# **Distances and similarity**

### Distances and similarity

- Distance and similarity are more or less opposite concepts.
- Distance is a **numerical measure** describing how are two objects (defined by certain variables) different (*pairwise distance*).
- Different distance measures exist for different data types.

### **Distance**

- Scale  $0-\infty$
- 0 Two objects with 0 distance between them.
- $\infty$  Two objects with infinite distance.
- In practice, maximum distance is often 1.
- Denoted by D (for distance, or dissimilarity).
- D = 1 S

### **Similarity**

- Scale 0 1
- 0 Two objects completely dissimilar (0%).
- 1 Two objects competely similar (100%).
- Denoted by S (for similarity).
- S = 1 D

### Different distance measures

- Dichotomous variables
  - Symmetrical Simple matching distance
  - Asymmetrical Jaccard index (binary distance)

- Categorical variables
  - Hamming distance
- Numeric continuous variables
  - Euclidean distance
  - Mahalanobis distance
- Mixed data sets
  - Gower's distance

### **Binary distances**

• For TRUE/FALSE, 1/0, presence/absence (etc.) data

### **Symmetrical**

- Two presences as match.
- Two absences as match.

If a trait is present, two objects are more similar. If a trait is absent, two objects are more similar. For example if *biological sex* is encoded in one variable with 0 for *male* and 1 for *female*, it is symmetrical.

• Simple maching distance

### **Asymmetrical**

- Two presences as match.
- Two absences as mismatch.

If a trait is present, two objects are more similar. If a trait is **absent** in both cases, e.g. **undetermined**, **missing** etc., this does not affect similarity. This is more practical in archaeology.

· Jaccard index, i.e. binary distance

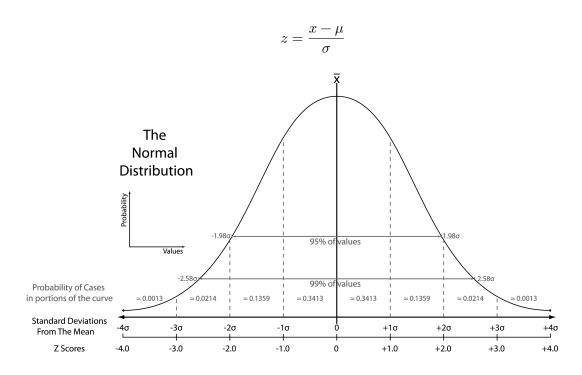
dist(x, method = "binary")

# Distance between (continuous) numeric data

• To **remove effects of scale** (different units etc.), variables should be scaled (normalized).

#### **Normalization**

• z-score or z-transformation



### **Euclidean distance**

- Defined for a Cartesian coordinate space.
- Uses Pythagorean theorem.

$$d(p,q) = \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2}$$

#### In R...

```
Normalization:
scale(x, center = TRUE, scale = TRUE)
Euclidean distance:
dist(x, method = "euclidean")
```

#### Code along

```
library(dplyr)
darts <- read.csv("https://petrpajdla.github.io/stat4arch/lect/w09/data/dartpoints_numeric.ca</pre>
# summary of values
summary(select(darts, Length, Width, Thickness, Weight))
    Length
                     Width
                                  Thickness
                                                    Weight
 Min. : 30.60 Min. :14.50 Min. : 4.000
                                                Min. : 2.300
 1st Qu.: 40.85 1st Qu.:18.55
                                1st Qu.: 6.250
                                                1st Qu.: 4.550
 Median: 47.10 Median: 21.10 Median: 7.200
                                                Median : 6.800
 Mean : 49.33 Mean :22.08
                                Mean : 7.271
                                                Mean : 7.643
                                3rd Qu.: 8.250
 3rd Qu.: 55.80 3rd Qu.:25.15
                                                3rd Qu.:10.050
 Max. :109.50 Max. :49.30
                                Max. :10.700
                                                Max. :28.800
# normalization
darts_norm <- darts %>%
  mutate(Length = scale(Length), Width = scale(Width),
        Thickness = scale(Thickness), Weight = scale(Weight))
# or this shorthand can be used
darts_norm <- darts %>%
  mutate(across(all_of(c("Length", "Width", "Thickness", "Weight")), scale))
# summary of normalized values
```

```
Length.V1 Width.V1 Thickness.V1
Min. :-1.470673 Min. :-1.469440 Min. :-2.1363403
1st Qu.:-0.665879 1st Qu.:-0.683998 1st Qu.:-0.6670233
```

summary(select(darts\_norm, Length, Width, Thickness, Weight))

### **Code along**

```
# subset of Travis and Darl types of dart points
darts_subset <- filter(darts_norm, Name %in% c("Travis", "Darl"))

# matrix with numerical variables only
darts_mx <- darts_subset %>%
    select(Length, Width, Thickness, Weight) %>%
    as.matrix()

# add row names to the matrix
rownames(darts_mx) <- darts_subset$Name

# count Euclidean distance
darts_d <- dist(darts_mx, method = "euclidean", diag = TRUE)

round(as.matrix(darts_d)[1:6, 1:6], 2)</pre>
```

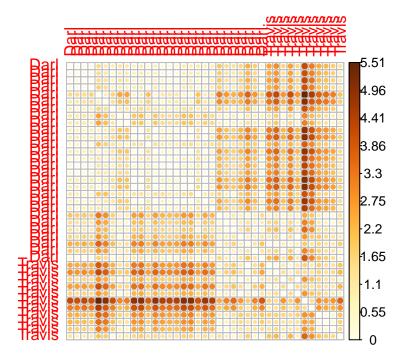
- Result is a distance matrix.
- It is symmetrical. Lower triangular is the same as upper triangular.
- On the diagonal, there is distance of the given object to itself, i.e. 0.

# Visualizing distance matrix

• Package corrplot has a nice way of plotting heatmaps.

```
library(corrplot)

# arg. is.corr set to FALSE, because we are not visualizing correlation matrix
corrplot(as.matrix(darts_d), is.corr = FALSE)
```



### Resources

For a much more detailed overview of distance methods, see the tutorial on classification by Schmidt, S. C. et al. DOI: 10.5281/zenodo.6325372 (direct link to a HTML file is here).