Measuring Typological and Goegraphical Distances in R

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Contents

1 R programming language **2**

1.1 Conditional statement (`ifelse` & `case_when`) 2

1.2 For loop (`for` and `rowwise`) 4

1.3 Function 5

2 Typological similarities between Uralic languages **6**

2.1 Function 6

2.2 Data preprocessing 6

2.3 Calculating typological similarities 9

2.4 Exercises 11

3 Geographical distances between languages **13**

3.1 Function 13

3.2 Measuring geographical distances 13

1 R programming language

1.1 Conditional statement (ifelse & case_when)

```
pi = 3.14
if(is.numeric(pi)){
  print("You have a numeric pi :)")
}else{
  print("You do not have a numeric pi :(")
}
```

```
[1] "You have a numeric pi :)"
```

```
mylogic = TRUE
if(is.logical(mylogic)){
  print("You have a logical variable :)")
}else{
  print("You do not have a logical variable :(")
}
```

```
[1] "You have a logical variable :)"
```

```
lang = "Estonian"
if(is.character(lang) & lang == "Estonian"){
  print("It is a character variable and it is Estonian!")
}else{
  print("It is not Estonian!")
}
```

```
[1] "It is a character variable and it is Estonian!"
```

```
lang = "Estonian"
if(is.character(lang) | lang == "Estonian"){
  print("It is a character or it is Estonian!")
}else{
  print("It is not Estonian!")
}
```

```
[1] "It is a character or it is Estonian!"
```

```
lang_df = data.frame(id = 1:5,
          lang = c("Estonian", "Finnish", "English",
                   "Chinese", "Esperanto"))
lang_df
```

```
  id      lang
1  1  Estonian
2  2   Finnish
3  3   English
4  4   Chinese
5  5 Esperanto
```

```
lang_df %>%
  mutate(family = ifelse(lang == "Estonian", "Estonian", "not Estonian"))
```

```
  id      lang       family
1  1  Estonian     Estonian
2  2   Finnish not Estonian
3  3   English not Estonian
4  4   Chinese not Estonian
5  5 Esperanto not Estonian
```

We can generalize the `ifelse` into a case of multiple conditions, so that you have not only two options but multiple options.

```
lang_df %>%
  mutate(family = case_when(lang %in% c("Estonian", "Finnish") ~ "Uralic",
                            lang %in% c("English") ~ "IE",
                            lang %in% c("Chinese") ~ "Sino-Tibetan",
                            TRUE ~ "unknown"))
```

```
  id      lang       family
1  1  Estonian       Uralic
2  2   Finnish       Uralic
3  3   English           IE
4  4   Chinese Sino-Tibetan
5  5 Esperanto      unknown
```

1.2 For loop (for and rowwise)

```
names = c("Yingqi", "John", "Emily", "David")
for(name in names){
  print(nchar(name))
}
```

```
[1] 6
[1] 4
[1] 5
[1] 5
```

Dplyr provides a convenient `rowwise` operation to work on each row of a data.frame. This can be viewed as an alternative to `for` loop in a data.frame. Note: `rowwise` groups your data by row (class: rowwise_df), and it is best to `ungroup` immediately.[1]

To facilitate `rowwise` operation, you may need to use `c_across` to select specific columns. For example, if you want to calculate the number of characters of language names in a data.frame.

```
mydf = data.frame(id = 1:4,
           names = c("Yingqi", "John", "Emily", "David"))
name_length = mydf %>%
  rowwise() %>%
  mutate(nchar_name = nchar(c_across(names))) %>%
  ungroup
name_length
```

```
# A tibble: 4 x 3
     id names  nchar_name
  <int> <chr>       <int>
1     1 Yingqi          6
2     2 John            4
3     3 Emily           5
4     4 David           5
```

[1] https://medium.com/p/da3638b5f46c

1.3 Function

```
myaverage = function(numvec){
  average = sum(numvec)/length(numvec)
  return(average)
}
```

```
myvec = c(2, 3)
myaverage(myvec)
```

```
[1] 2.5
```

```
name_length %>%
  pull(nchar_name) %>%
  myaverage()
```

```
[1] 5
```

2 Typological similarities between Uralic languages

2.1 Function

```
typological_sim = function(data = ut_final, x, y){
  subdata = data %>%
    dplyr::select(-matches("subfamily|area", ignore.case = T)) %>%
    column_to_rownames(var = "Name")
  sim = sum(abs(as.vector(subdata[x, ]) == as.vector(subdata[y, ])))
  sim_p = sim/ncol(subdata)
  return(sim_p)
}
```

2.2 Data preprocessing

```
uratyp_df = read.csv("https://raw.githubusercontent.com/cldf-datasets/uratyp/v1.1/cldf/values.csv")
lang_df = read.csv("https://raw.githubusercontent.com/cldf-datasets/uratyp/v1.1/cldf/languages.csv")
# uratyp_df = read.csv("../data/values.csv")
# lang_df = read.csv("../data/languages.csv")
ut_data = uratyp_df %>%
  inner_join(., lang_df, by = c("Language_ID" = "ID")) %>%
  dplyr::select(Name, Parameter_ID, Value, Subfamily) %>%
  filter(grepl("UT", Parameter_ID))
```

(1) Convert all data into binary (0, 1)

```
ut_wide = ut_data %>%
  mutate(Value = case_when(
    Value == "0" ~ 0L,
    Value == "1" ~ 1L,
    TRUE ~ NA_integer_ # convert all "?" into NA
  )) %>%
  pivot_wider(., names_from = Parameter_ID, values_from = Value)
```

(2) Remove all columns with missing values

```
ut_wide = ut_wide %>%
  select_if(function(x) !any(is.na(x)))
# alternatively, select_if(~ !any(is.na(.x)))
# select_if(~ sum(is.na(.x)) == 0)
# select(where(~ sum(is.na(.x)) == 0))
```

(3) Remove all constant columns

```
ut_final = ut_wide %>%
  remove_constant(.)
  # select_if(~ length(unique(.x)) > 1)
head(ut_final)
```

```
# A tibble: 6 x 143
  Name     Subfamily UT001 UT002 UT003 UT004 UT005 UT006 UT007 UT008 UT009 UT010
  <chr>    <chr>     <int> <int> <int> <int> <int> <int> <int> <int> <int> <int>
1 Central~ Finnic        0     1     0     1     1     0     1     0     0     0
2 Courlan~ Finnic        0     0     0     1     1     0     1     1     0     0
3 East_Ma~ Ugric         1     0     1     0     1     0     1     0     0     1
4 Erzya    Mordvin       0     0     1     0     1     1     1     1     1     1
```

```
5 Estonian Finnic        0     0     0     1     1     0     1     1     0     0
6 Finnish  Finnic        0     1     0     1     0     0     1     1     0     0
# ... with 131 more variables: UT011 <int>, UT012 <int>, UT013 <int>,
#   UT015 <int>, UT016 <int>, UT017 <int>, UT020 <int>, UT021 <int>,
#   UT022 <int>, UT023 <int>, UT024 <int>, UT025 <int>, UT026 <int>,
#   UT028 <int>, UT029 <int>, UT031 <int>, UT032 <int>, UT034 <int>,
#   UT035 <int>, UT036 <int>, UT037 <int>, UT038 <int>, UT039 <int>,
#   UT042 <int>, UT043 <int>, UT044 <int>, UT045 <int>, UT047 <int>,
#   UT048 <int>, UT049 <int>, UT050 <int>, UT051 <int>, UT052 <int>, ...
```

(4) reshape the data into long format

```r
lang_sorted = ut_final %>%
  arrange(Subfamily) %>%
  pull(Name)
ut_final_long = ut_final %>%
  pivot_longer(., names_to = "feature", values_to = "value", -c("Name", "Subfamily")) %>%
  mutate(value = factor(value),
         Name = factor(Name, levels = lang_sorted))
head(ut_final_long)
```

```
# A tibble: 6 x 4
  Name         Subfamily feature value
  <fct>        <chr>     <chr>   <fct>
1 Central_Veps Finnic    UT001   0
2 Central_Veps Finnic    UT002   1
3 Central_Veps Finnic    UT003   0
4 Central_Veps Finnic    UT004   1
5 Central_Veps Finnic    UT005   1
6 Central_Veps Finnic    UT006   0
```

(5) Visualize data via heatmap

```r
ut_final_long %>%
  ggplot(., aes(x = feature, y = Name, fill = value)) +
  geom_tile() +
  scale_fill_manual(values = alpha(c("blue", "red"), 0.65)) +
  theme(axis.text.x = element_text(angle = 90, size = 6, hjust = 0),
        axis.ticks = element_blank()) +
  labs(x = NULL, y = NULL)
```

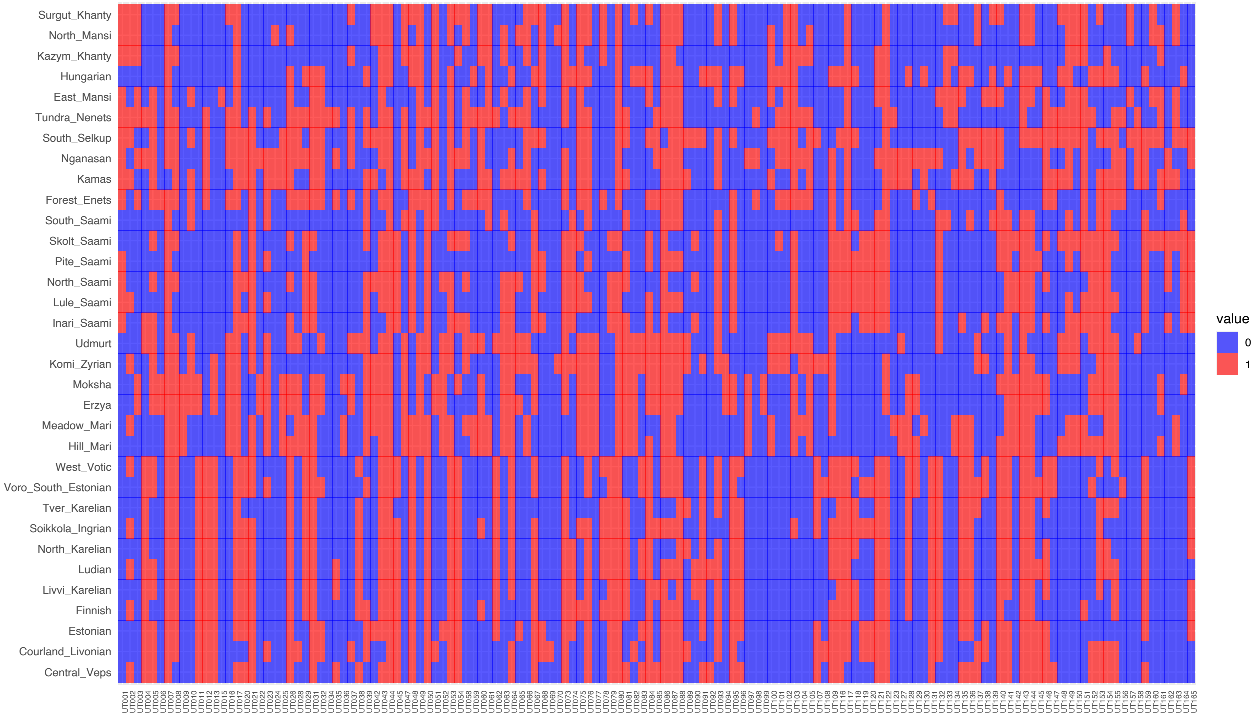
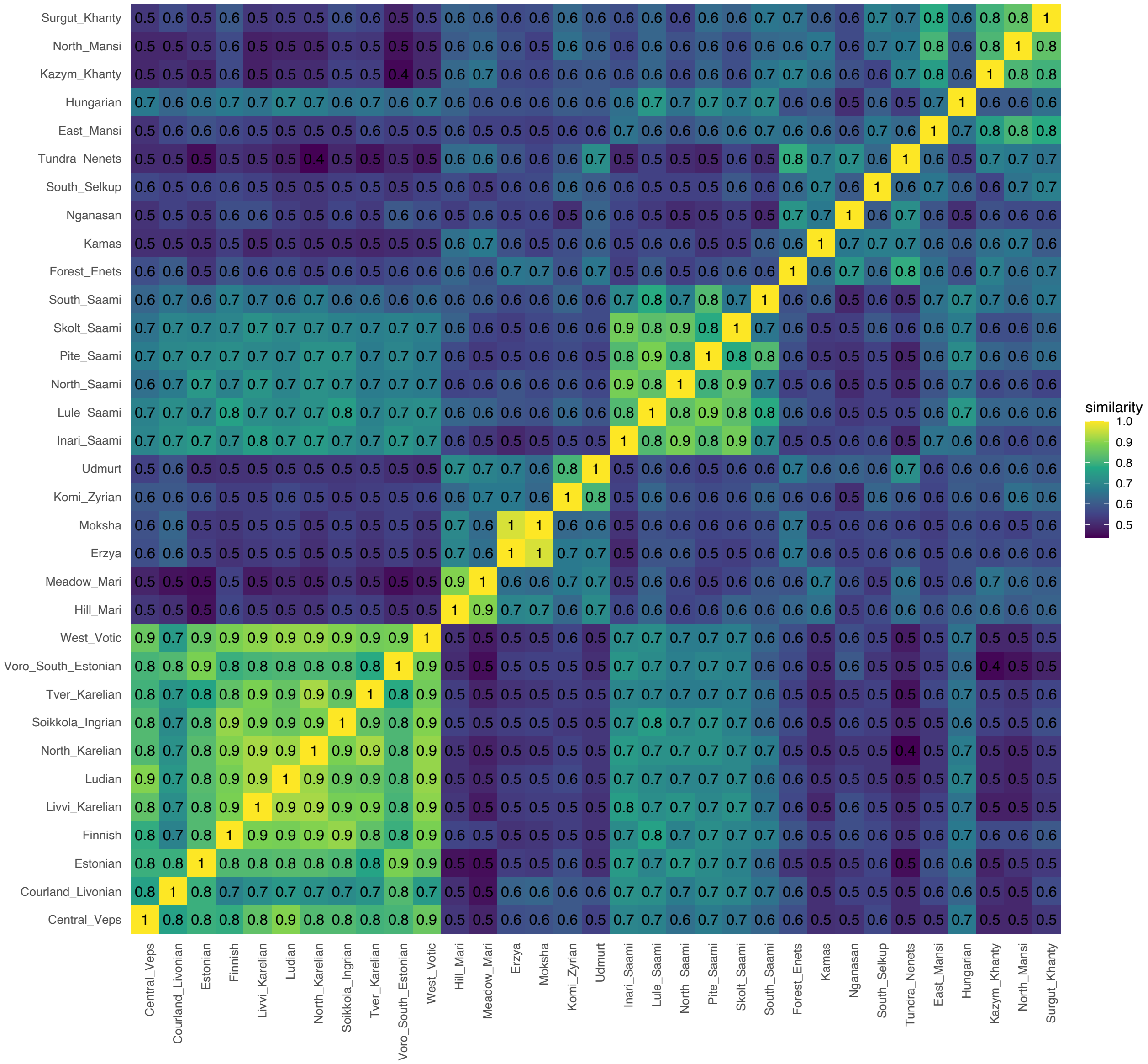


Figure 1: Overview of typological data in UT database

2.3 Calculating typological similarities

```
lgs = ut_final$Name
lgs_sim = expand.grid(lgs, lgs, stringsAsFactors = F) %>%
  rowwise() %>%
  mutate(similarity = typological_sim(ut_final, Var1, Var2))
```

```
lgs_sim_sorted = lgs_sim %>%
  mutate(Var1 = factor(Var1, levels = lang_sorted),
         Var2 = factor(Var2, levels = lang_sorted))
ggplot(lgs_sim_sorted, aes(Var1, Var2, fill = similarity)) +
  geom_tile() +
  geom_text(data = lgs_sim_sorted,
            mapping = aes(Var1, Var2,
                          label = round(similarity, digit = 1))) +
  scale_fill_continuous(type = "viridis") +
  labs(x = NULL, y = NULL) +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"),
        axis.text.y = element_text(size = 9),
        axis.text.x = element_text(angle = 90, size = 9, hjust = 1),
        axis.ticks = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank()) +
  coord_fixed()
```


Surgut_Khanty 0.5 0.6 0.5 0.6 0.5 0.5 0.5 0.6 0.6 0.5 0.5 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.7 0.7 0.6 0.6 0.7 0.7 0.8 0.6 0.8 0.8 1
North_Mansi 0.5 0.5 0.5 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.6 0.6 0.6 0.5 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.7 0.6 0.7 0.7 0.8 0.6 0.8 1 0.8
Kazym_Khanty 0.5 0.5 0.5 0.6 0.5 0.5 0.5 0.5 0.5 0.4 0.5 0.6 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.7 0.7 0.6 0.6 0.6 0.7 0.8 0.6 1 0.8 0.8
Hungarian 0.7 0.6 0.6 0.7 0.7 0.7 0.7 0.6 0.7 0.6 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.5 0.6 0.5 0.7 1 0.6 0.6 0.6
East_Mansi 0.5 0.6 0.6 0.6 0.5 0.5 0.5 0.5 0.6 0.5 0.5 0.6 0.5 0.5 0.5 0.6 0.6 0.7 0.6 0.6 0.6 0.6 0.7 0.6 0.6 0.6 0.7 0.6 1 0.7 0.8 0.8 0.8
Tundra_Nenets 0.5 0.5 0.5 0.5 0.5 0.5 0.4 0.5 0.5 0.5 0.5 0.6 0.6 0.6 0.6 0.6 0.7 0.5 0.5 0.5 0.5 0.6 0.5 0.8 0.7 0.7 0.6 1 0.6 0.5 0.7 0.7 0.7
South_Selkup 0.6 0.5 0.6 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.6 0.5 0.6 0.6 0.6 0.6 0.6 0.5 0.5 0.5 0.6 0.6 0.6 0.7 0.6 1 0.6 0.7 0.6 0.6 0.7 0.7
Nganasan 0.5 0.5 0.5 0.6 0.6 0.5 0.5 0.6 0.5 0.6 0.6 0.5 0.6 0.5 0.6 0.5 0.6 0.6 0.5 0.5 0.5 0.5 0.5 0.7 0.7 1 0.6 0.7 0.6 0.5 0.6 0.6 0.6
Kamas 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.6 0.7 0.6 0.5 0.6 0.6 0.5 0.6 0.6 0.5 0.5 0.6 0.6 1 0.7 0.7 0.7 0.6 0.6 0.6 0.7 0.6
Forest_Enets 0.6 0.6 0.5 0.6 0.6 0.6 0.5 0.6 0.5 0.6 0.6 0.6 0.6 0.7 0.7 0.6 0.7 0.5 0.6 0.5 0.6 0.6 0.6 1 0.6 0.7 0.6 0.8 0.6 0.6 0.7 0.6 0.7
South_Saami 0.6 0.7 0.6 0.7 0.7 0.6 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.7 0.8 0.7 0.8 0.7 1 0.6 0.6 0.5 0.6 0.5 0.7 0.7 0.7 0.6 0.7
Skolt_Saami 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.5 0.6 0.6 0.6 0.9 0.8 0.9 0.8 1 0.7 0.6 0.5 0.5 0.6 0.6 0.6 0.7 0.6 0.6 0.6
Pite_Saami 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.6 0.6 0.5 0.8 0.9 0.8 1 0.8 0.8 0.6 0.5 0.5 0.5 0.5 0.6 0.7 0.6 0.6 0.6
North_Saami 0.6 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.9 0.8 1 0.8 0.9 0.7 0.5 0.6 0.5 0.5 0.5 0.6 0.7 0.6 0.6 0.6
Lule_Saami 0.7 0.7 0.7 0.8 0.7 0.7 0.7 0.8 0.7 0.7 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.8 1 0.8 0.9 0.8 0.8 0.6 0.6 0.5 0.5 0.5 0.6 0.7 0.6 0.6 0.6
Inari_Saami 0.7 0.7 0.7 0.7 0.8 0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5 0.5 0.5 1 0.8 0.9 0.8 0.9 0.7 0.5 0.5 0.6 0.6 0.5 0.7 0.6 0.6 0.6 0.6
Udmurt 0.5 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.7 0.7 0.6 0.8 1 0.5 0.6 0.6 0.5 0.6 0.6 0.7 0.6 0.6 0.6 0.7 0.6 0.6 0.6 0.6 0.6
Komi_Zyrian 0.6 0.6 0.6 0.5 0.5 0.6 0.5 0.5 0.5 0.5 0.6 0.6 0.7 0.7 0.6 1 0.8 0.5 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.5 0.6 0.6 0.6 0.6 0.6 0.6 0.6
Moksha 0.6 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.6 1 1 0.6 0.6 0.5 0.6 0.6 0.6 0.6 0.6 0.7 0.5 0.6 0.6 0.6 0.5 0.6 0.6 0.5 0.6
Erzya 0.6 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.6 1 1 0.7 0.7 0.5 0.6 0.6 0.5 0.5 0.6 0.7 0.6 0.5 0.6 0.6 0.5 0.6 0.6 0.6 0.6
Meadow_Mari 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.9 1 0.6 0.6 0.7 0.7 0.5 0.6 0.6 0.5 0.6 0.6 0.6 0.7 0.6 0.5 0.6 0.5 0.6 0.7 0.6 0.6
Hill_Mari 0.5 0.5 0.5 0.6 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1 0.9 0.7 0.7 0.6 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.5 0.6 0.6 0.6 0.6 0.6 0.6 0.6
West_Votic 0.9 0.7 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 1 0.5 0.5 0.5 0.5 0.6 0.5 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.5 0.6 0.5 0.5 0.5 0.7 0.5 0.5 0.5
Voro_South_Estonian 0.8 0.8 0.9 0.8 0.8 0.8 0.8 0.8 0.8 1 0.9 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.5 0.6 0.5 0.5 0.5 0.6 0.4 0.5 0.5
Tver_Karelian 0.8 0.7 0.8 0.8 0.9 0.9 0.9 0.9 1 0.8 0.9 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5 0.5 0.5 0.6 0.7 0.5 0.5 0.6
Soikkola_Ingrian 0.8 0.7 0.8 0.9 0.9 0.9 0.9 1 0.9 0.8 0.9 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.8 0.7 0.7 0.7 0.6 0.6 0.5 0.6 0.5 0.5 0.5 0.6 0.5 0.5 0.6
North_Karelian 0.8 0.7 0.8 0.9 0.9 0.9 1 0.9 0.9 0.8 0.9 0.5 0.5 0.5 0.5 0.5 0.5 0.7 0.7 0.7 0.7 0.7 0.7 0.5 0.5 0.5 0.5 0.4 0.5 0.7 0.5 0.5 0.5
Ludian 0.9 0.7 0.8 0.9 0.9 1 0.9 0.9 0.9 0.8 0.9 0.5 0.5 0.5 0.5 0.6 0.5 0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.5 0.5 0.5 0.5 0.5 0.7 0.5 0.5 0.5
Livvi_Karelian 0.8 0.7 0.8 0.9 1 0.9 0.9 0.9 0.9 0.8 0.9 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.6 0.5 0.5 0.5 0.7 0.5 0.5 0.5
Finnish 0.8 0.7 0.8 1 0.9 0.9 0.9 0.9 0.8 0.8 0.9 0.6 0.5 0.5 0.5 0.5 0.5 0.7 0.8 0.7 0.7 0.7 0.7 0.6 0.5 0.6 0.6 0.5 0.6 0.7 0.6 0.6 0.6
Estonian 0.8 0.8 1 0.8 0.8 0.8 0.8 0.8 0.8 0.9 0.9 0.5 0.5 0.5 0.5 0.6 0.5 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5 0.6 0.5 0.6 0.6 0.5 0.5 0.5
Courland_Livonian 0.8 1 0.8 0.7 0.7 0.7 0.7 0.7 0.7 0.8 0.7 0.5 0.5 0.6 0.6 0.6 0.6 0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5 0.5 0.6 0.6 0.5 0.5 0.6
Central_Veps 1 0.8 0.8 0.8 0.8 0.9 0.8 0.8 0.8 0.8 0.9 0.5 0.5 0.6 0.6 0.6 0.5 0.7 0.7 0.6 0.7 0.7 0.6 0.6 0.5 0.5 0.6 0.5 0.5 0.7 0.5 0.5 0.5
Central_Veps
Courland_Livonian
Estonian
Finnish
Livvi_Karelian
Ludian
North_Karelian
Soikkola_Ingrian
Tver_Karelian
Voro_South_Estonian
West_Votic
Hill_Mari
Meadow_Mari
Erzya
Moksha
Komi_Zyrian
Udmurt
Inari_Saami
Lule_Saami
North_Saami
Pite_Saami
Skolt_Saami
South_Saami
Forest_Enets
Kamas
Nganasan
South_Selkup
Tundra_Nenets
East_Mansi
Hungarian
Kazym_Khanty
North_Mansi
Surgut_Khanty
similarity
1.0
0.9
0.8
0.7
0.6
0.5

2.4 Exercises

(1) Pls add the information of typological areas (*parameters.csv*) to UT dataset. Note: you can use the preprocessed UT data **ut_final_long**.

```
feat_areas = read.csv("https://raw.githubusercontent.com/cldf-datasets/uratyp/v1.1/cldf/parameters.csv")
# feat_areas = read.csv("../Data/parameters.csv")
feat_areas = feat_areas %>%
  dplyr::select(ID, Area)
ut_areas = ut_final_long %>%
  inner_join(., feat_areas, by = c("feature" = "ID"))
```

(2) Pls calculate the typological similarities between languages across typological areas (phonology, morphology and syntax) in UT dataset, and plot them as heatmaps separately. Note: you can remove the lexicon features, and use `facet_wrap` function to create subpanels.

```
ut_area_sim = ut_areas %>%
  filter(Area %in% c("Phonology", "Morphology", "Syntax")) %>%
  split(.$Area) %>%
  map_dfr(., ~{subdata = .x %>% spread(., key = feature, value = value)
               expand.grid(lgs, lgs, stringsAsFactors = F) %>%
                 rowwise() %>%
                 mutate(similarity = typological_sim(subdata, Var1, Var2)) %>%
                 mutate(Area = subdata$Area[1])})
```

```
ut_area_sim_sorted = ut_area_sim %>%
  mutate(Var1 = factor(Var1, levels = lang_sorted),
         Var2 = factor(Var2, levels = lang_sorted),
         Area = factor(Area, levels = c("Phonology", "Morphology", "Syntax")))
ut_area_sim_sorted %>%
  ggplot(., aes(Var1, Var2, fill = similarity)) +
  geom_tile() +
  # geom_text(data = lgs_sim_sorted,
  #           mapping = aes(Var1, Var2,
  #                         label = round(similarity, digit = 1))) +
  scale_fill_continuous(type = "viridis") +
  facet_wrap(~Area) +
  # scale_x_discrete(position = "bottom") +
  labs(x = NULL, y = NULL) +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"),
        axis.text.y = element_text(size = 9),
        axis.text.x = element_text(angle = 90, size = 9, hjust = 1),
        axis.ticks = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank()) +
  coord_fixed()
```

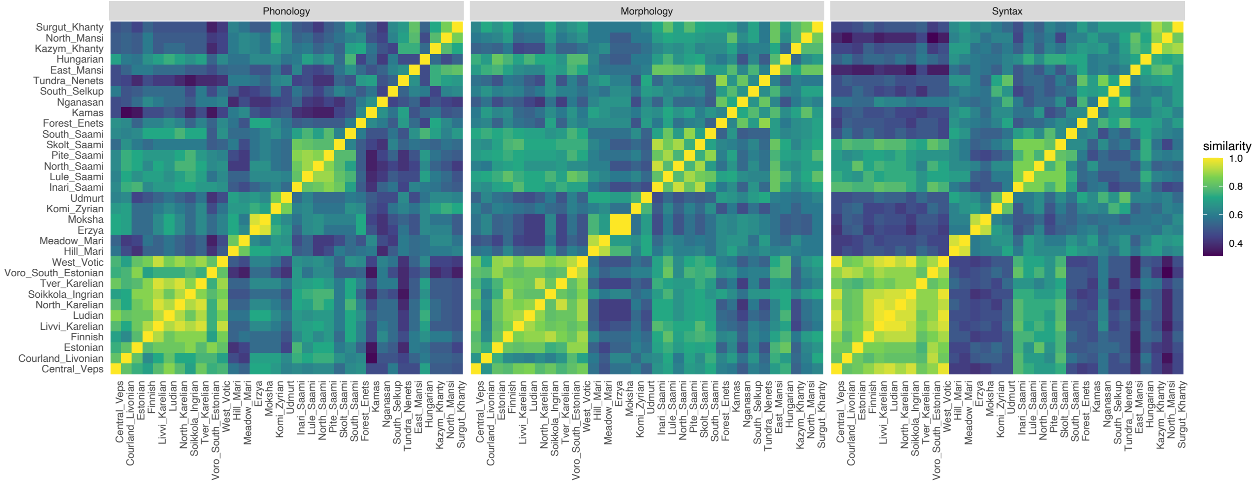


Figure 2: Typological similarities between Uralic languages across different areas in UT data

3 Geographical distances between languages

3.1 Function

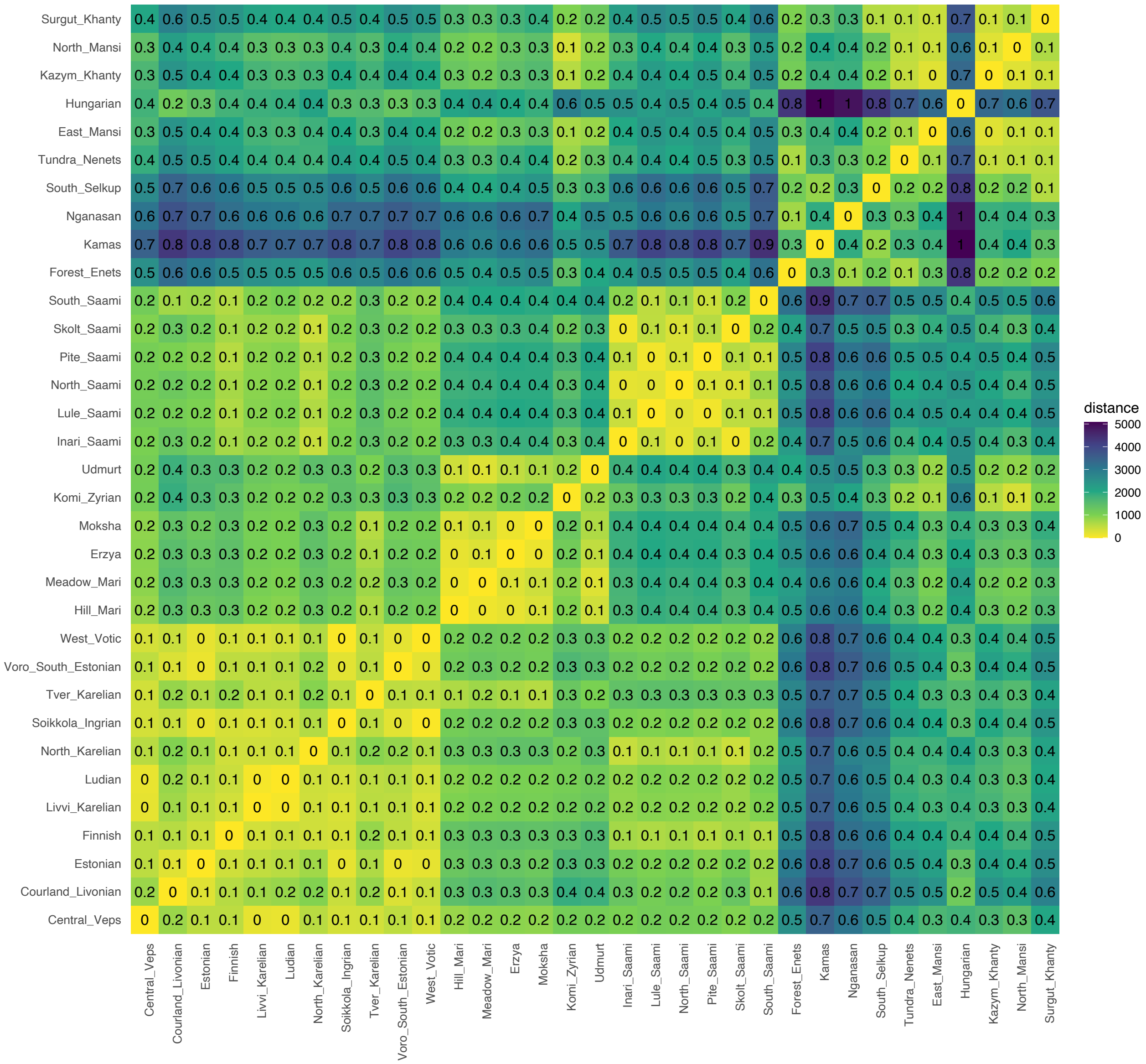
```
geographical_dist = function(data = lang_geo, x = lang1, y = lang2){
  lang1_location = data[x, ]
  lang2_location = data[y, ]
  return(distHaversine(lang1_location, lang2_location)/1000)
}
```

3.2 Measuring geographical distances

```
lang_geo = lang_df %>%
  dplyr::select(Name, Longitude, Latitude) %>%
  column_to_rownames(var = "Name")
```

```
geo_dist = expand.grid(lgs, lgs, stringsAsFactors = F) %>%
  rowwise() %>%
  mutate(distance = geographical_dist(data = lang_geo,
                                      x = Var1,
                                      y = Var2)) %>%
  ungroup %>%
  mutate(dist_scaled = distance/max(distance))
geo_dist_sorted = geo_dist %>%
  mutate(Var1 = factor(Var1, levels = lang_sorted),
         Var2 = factor(Var2, levels = lang_sorted))
```

```
geo_dist_sorted %>%
  ggplot(., aes(Var1, Var2, fill = distance)) +
  geom_tile() +
  geom_text(data = geo_dist_sorted,
            mapping = aes(Var1, Var2,
                          label = round(dist_scaled, digit = 1))) +
  scale_fill_continuous(type = "viridis", direction = -1) +
  labs(x = NULL, y = NULL) +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"),
        axis.text.y = element_text(size = 9),
        axis.text.x = element_text(angle = 90, size = 9, hjust = 1),
        axis.ticks = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank()) +
  coord_fixed()
```



	Central_Veps	Courland_Livonian	Estonian	Finnish	Livvi_Karelian	Ludian	North_Karelian	Soikkola_Ingrian	Tver_Karelian	Voro_South_Estonian	West_Votic	Hill_Mari	Meadow_Mari	Erzya	Moksha	Komi_Zyrian	Udmurt	Inari_Saami	Lule_Saami	North_Saami	Pite_Saami	Skolt_Saami	South_Saami	Forest_Enets	Kamas	Nganasan	South_Selkup	Tundra_Nenets	East_Mansi	Hungarian	Kazym_Khanty	North_Mansi	Surgut_Khanty
Surgut_Khanty	0.4	0.6	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.4	0.2	0.2	0.4	0.5	0.5	0.5	0.4	0.6	0.2	0.3	0.3	0.1	0.1	0.1	0.7	0.1	0.1	0
North_Mansi	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.2	0.2	0.3	0.3	0.1	0.2	0.3	0.4	0.4	0.4	0.3	0.5	0.2	0.4	0.4	0.2	0.1	0.1	0.6	0.1	0	0.1
Kazym_Khanty	0.3	0.5	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.2	0.3	0.3	0.1	0.2	0.4	0.4	0.4	0.5	0.4	0.5	0.2	0.4	0.4	0.2	0.1	0	0.7	0	0.1	0.1
Hungarian	0.4	0.2	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.6	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.8	1	1	0.8	0.7	0.6	0	0.7	0.6	0.7
East_Mansi	0.3	0.5	0.4	0.4	0.3	0.3	0.4	0.4	0.3	0.4	0.4	0.2	0.2	0.3	0.3	0.1	0.2	0.4	0.5	0.4	0.5	0.4	0.5	0.3	0.4	0.4	0.2	0.1	0	0.6	0	0.1	0.1
Tundra_Nenets	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.4	0.2	0.3	0.4	0.4	0.4	0.5	0.3	0.5	0.1	0.3	0.3	0.2	0	0.1	0.7	0.1	0.1	0.1
South_Selkup	0.5	0.7	0.6	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.4	0.4	0.4	0.5	0.3	0.3	0.6	0.6	0.6	0.6	0.5	0.7	0.2	0.2	0.3	0	0.2	0.2	0.8	0.2	0.2	0.1
Nganasan	0.6	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.7	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.7	0.1	0.4	0	0.3	0.3	0.4	1	0.4	0.4	0.3
Kamas	0.7	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.6	0.6	0.6	0.6	0.5	0.5	0.7	0.8	0.8	0.8	0.7	0.9	0.3	0	0.4	0.2	0.3	0.4	1	0.4	0.4	0.3
Forest_Enets	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.4	0.5	0.5	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.6	0	0.3	0.1	0.2	0.1	0.3	0.8	0.2	0.2	0.2
South_Saami	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.1	0.1	0.1	0.2	0	0.6	0.9	0.7	0.7	0.5	0.5	0.4	0.5	0.5	0.6
Skolt_Saami	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.2	0.3	0	0.1	0.1	0.1	0	0.2	0.4	0.7	0.5	0.5	0.3	0.4	0.5	0.4	0.3	0.4
Pite_Saami	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.4	0.3	0.4	0.1	0	0.1	0	0.1	0.1	0.5	0.8	0.6	0.6	0.5	0.5	0.4	0.5	0.4	0.5
North_Saami	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.4	0.3	0.4	0	0	0	0.1	0.1	0.1	0.5	0.8	0.6	0.6	0.4	0.4	0.5	0.4	0.4	0.5
Lule_Saami	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.4	0.3	0.4	0.1	0	0	0	0.1	0.1	0.5	0.8	0.6	0.6	0.4	0.5	0.4	0.4	0.4	0.5
Inari_Saami	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.4	0	0.1	0	0.1	0	0.2	0.4	0.7	0.5	0.6	0.4	0.4	0.5	0.4	0.3	0.4
Udmurt	0.2	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.1	0.1	0.1	0.1	0.2	0	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.3	0.3	0.2	0.5	0.2	0.2	0.2
Komi_Zyrian	0.2	0.4	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0	0.2	0.3	0.3	0.3	0.3	0.2	0.4	0.3	0.5	0.4	0.3	0.2	0.1	0.6	0.1	0.1	0.2
Moksha	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0	0	0.2	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.5	0.4	0.3	0.4	0.3	0.3	0.4
Erzya	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0	0.1	0	0	0.2	0.1	0.4	0.4	0.4	0.4	0.3	0.4	0.5	0.6	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.3
Meadow_Mari	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0	0	0.1	0.1	0.2	0.1	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.6	0.6	0.4	0.3	0.2	0.4	0.2	0.2	0.3
Hill_Mari	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0	0	0	0.1	0.2	0.1	0.3	0.4	0.4	0.4	0.3	0.4	0.5	0.6	0.6	0.4	0.3	0.2	0.4	0.3	0.2	0.3
West_Votic	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0	0	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.8	0.7	0.6	0.4	0.4	0.3	0.4	0.4	0.5
Voro_South_Estonian	0.1	0.1	0	0.1	0.1	0.1	0.2	0	0.1	0	0	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.8	0.7	0.6	0.5	0.4	0.3	0.4	0.4	0.5
Tver_Karelian	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.7	0.7	0.5	0.4	0.3	0.3	0.4	0.3	0.4
Soikkola_Ingrian	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0	0	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.8	0.7	0.6	0.4	0.4	0.3	0.4	0.4	0.5
North_Karelian	0.1	0.2	0.1	0.1	0.1	0.1	0	0.1	0.2	0.2	0.1	0.3	0.3	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.7	0.6	0.5	0.4	0.4	0.4	0.3	0.3	0.4
Ludian	0	0.2	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.7	0.6	0.5	0.4	0.3	0.4	0.3	0.3	0.4
Livvi_Karelian	0	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.7	0.6	0.5	0.4	0.3	0.4	0.3	0.3	0.4
Finnish	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.8	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.5
Estonian	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0	0	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.8	0.7	0.6	0.5	0.4	0.3	0.4	0.4	0.5
Courland_Livonian	0.2	0	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.3	0.1	0.6	0.8	0.7	0.7	0.5	0.5	0.2	0.5	0.4	0.6
Central_Veps	0	0.2	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.7	0.6	0.5	0.4	0.3	0.4	0.3	0.3	0.4

Figure 3: Geographical distances between Uralic languages