Quantifying degradation in synthesized sounds

baRulho:quantifying habitat-induced degradation of (animal) acoustic signals

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Table of contents

0.1 Load package

```
library(baRulho)
library(warbleR)
library(ggplot2)
library(cowplot)
library(grid)
```

0.2 Synthetize sounds

Create synthesized sounds to be used for making the master sound file for playback experiments:

```
synth_data <-
    synth_sounds(
        replicates = 3, # number of replicates for each unique combination of varying featur
        frequencies = seq(0.5, 10, length.out = 20),
        durations = c(0.2, 0.1),
        am = TRUE, # amplitude modulation
        fm = TRUE, # frequency modulation
        sig2 = 0.8, # frequency modulation parameter
        shuffle = TRUE # randomize the position of sounds
    )
```

The output is of class data frame and extended selection table (warbleR package format, here printed as a data frame):

```
head(synth_data, 10)
```

sound.files	selec	start	end	bottom.freq	top.freq	frequency	duration	frequency.modulation	amplitude.modulat
synthetic_sound_68	1	0.05	0.25	7.000	11.000	9	0.2	fm	am
synthetic_sound_70	1	0.05	0.25	1.990	6.023	4	0.2	fm	am
synthetic_sound_72	1	0.05	0.25	0.020	3.000	1	0.2	fm	am
synthetic_sound_119	1	0.05	0.25	4.984	9.009	7	0.2	fm	am
synthetic_sound_78	1	0.05	0.25	7.450	11.500	9.5	0.2	fm	am
synthetic_sound_120	1	0.05	0.25	2.486	6.688	4.5	0.2	fm	am
synthetic_sound_86	1	0.05	0.25	0.784	5.000	3	0.2	fm	am
synthetic_sound_78	2	0.05	0.25	7.450	11.500	9.5	0.2	fm	am
synthetic_sound_33	1	0.05	0.25	0.100	4.000	2	0.2	fm	am
synthetic_sound_93	1	0.05	0.25	4.343	8.500	6.5	0.2	fm	am

1 Create master sound file

This step puts all sounds together into a single sound file:

```
master_annotations <- master_sound_file(X = synth_data, # synthesized sound data
                      file.name = "master", # name of the sound file
                      gap.duration = 0.2) # duration of silence in between sounds
```

The output file is saved in the current working directory (can be modified using argument 'path'). A similar file was used for the playback experiments detailed in the paper. The following section shows how to access the test (re-recorded) files.

These are the annotations for the sounds in the master sound files:

```
head(master_annotations)
```

sound.files	selec	start	end	bottom.freq	top.freq	sound.id
master.wav	1	1.000000	2.000000	1.333333	2.666667	start_marker
master.wav	2	2.050000	2.250023	7.875000	8.805000	dur:0.2;freq:9;fm;am_1
master.wav	3	2.300023	2.500045	3.208000	4.069000	dur:0.2;freq:4;fm;am_1
master.wav	4	2.550045	2.750068	0.422000	1.223000	dur:0.2;freq:1;fm;am_1
master.wav	5	2.800068	3.000091	6.905000	7.917000	dur:0.2;freq:7;fm;am_1
master.wav	6	3.050091	3.250113	8.417000	9.416000	dur:0.2;freq:9.5;fm;am_1
master.wav	7	3.300113	3.500136	4.171000	4.839000	dur:0.2;freq:4.5;fm;am_1
master.wav	8	3.550136	3.750159	2.097000	2.961000	dur:0.2;freq:3;fm;am_1
master.wav	9	3.800159	4.000181	9.181000	10.033000	dur:0.2;freq:9.5;fm;am_2
master.wav	10	4.050181	4.250204	1.849000	2.506000	dur:0.2;freq:2;fm;am_1

1.1 Download data

This code downloads the test files. The files were re-recorded during a transmission experiment at 10, 30, 65 and 100 m:

```
path_to_files <- "PATH_TO_FILES"  # add folder path to keep master and test files

# directory path where supplementary files have been saved

options(sound.files.path = path_to_files)

download.file("https://figshare.com/ndownloader/files/41905809", destfile = file.path(path_to
    "degrad_exp_files.zip"))

unzip(file.path(path_to_files, "degrad_exp_files.zip"), exdir = file.path(path_to_files))
```

2 Find markers

The code below finds the position of the start and end markers in the test files:

```
# directory path where supplementary files have been saved
options(sound.files.path = path_to_files)

markers_in_tests <- find_markers(X = master_annotations)  # annotations of sounds in master

head(markers_in_tests)
```

running cross-correlation (step 1 out of 2): running peak detection (step 2 out of 2): ::: {.cell-output-display}

sound.files	selec	start	end	scores	marker	time.mismatch
trnsc1_100m_closed.wav	1	6.049203	7.049203	0.2228059	start_marker	0.0300544
trnsc1_100m_closed.wav	2	257.700686	258.700686	0.2727442	end_marker	NA
trnsc1_100m_open.wav	3	29.502300	30.502300	0.7150524	start_marker	0.0131017
trnsc1_100m_open.wav	4	281.136830	282.136830	0.6083450	end_marker	NA
trnsc1_10m_closed.wav	5	39.452253	40.452253	0.7046298	start_marker	0.0114997
trnsc1_10m_closed.wav	6	291.085182	292.085182	0.8364759	end_marker	NA
trnsc1_10m_open.wav	7	30.083747	31.083747	0.7667911	start_marker	0.0208117
trnsc1_10m_open.wav	8	281.725987	282.725987	0.8284335	end_marker	NA
trnsc1_1m_open.wav	9	100.116084	101.116084	0.8674470	start_marker	0.0097773
trnsc1_1m_open.wav	10	351.747290	352.747290	0.8857788	end_marker	NA

:::

The column 'time.mismatch' compares the time difference between the two templates on test-files against that in the master sound file. In a perfect marker detection the value must be 0, meaning that the time in between markers in the master and test files is exactly the same. In this case the average mismatch is of 14 ms and the highest of 32 ms:

```r
# average mismatch
mean(markers_in_tests$time.mismatch, na.rm = TRUE)
```

```
[1] 0.01438455
```

```r
# maximum mismatch
max(markers_in_tests$time.mismatch, na.rm = TRUE)
```

```
[1] 0.03171009
```

Modifying detection parameters as spectrogram type ('type' argument), time window overlap ('ovlp' argument) and hop size ('hop.size' argument) can be adjusted in order to improve precision. Note that for aligning all other sounds only the marker with the highest correlation will be used. Therefore the time mismatch is likely to be lower in the aligned test sounds.

3 Align sounds

Once we know the position of markers we can compute the position for all other sounds in the test files (i.e. align):

```r
aligned_tests <-
    align_test_files(X = master_annotations, # annotations of sounds in master file
                     Y = markers_in_tests) # position of markers in test files


head(aligned_tests)
```

sound.files	selec	start	end	bottom.freq	top.freq	sound.id	marker
trnsc1_100m_closed.wav	1	6.060315	7.060315	1.333333	2.666667	start_marker	end_marker
trnsc1_100m_closed.wav	2	7.110315	7.310338	7.875000	8.805000	dur:0.2;freq:9;fm;am_1	end_marker
trnsc1_100m_closed.wav	3	7.360338	7.560361	3.208000	4.069000	dur:0.2;freq:4;fm;am_1	end_marker
trnsc1_100m_closed.wav	4	7.610361	7.810383	0.422000	1.223000	dur:0.2;freq:1;fm;am_1	end_marker
trnsc1_100m_closed.wav	5	7.860383	8.060406	6.905000	7.917000	dur:0.2;freq:7;fm;am_1	end_marker
trnsc1_100m_closed.wav	6	8.110406	8.310429	8.417000	9.416000	dur:0.2;freq:9.5;fm;am_1	end_marker
trnsc1_100m_closed.wav	7	8.360429	8.560451	4.171000	4.839000	dur:0.2;freq:4.5;fm;am_1	end_marker
trnsc1_100m_closed.wav	8	8.610451	8.810474	2.097000	2.961000	dur:0.2;freq:3;fm;am_1	end_marker
trnsc1_100m_closed.wav	9	8.860474	9.060497	9.181000	10.033000	dur:0.2;freq:9.5;fm;am_2	end_marker
trnsc1_100m_closed.wav	10	9.110497	9.310519	1.849000	2.506000	dur:0.2;freq:2;fm;am_1	end_marker