330897 2.5495813 2.7477985 1.7618861
## 85  2.3445828 3.2323615 2.0648534 1.2029904 1.8708394 1.8708394 0.9177126
## 86  1.3975969 2.3227101 1.3568154 1.1108209 0.9866359 1.4224916 0.7245798
## 87  2.3334321 3.2177753 2.4152524 2.1390753 2.0093791 2.5125034 1.7141743
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## 93  3.2119942 4.1314722 3.0214303 2.2311936 2.7557852 2.8799954 1.8979269
## 94  4.0181508 4.8915893 3.7024970 2.7557852 3.5437259 3.4435406 2.5695236
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## 150 2.2974577 3.2210623 2.1513285 1.4997645 1.8512485 2.0741619 1.0985403
##           22        23        24        25        26        27        28
## 2
## 3
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## 23  0.6459347
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## 25  0.7778107 0.5185405 0.4288254
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## 41  0.4744817 0.5347688 0.4744817 0.3331252 1.1471408 0.2294282 0.2415266
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## 82  3.0214303 2.9599078 2.1206037 2.4450630 1.5031755 2.3724086 2.5495813
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## 137 1.6043064 2.1036302 1.4672085 1.8114495 1.8184759 1.5699229 1.3480631
## 138 2.0879655 2.4578599 1.6356060 2.0511416 1.7061821 1.8254193 1.7153018
## 139 1.9392041 2.1802206 1.2864763 1.7153018 1.2076330 1.5167643 1.4997645
## 140 2.5729526 3.0051205 2.2216418 2.6277710 2.3059445 2.3955121 2.2487569
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## 145 2.1390753 2.6277710 1.9322128 2.3059445 2.1652821 2.0657561 1.8686622
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## 148 2.3318762 2.6757588 1.8254193 2.2487569 1.8114495 2.0306516 1.9443739
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## 30  0.7583822
## 31  0.8408781 0.2592702
## 32  0.2415266 0.9618493 0.9993755
## 33  1.6059971 2.1513285 2.3445828 1.6240572
## 34  1.8708394 2.4893954 2.6615251 1.8393939 0.4288254
## 35  0.7778107 0.3331252 0.1207633 0.9156036 2.3227101 2.6256669
## 36  0.5185405 0.3622899 0.3331252 0.6662503 2.0789312 2.3724086 0.2592702
## 37  0.4288254 1.1862113 1.2477185 0.2592702 1.4234451 1.6059971 1.1692786
## 38  0.5846393 0.9489634 1.1534799 0.7583822 1.2029904 1.5556214 1.1471408
## 39  1.3325007 0.5846393 0.5347688 1.5167643 2.7023088 3.0568620 0.6459347
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## 40  0.1207633 0.6662503 0.7778107 0.3622899 1.6105311 1.8979269 0.7294317
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## 44  0.3331252 0.7778107 0.9489634 0.5347688 1.3975969 1.7157567 0.9256243
## 45  0.9256243 1.4588634 1.6463538 0.9866359 0.6987985 1.0370809 1.6240572
## 46  1.0370809 0.4744817 0.2294282 1.1692786 2.5695236 2.8799954 0.2592702
## 47  0.9256243 1.4588634 1.6463538 0.9866359 0.6987985 1.0370809 1.6240572
## 48  0.8576509 0.1207633 0.3331252 1.0695376 2.1882951 2.5387032 0.4288254
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## 52  1.5200700 2.0529761 1.9457861 1.2918694 2.5226342 2.5387032 1.8259208
## 53  2.1652821 2.6666804 2.5360293 1.9378042 3.0787074 3.0376851 2.4152660
## 54  2.5495813 2.2796889 2.0207402 2.5265975 4.1455679 4.3591351 1.9732719
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## 73  2.4552508 2.5125034 2.2751465 2.3334321 3.9038162 4.0181508 2.1802206
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## 103 2.5772066 2.2470822 2.9922382 3.2606092 2.5837389 2.7834110 3.5267349
## 104 1.7141743 1.6817561 2.3318762 2.3059445 1.8482412 2.0879655 2.5729526
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## 106 3.1731973 2.7834110 3.5392816 3.8644257 3.1554803 3.3428377 4.0736022
## 107 1.6105311 2.4059809 2.5237098 1.2963512 2.0789312 2.2974577 0.6662503
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## 109 2.6065183 2.7136307 3.3308038 3.0051205 2.8279084 3.0787074 2.6961262
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## 128 1.4054131 1.3568154 1.9987510 2.0529761 1.5167643 1.7551549 2.5125034
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## 147 2.2458595 2.4893954 3.0376851 2.5652826 2.5226342 2.7799975 2.2216418
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## 64  2.1652821 1.9130026 2.3920697 1.5865987 2.3920697 1.9378042 2.0741619
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## 69  3.1605176 3.3159861 3.9038162 2.4954370 3.9038162 2.9995291 3.6089713
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## 73  2.8007088 2.7799975 3.3159861 2.1441272 3.3159861 2.6065183 3.0063509
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## 88  3.0868046 3.1692943 3.7340932 2.4208627 3.7340932 2.9117573 3.4315135
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## 103 3.2927376 2.7834110 3.0335286 2.7775559 3.0335286 3.0537532 2.7026598
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## 106 3.8915723 3.3428377 3.5332203 3.3813725 3.5332203 3.6518416 3.2084332
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## 112 2.6738441 2.4954370 2.9721657 2.0511416 2.9721657 2.4578599 2.6511063
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## 118 4.2162392 3.3324627 3.1398459 3.9539526 3.1398459 3.9887279 2.9073857
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## 135 2.4717713 2.4552508 3.0063509 1.8184759 3.0063509 2.2751465 2.7023088
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## 137 2.3399342 1.5865987 1.7153018 2.0306516 1.7153018 2.1036302 1.3900047
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## 72  1.7551549 1.4224916 0.9866359 1.1862113 1.3568154 0.4830532 0.4830532
## 73  2.4152524 1.8148917 1.6105311 1.5556214 1.0695376 0.7294317 0.9993755
## 74  1.7551549 1.4224916 0.9866359 1.1862113 1.3568154 0.4830532 0.4830532
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## 76  2.0511416 0.6662503 0.5185405 0.4288254 2.0841937 0.4744817 1.1797605
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## 85  0.8408781 1.9859495 1.2918694 1.8259208 1.6105311 1.4054131 0.5846393
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## 90  1.9321957 2.4208627 1.9392041 2.1802206 0.4588563 1.3900047 0.7294317
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## 92  1.4961191 1.1797605 0.5846393 0.9929748 1.7618861 0.6662503 0.6662503
## 93  1.8741901 1.9987510 1.5556214 1.7551549 0.7778107 0.9618493 0.4744817
## 94  2.2942816 3.1775981 2.6687150 2.9382867 0.6038165 2.1441272 1.4249691
## 95  1.5556214 2.0431231 1.4997645 1.8184759 0.9256243 1.1108209 0.2592702
## 96  1.0901103 1.6356060 0.9618493 1.4672085 1.6240572 1.0695376 0.4588563
## 97  1.2477185 1.7141743 1.0901103 1.5200700 1.3975969 0.9929748 0.2294282
## 98  1.7153018 1.1862113 0.7294317 0.9618493 1.6154093 0.4288254 0.6459347
## 99  1.8393939 2.8007088 2.2458595 2.5729526 0.6662503 1.8254193 0.9993755
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## 103 2.6277710 0.4744817 0.9618493 0.3331252 2.5125034 0.8576509 1.7518473
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## 105 1.9378042 0.7583822 0.4744817 0.5347688 2.0093791 0.4588563 1.0695376
## 106 3.2144000 0.8576509 1.5200700 0.8759237 3.0017781 1.4054131 2.3399342
## 107 1.8393939 3.0017781 2.4208627 2.7800094 0.8576509 2.0511416 1.1862113
## 108 2.9252373 0.7778107 1.2864763 0.6662503 2.5729526 0.9929748 1.9457861
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## 110 2.7445004 0.9489634 1.3325007 1.2029904 3.6208302 2.0207402 2.5787856
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## 113 2.2801050 0.5185405 0.6662503 0.2592702 2.2458595 0.5846393 1.4054131
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## 118 3.4565162 1.6154093 2.0879655 1.8741901 4.3476356 2.7136307 3.3312517
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## 123 3.4565162 1.2477185 1.8184759 1.1862113 2.8938692 1.4491596 2.4152660
## 124 2.0879655 1.4249691 1.1534799 1.1692786 1.3325007 0.3331252 0.7600350
## 125 2.0529761 0.4288254 0.4288254 0.5185405 2.7136307 1.1722914 1.6656259
## 126 2.6666804 0.2415266 0.9661064 0.4288254 2.9117573 1.2477185 2.0306516
## 127 1.8482412 1.3325007 0.9489634 1.0901103 1.4249691 0.3622899 0.6038165
## 128 1.4961191 1.1797605 0.5846393 0.9929748 1.7618861 0.6662503 0.6662503
## 129 2.0431231 1.1692786 0.9177126 0.9156036 1.5802588 0.1207633 0.8453431
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## 132 3.6852255 1.7539179 2.2751465 2.0093791 4.4992936 2.8499382 3.5103099
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## 134 1.9443739 1.2477185 0.9256243 0.9993755 1.4997645 0.2415266 0.7245798
## 135 2.0841937 1.7539179 1.4234451 1.4997645 0.9993755 0.6662503 0.6662503
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## 137 1.5865987 0.9618493 0.4744817 0.9993755 2.7023088 1.3975969 1.5556214
## 138 1.7518473 0.7600350 0.2294282 0.6038165 2.1330897 0.6987985 1.0901103
## 139 1.3900047 1.2918694 0.6662503 1.1108209 1.7157567 0.7583822 0.5846393
## 140 2.3399342 0.2592702 0.6459347 0.0000000 2.4954370 0.8408781 1.6043064
## 141 2.1036302 0.4288254 0.4288254 0.2415266 2.3385572 0.7294317 1.3900047
## 142 2.3399342 0.2592702 0.6459347 0.0000000 2.4954370 0.8408781 1.6043064
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## 144 2.1858134 0.2415266 0.4830532 0.2592702 2.5938924 0.9866359 1.6145691
## 145 2.0529761 0.4288254 0.4288254 0.5185405 2.7136307 1.1722914 1.6656259
## 146 2.1652821 0.5846393 0.5846393 0.3331252 2.1631667 0.5185405 1.2918694
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## 148 1.9378042 0.7583822 0.4744817 0.5347688 2.0093791 0.4588563 1.0695376
## 149 1.4672085 1.0695376 0.5185405 1.0901103 2.6615251 1.4234451 1.5031755
## 150 1.2864763 1.4054131 0.7583822 1.2292334 1.6770710 0.8576509 0.5185405
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## 64  0.9489634 1.8482412 0.6038165 1.1797605 2.4552508 0.3331252 1.6105311
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## 66  0.6662503 2.7026598 0.4744817 2.0306516 3.2532787 0.9929748 2.2311936
## 67  1.0901103 1.6154093 1.2292334 0.8408781 2.4059809 0.3622899 1.8979269
## 68  1.5031755 1.2864763 1.0695376 0.7245798 1.8741901 0.6987985 1.1722914
## 69  2.5265975 1.6356060 1.6770710 1.6656259 1.5200700 1.8708394 0.2415266
## 70  2.0207402 0.8759237 1.5167643 0.6662503 1.3568154 1.2029904 0.8408781
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## 72  1.1722914 1.7153018 0.6459347 1.1108209 2.2657058 0.5185405 1.3818560
## 73  1.8354253 1.7061821 0.9866359 1.4054131 1.9443739 1.2446977 0.7778107
## 74  1.1722914 1.7153018 0.6459347 1.1108209 2.2657058 0.5185405 1.3818560
## 75  0.9256243 2.1441272 0.2415266 1.5200700 2.6687150 0.6459347 1.6770710
## 76  0.7778107 2.4717713 0.2294282 1.8254193 2.9995291 0.8453431 1.9732719
## 77  1.2963512 2.4712222 0.3331252 1.9457861 2.8449831 1.1797605 1.6817561
## 78  0.8408781 2.5729526 0.2592702 1.9378042 3.0787074 0.9661064 2.0207402
## 79  0.9866359 1.7551549 0.7245798 1.0695376 2.3920697 0.2592702 1.6059971
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## 82  2.2796889 0.7245798 1.7551549 0.7778107 1.0985403 1.4588634 0.7583822
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## 85  1.2864763 1.5031755 1.4672085 0.7294317 2.3445828 0.6038165 1.9732719
## 86  0.4288254 2.6511063 1.3568154 1.8741901 3.4315135 0.9256243 2.7531379
## 87  0.6662503 2.7026598 0.4744817 2.0306516 3.2532787 0.9929748 2.2311936
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## 88  2.2942816 1.7061821 1.4234451 1.6145691 1.7141743 1.6770710 0.4288254
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## 90  2.0741619 0.7600350 1.6145691 0.5846393 1.2963512 1.2446977 0.9156036
## 91  1.8741901 0.8576509 1.4961191 0.4288254 1.5031755 1.0370809 1.0985403
## 92  0.7294317 1.9987510 0.6459347 1.2864763 2.6511063 0.2415266 1.8393939
## 93  1.7157567 1.1797605 1.1862113 0.7600350 1.6817561 0.9256243 0.9489634
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## 100 1.3568154 1.3325007 1.1108209 0.6459347 2.0207402 0.5185405 1.4234451
## 101 0.0000000 2.6687150 0.9866359 1.9130026 3.3705131 0.8408781 2.5495813
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## 125 0.4830532 2.9981266 0.9256243 2.2751465 3.6208302 1.1862113 2.6615251
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## 142 0.8576509 2.9004718 0.5846393 2.2487569 3.4108436 1.2292334 2.3334321
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## 146 0.8408781 2.5729526 0.2592702 1.9378042 3.0787074 0.9661064 2.0207402
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## 148 0.7294317 2.3724225 0.2592702 1.7141743 2.9231965 0.7245798 1.9321957
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## 80  0.8408781 0.6987985 1.6656259 0.9256243 0.2592702 1.0985403 0.2592702
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## 83  0.5846393 0.5185405 1.4224916 0.7294317 0.0000000 1.2446977 0.5185405
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## 91  0.9993755 0.6987985 1.8482412 0.9256243 0.4288254 1.2477185 0.2592702
## 92  0.2294282 0.6459347 0.7600350 0.6038165 0.7778107 1.8393939 1.2963512
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## 94  1.9130026 1.5556214 2.7538150 1.7618861 1.3325007 1.4672085 0.8576509
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## 96  0.5347688 0.2592702 1.2292334 0.1207633 0.6987985 1.9321957 1.1534799
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## 100 0.5347688 0.2592702 1.3900047 0.4744817 0.2592702 1.5031755 0.6987985
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## 104 0.2415266 0.8453431 0.6662503 0.8759237 0.7583822 1.6105311 1.2477185
## 105 0.5347688 1.1108209 0.3331252 1.0868697 1.0901103 1.8708394 1.5802588
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## 109 1.1692786 1.6145691 1.3765690 1.7551549 1.1797605 0.9156036 1.3283963
## 110 2.0841937 2.5125034 1.2963512 2.3724225 2.6687150 3.4315135 3.1784520
## 111 0.8408781 1.2864763 0.3331252 1.1797605 1.4249691 2.3227101 1.9392041
## 112 0.5846393 1.0695376 0.9866359 1.1862113 0.7245798 1.1722914 1.0695376
## 113 0.8759237 1.4672085 0.2592702 1.4491596 1.3900047 1.9732719 1.8482412
## 114 1.0370809 0.9256243 1.8312071 1.1534799 0.4744817 0.9156036 0.1207633
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## 116 0.7778107 1.1862113 0.4288254 1.0695376 1.3568154 2.3069597 1.8741901
## 117 0.5347688 1.1108209 0.3331252 1.0868697 1.0901103 1.8708394 1.5802588
## 118 2.8279084 3.2703310 2.0093791 3.1305320 3.4108436 4.0934696 3.9149898
## 119 2.0511416 2.6277710 1.6656259 2.6969689 2.3059445 2.0306516 2.5463861
## 120 1.6105311 1.6770710 2.2311936 1.8979269 1.1722914 0.2415266 0.8408781
## 121 1.1862113 1.7141743 0.3331252 1.6356060 1.7551549 2.4450630 2.2458595
## 122 0.6459347 0.2294282 1.4961191 0.4588563 0.3331252 1.5556214 0.6882845
## 123 1.9457861 2.5463861 1.3900047 2.5772066 2.3059445 2.2751465 2.6277710
## 124 0.5185405 0.9618493 1.0370809 1.0901103 0.6038165 1.1534799 0.9618493
## 125 1.1692786 1.6145691 0.4588563 1.4961191 1.7539179 2.5949384 2.2657058
## 126 1.4961191 2.0511416 0.6459347 1.9859495 2.0431231 2.5927024 2.5125034
## 127 0.2592702 0.7600350 0.9156036 0.8576509 0.5347688 1.3765690 0.9993755
## 128 0.2294282 0.6459347 0.7600350 0.6038165 0.7778107 1.8393939 1.2963512
## 129 0.4288254 0.9929748 0.7778107 1.0695376 0.7600350 1.3975969 1.1862113
## 130 1.3480631 1.9457861 0.6459347 1.9322128 1.8254193 2.1970807 2.2470822
## 131 1.5865987 2.1858134 1.0901103 2.2216418 1.9457861 1.9987510 2.2801050
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## 136 1.9457861 2.5463861 1.2292334 2.5360293 2.3955121 2.5787856 2.7834110
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## 141 0.8576509 1.4054131 0.0000000 1.3480631 1.4224916 2.1513285 1.9130026
## 142 1.0695376 1.6356060 0.2415266 1.5865987 1.6145691 2.2311936 2.0879655
## 143 0.5846393 0.5185405 1.4224916 0.7294317 0.0000000 1.2446977 0.5185405
## 144 1.0901103 1.6043064 0.2592702 1.5200700 1.6656259 2.4059809 2.1631667
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## 148 0.5347688 1.1108209 0.3331252 1.0868697 1.0901103 1.8708394 1.5802588
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## 150 0.3331252 0.4288254 0.9929748 0.3622899 0.6987985 1.8708394 1.2029904
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## 79  0.6987985 0.2592702 0.9866359 0.2592702 0.4830532 0.7600350 0.9929748
## 80  1.3975969 0.6662503 0.7600350 0.6662503 1.0901103 1.4224916 1.4054131
## 81  1.8979269 1.1692786 0.9929748 1.1692786 1.5802588 1.9130026 1.8184759
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## 83  1.1534799 0.4288254 0.7583822 0.4288254 0.8576509 1.1862113 1.2292334
## 84  1.1534799 0.2592702 0.5846393 0.2592702 0.6662503 0.9993755 0.9929748
## 85  0.7583822 0.9618493 1.5802588 0.9618493 1.2292334 1.4491596 1.7518473
## 86  0.4744817 1.3818560 2.0963954 1.3818560 1.2446977 1.1692786 1.6817561
## 87  0.9929748 0.9993755 1.4588634 0.9993755 0.5846393 0.2592702 0.6987985
## 88  2.1206037 1.1722914 0.4588563 1.1722914 1.3818560 1.6463538 1.2963512
## 89  0.5846393 0.7583822 1.4249691 0.7583822 0.9929748 1.2076330 1.5200700
## 90  1.6770710 0.9993755 0.9661064 0.9993755 1.4224916 1.7551549 1.7141743
## 91  1.4588634 0.8576509 0.9929748 0.8576509 1.2864763 1.6145691 1.6356060
## 92  0.5185405 0.4588563 1.1722914 0.4588563 0.4288254 0.6038165 0.9618493
## 93  1.3818560 0.5846393 0.6459347 0.5846393 0.9993755 1.3325007 1.2918694
## 94  2.3334321 1.7551549 1.6356060 1.7551549 2.1802206 2.5125034 2.4578599
## 95  1.2029904 0.6459347 0.9618493 0.6459347 1.0695376 1.3900047 1.4672085
## 96  0.5185405 0.6662503 1.3568154 0.6662503 0.8759237 1.0868697 1.4054131
## 97  0.7294317 0.5347688 1.1692786 0.5347688 0.8453431 1.1108209 1.3480631
## 98  0.7778107 0.2592702 0.9256243 0.2592702 0.2415266 0.5347688 0.7600350
## 99  1.8741901 1.3900047 1.4491596 1.3900047 1.8184759 2.1441272 2.1652821
## 100 0.9489634 0.4830532 0.9993755 0.4830532 0.8759237 1.1797605 1.3283963
## 101 0.5347688 1.1722914 1.8354253 1.1722914 0.9256243 0.7778107 1.2963512
## 102 1.1534799 0.4288254 0.7583822 0.4288254 0.8576509 1.1862113 1.2292334
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## 104 0.8408781 0.3331252 0.9177126 0.3331252 0.1207633 0.4288254 0.6459347
## 105 0.8576509 0.6662503 1.1722914 0.6662503 0.2592702 0.1207633 0.5846393
## 106 2.1036302 1.8686622 1.9443739 1.8686622 1.4672085 1.2076330 1.0695376
## 107 2.0093791 1.6043064 1.6906862 1.6043064 2.0306516 2.3517319 2.3955121
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## 110 1.8184759 2.2657058 2.7477985 2.2657058 1.8741901 1.5556214 1.8979269
## 111 0.7245798 1.0370809 1.6240572 1.0370809 0.6987985 0.4744817 0.9866359
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## 112 1.2963512 0.4288254 0.4744817 0.4288254 0.4588563 0.7294317 0.5347688
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## 116 0.6038165 0.9866359 1.6105311 0.9866359 0.6882845 0.5185405 1.0370809
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## 118 2.5729526 2.9995291 3.4284283 2.9995291 2.5938924 2.2657058 2.5387032
## 119 2.5729526 1.9859495 1.7061821 1.9859495 1.7141743 1.6145691 1.1797605
## 120 2.2974577 1.3818560 0.7778107 1.3818560 1.6770710 1.9732719 1.6817561
## 121 1.2076330 1.3325007 1.7618861 1.3325007 0.9156036 0.5846393 0.9256243
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## 123 2.3595211 1.9322128 1.8254193 1.9322128 1.5865987 1.4054131 1.0868697
## 124 1.2446977 0.3331252 0.4588563 0.3331252 0.4744817 0.7778107 0.6459347
## 125 0.9929748 1.3568154 1.8979269 1.3568154 0.9866359 0.6987985 1.1534799
## 126 1.5699229 1.6145691 1.9392041 1.6145691 1.1862113 0.8576509 1.0370809
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## 128 0.5185405 0.4588563 1.1722914 0.4588563 0.4288254 0.6038165 0.9618493
## 129 1.0985403 0.3622899 0.6987985 0.3622899 0.2294282 0.5185405 0.4830532
## 130 1.6356060 1.4054131 1.5802588 1.4054131 0.9929748 0.7245798 0.6662503
## 131 2.0306516 1.5699229 1.4961191 1.5699229 1.2292334 1.0695376 0.7245798
## 132 2.7800094 3.1605176 3.5537511 3.1605176 2.7468107 2.4152524 2.6511063
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## 136 2.2216418 1.9859495 2.0431231 1.9859495 1.5865987 1.3283963 1.1797605
## 137 0.6662503 1.3975969 2.0648534 1.3975969 1.1534799 0.9866359 1.5031755
## 138 0.6459347 0.7778107 1.3818560 0.7778107 0.4588563 0.3331252 0.8408781
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## 140 1.2292334 1.1862113 1.5556214 1.1862113 0.7583822 0.4288254 0.6987985
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## 149 0.5846393 1.3818560 2.0683819 1.3818560 1.1722914 1.0370809 1.5556214
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## 86  1.2477185 1.1471408 1.8708394 2.3724086 2.3724086 1.6240572 1.6059971
## 87  0.2294282 0.9618493 1.6656259 2.1631667 2.1631667 1.4224916 1.2477185
## 88  1.6770710 1.4234451 0.9993755 0.9929748 0.9929748 1.0985403 0.9866359
## 89  1.3283963 0.5347688 0.9256243 1.3818560 1.3818560 0.7294317 0.8408781
## 90  1.8482412 1.0985403 0.3331252 0.2294282 0.2294282 0.5846393 0.7583822
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## 93  1.4224916 0.7294317 0.1207633 0.5846393 0.5846393 0.2294282 0.3331252
## 94  2.6065183 1.8312071 1.0901103 0.6459347 0.6459347 1.3325007 1.5167643
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## 96  1.2076330 0.4288254 0.9177126 1.3975969 1.3975969 0.6987985 0.7778107
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## 102 1.2864763 0.5185405 0.2592702 0.7778107 0.7778107 0.0000000 0.2415266
## 103 0.4830532 1.3480631 1.9236986 2.3724225 2.3724225 1.7141743 1.4961191
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## 105 0.2415266 0.6459347 1.3325007 1.8312071 1.8312071 1.0901103 0.9156036
## 106 1.0868697 1.9457861 2.4712222 2.8855479 2.8855479 2.2801050 2.0511416
## 107 2.4578599 1.6145691 0.9929748 0.7600350 0.7600350 1.1797605 1.4054131
## 108 0.7600350 1.5699229 2.0511416 2.4578599 2.4578599 1.8686622 1.6356060
## 109 1.1471408 1.2477185 1.2292334 1.4672085 1.4672085 1.1797605 0.9618493
## 110 1.5031755 2.1631667 2.9231965 3.4343092 3.4343092 2.6687150 2.5226342
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## 118 2.1970807 2.9117573 3.6624143 4.1683875 4.1683875 3.4108436 3.2532787
## 119 1.5167643 2.1652821 2.4152660 2.6961262 2.6961262 2.3059445 2.0657561
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## 121 0.5185405 1.2864763 1.9987510 2.4954370 2.4954370 1.7551549 1.5802588
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## 124 0.8408781 0.5846393 0.7600350 1.1862113 1.1862113 0.6038165 0.3622899
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## 131 0.9618493 1.7061821 2.1036302 2.4712222 2.4712222 1.9457861 1.7061821
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## 138 0.4288254 0.6662503 1.4249691 1.9392041 1.9392041 1.1692786 1.0370809
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## 90  1.1534799 2.1513285 1.9987510 1.0695376 1.1534799
## 91  0.9256243 1.9321957 1.8482412 1.1862113 0.9256243 0.2294282
## 92  0.8453431 0.9256243 0.7600350 1.6240572 0.6038165 1.3568154 1.1692786
## 93  1.0370809 1.8512485 1.5802588 0.9156036 0.9489634 0.4288254 0.3622899
## 94  1.6770710 2.7977649 2.7538150 1.5699229 1.7618861 0.7583822 0.9156036
## 95  0.7294317 1.6770710 1.6145691 1.2477185 0.6882845 0.4744817 0.2592702
## 96  0.3622899 0.9866359 1.2292334 1.7618861 0.1207633 1.1722914 0.9489634
## 97  0.4288254 1.2029904 1.2918694 1.5556214 0.2592702 0.9489634 0.7294317
## 98  0.9929748 1.1722914 0.7583822 1.3818560 0.7600350 1.2477185 1.0901103
## 99  1.2029904 2.3334321 2.3724225 1.5200700 1.2963512 0.4830532 0.5347688
## 100 0.5846393 1.4234451 1.3900047 1.3568154 0.4744817 0.7294317 0.5185405
## 101 1.2864763 0.4288254 0.6662503 2.2942816 1.0901103 2.0741619 1.8741901
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## 103 2.0529761 1.6145691 0.5347688 1.8741901 1.8114495 2.2470822 2.1390753
## 104 1.1108209 1.2029904 0.6662503 1.3765690 0.8759237 1.3325007 1.1862113
## 105 1.3283963 1.0985403 0.3331252 1.6240572 1.0868697 1.6656259 1.5167643
## 106 2.6567926 2.1390753 1.1108209 2.2458595 2.4152660 2.7834110 2.6969689
## 107 1.2963512 2.4552508 2.5729526 1.7518473 1.4249691 0.7245798 0.7600350
## 108 2.3059445 1.9443739 0.8576509 1.8312071 2.0657561 2.3595211 2.2801050
## 109 1.9443739 2.2311936 1.3765690 0.6662503 1.7551549 1.4491596 1.4672085
## 110 2.5729526 1.5200700 1.2963512 3.1744269 2.3724225 3.2532787 3.0787074
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## 118 3.3292046 2.2487569 2.0093791 3.8342937 3.1305320 3.9942769 3.8260052
## 119 2.9252373 2.7538150 1.6656259 1.8254193 2.6969689 2.6666804 2.6567926
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## 131 2.4584668 2.1802206 1.0901103 1.7551549 2.2216418 2.3955121 2.3399342
## 132 3.5332203 2.4712222 2.1631667 3.9467499 3.3292046 4.1588406 3.9975021
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## 136 2.7775559 2.2487569 1.2292334 2.3318762 2.5360293 2.8938692 2.8108262
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## 138 1.2292334 0.8408781 0.3622899 1.8393939 0.9929748 1.7539179 1.5802588
## 139 0.7245798 0.9177126 0.8759237 1.6463538 0.4830532 1.2963512 1.0985403
## 140 1.8259208 1.2864763 0.2415266 1.9732719 1.5865987 2.1802206 2.0431231
## 141 1.5865987 1.0901103 0.0000000 1.8979269 1.3480631 1.9987510 1.8482412
## 142 1.8259208 1.2864763 0.2415266 1.9732719 1.5865987 2.1802206 2.0431231
## 143 0.8408781 1.6240572 1.4224916 1.0985403 0.7294317 0.5846393 0.4288254
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## 147 1.5802588 2.0963954 1.4588634 0.4588563 1.4249691 0.9661064 0.9929748
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## 98  0.2592702 0.8408781 1.9987510 0.8576509 0.6459347 0.6038165
## 99  1.6656259 0.8759237 0.4744817 0.7583822 1.3568154 1.1692786 1.6145691
## 100 0.6662503 0.4744817 1.4249691 0.2592702 0.4588563 0.2294282 0.6459347
## 101 0.7294317 1.7157567 2.7799975 1.6154093 0.9993755 1.1692786 0.9256243
## 102 0.7778107 0.2294282 1.3325007 0.2415266 0.6987985 0.4744817 0.6662503
## 103 1.2076330 1.8184759 3.0017781 1.9378042 1.6906862 1.7061821 1.1108209
## 104 0.3331252 0.9156036 2.0879655 0.9618493 0.7600350 0.7245798 0.1207633
## 105 0.4830532 1.2477185 2.4208627 1.2864763 0.9661064 0.9929748 0.4288254
## 106 1.8114495 2.3595211 3.5267349 2.5114230 2.2945027 2.3059445 1.7061821
## 107 1.8482412 1.1108209 0.4744817 0.9618493 1.4997645 1.3325007 1.8184759
## 108 1.4672085 1.9378042 3.0999612 2.1036302 1.9457861 1.9322128 1.3283963
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## 133 0.5846393 0.8576509 2.0431231 0.9929748 0.9618493 0.8759237 0.3331252
## 134 0.5185405 0.7583822 1.9443739 0.8759237 0.8576509 0.7600350 0.2592702
## 135 0.9177126 0.3622899 1.4961191 0.6459347 1.0370809 0.8408781 0.6987985
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## 140 0.9929748 1.7551549 2.9382867 1.8184759 1.4672085 1.5200700 0.9618493
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## 146 0.7245798 1.4224916 2.6065183 1.4961191 1.2076330 1.2292334 0.6459347
## 147 1.1722914 0.6459347 1.6356060 0.9618493 1.3568154 1.1692786 0.9256243
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## 148 0.4830532 1.2477185 2.4208627 1.2864763 0.9661064 0.9929748 0.4288254
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## 150 0.2415266 0.9256243 1.9392041 0.7778107 0.2415266 0.3331252 0.4288254
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## 106 3.2296736 2.3399342 1.7141743 2.2801050 0.6038165 1.5865987 1.3283963
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## 147 1.4588634 1.5556214 0.7583822 1.7157567 1.8979269 1.2446977
## 148 0.3331252 0.5347688 1.0901103 0.5846393 0.7294317 0.2415266 1.1722914
## 149 0.9156036 1.0901103 1.6770710 0.8576509 0.6459347 1.0985403 2.0683819
## 150 0.9929748 1.2292334 0.6987985 1.1797605 1.1862113 0.9661064 1.2446977
##           148       149
## 2
## 3
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## 142
## 143
## 144
## 145
## 146
## 147
## 148
## 149 0.9866359
## 150 0.7245798 0.9866359
```

8. Fit an agglomerative hierarchical clustering algorithm using complete linkage on your subset data and render the dendrogram of clustering results. What do you see?

```
library(dendextend)
```

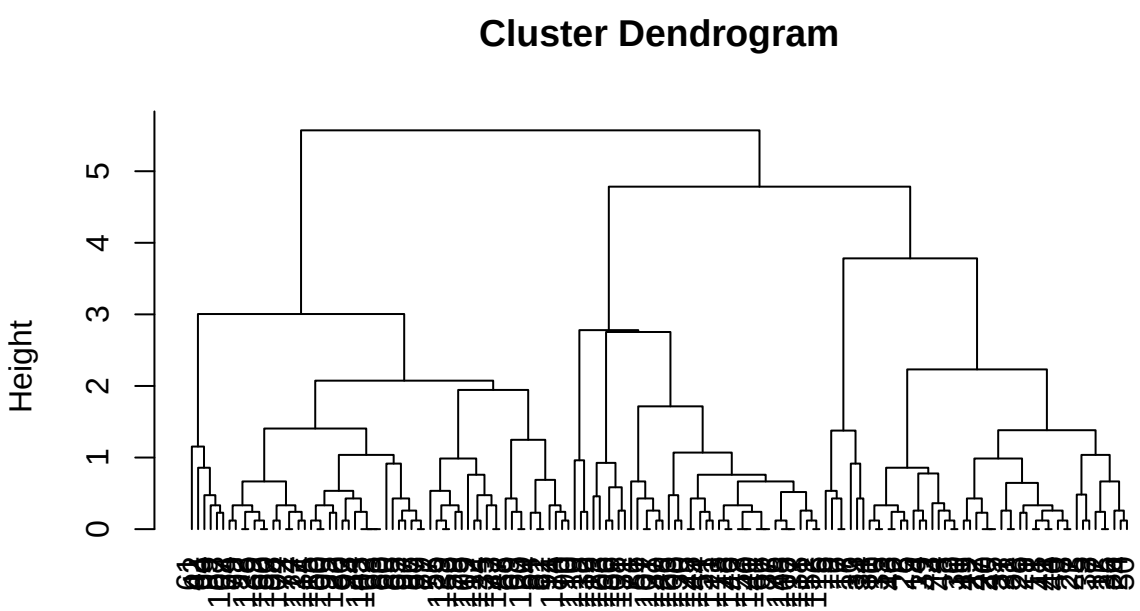
```
## Warning: package 'dendextend' was built under R version 3.5.3
```

```
##
## ---------------------
## Welcome to dendextend version 1.12.0
## Type citation('dendextend') for how to cite the package.
##
## Type browseVignettes(package = 'dendextend') for the package vignette.
## The github page is: https://github.com/talgalili/dendextend/
##
## Suggestions and bug-reports can be submitted at: https://github.com/talgalili/dendextend/issues
## Or contact: <tal.galili@gmail.com>
##
##  To suppress this message use:  suppressPackageStartupMessages(library(dendextend))
## ---------------------
```

```
##
## Attaching package: 'dendextend'
```

```
## The following object is masked from 'package:stats':
##
##     cutree
```

```
hc_complete <- hclust(iris_sub,
                      method = "complete"); plot(hc_complete, hang = -1)
```



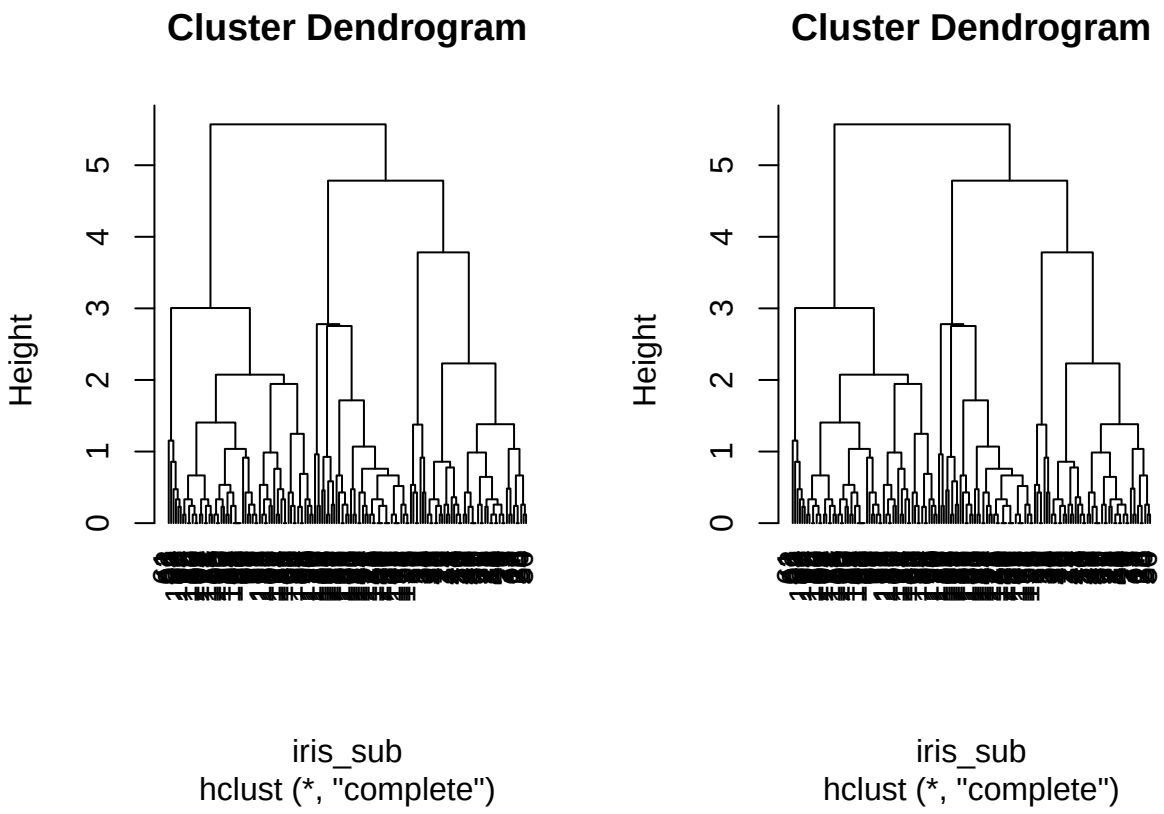
9. Try cutting the tree at 2 and 3 branches and show these trees side-by-side. How do they differ?

```
cuts <- cutree(hc_complete,
               k = c(2,3))
table(`2 Clusters` = cuts[,1],
      `3 Clusters` = cuts[,2])
```

```
##            3 Clusters
## 2 Clusters  1  2  3
##          1 49  0 40
##          2  0 61  0
```

From this preliminary inspection,we see that the 2 classifications roughly agree on which flowers belong in clusters 1 and 2. The disagreement lies around the 3rd cluster.

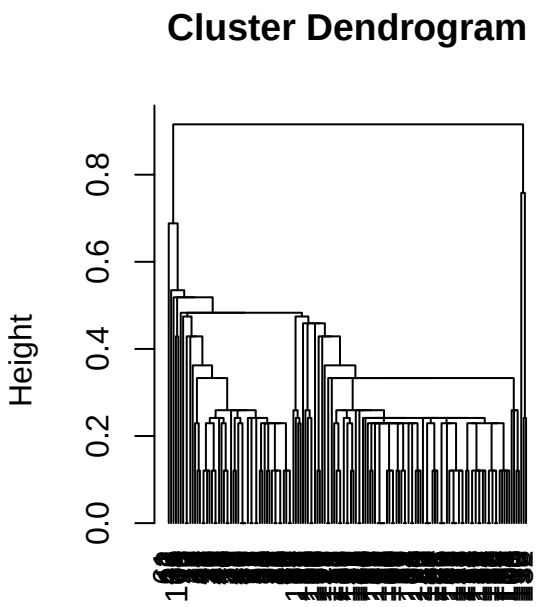
```
par(mfrow = c(1,2))
hc_complete_two <- hclust(iris_sub,
                    method = "complete"); plot(hc_complete_two, hang = -1)
hc_complete_three <- hclust(iris_sub,
                    method = "complete"); plot(hc_complete_three, hang = -1)
```

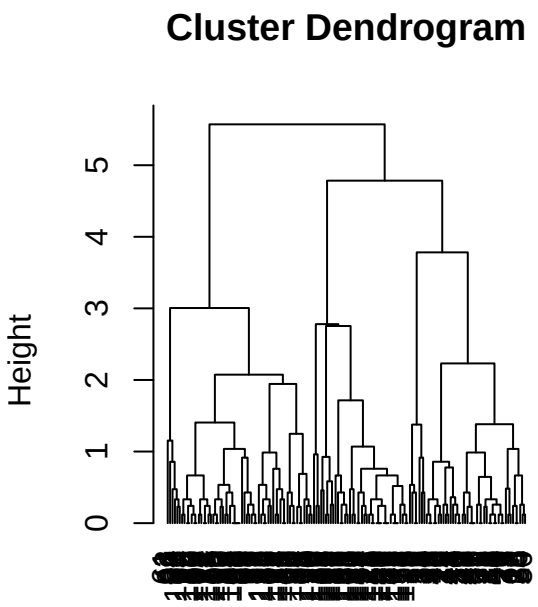


10. Now fit the algorithm using single and complete linkage and present each dendrogram side-by-side. Discuss the differences. What effects can we see in the clustering patterns when using different linkage methods?

```
par(mfrow = c(1,2))
hc_single <- hclust(iris_sub,
                    method = "single"); plot(hc_single, hang = -1)

hc_complete <- hclust(iris_sub,
                      method = "complete"); plot(hc_complete, hang = -1)
```





The core difference lies in how these methods are defined. In the single method, the distance between clusters is defined between the closest pairs, while the complete method calculates this distance between the points furthest apart.

In the clustering by the single method (on the left), we see a much higher degree of branching (considerably more sub-clusters). Interestingly the lengths of the y axis along appears consistent at each level of clustering process, leading to a more geometric and seemingly orderly pattern to the clustering. Conversely, in the complete method, we see fewer sub-clusters, with the agglomeration occurring at a variety of heights in the bottom-up process.

CRITICAL THINKING

1. You just assessed the clusterability of some feature space, ???". Address the following questions:

a. How would you go about determining whether clustering made sense to consider or not?

One method, like with the iris data, would be to plot known labels (in this case, species) and see if the clustering matches with the known labels.

If such labels do not

b. What are techniques you would use, and what might you be looking for from each?

c. How might these techniques work together to motivate clustering or not?

d. And ultimately, can/should you proceed if you find little to no support for clusterability? Why or why not?

2. Locate (and read) a paper that applies the hierarchical agglomerative clustering technique. Address the following questions:

a. Describe the author(s) process.

b. Do they go through similar steps as we covered this week both in setting the stage for clustering (e.g., assessing clusterability, calculating distance, etc.), as well as in fitting the algorithm? If not, what did they omit and does this omission impact their findings in your opinion?
c. Describe at least one possible extension from the study that could emerge based on their findings.