

Diffrogram v2.3

Examples of usage with code (Matlab 2014b)

Version of the doc: 2.3

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1. Identical sine waves 1000 Hz as input and output; without time warping

Preparing the test signals

```
% Sine wave 1000 Hz
% 30s, -10 dBFS (rms), 2 channels, 44100 Hz, 32 bit
Fs = 44100; % [Hz]
L = 30; % [s]
G = -10; % [dB]
F = 1000; % [Hz]
Ls = round(L*Fs);
t = (0:Ls-1)';
x = 10^(G/20) * sin(t*2*pi/(Fs/F));
x = [x,x];
audiowrite('ref_sine1k_44.wav', x, Fs, 'BitsPerSample',32)
```

Computing the diffrogram

```
diffrogram('ref_sine1k_44.wav', 'ref_sine1k_44.wav', 100, 'Mono NoWarp');
```

Results

```
*****
***          Diffrogram V2.3          ***
***          soundexpert.org          ***
*****
FileRef: ref_sine1k_44.wav, 2 channel(s), 44100 Hz
FileOut: ref_sine1k_44.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: no
Low-pass filtering of OUT: no
Warping: no
Computing Df values .....
Resulting Df statistics (300 values):
Df.first = -Inf dB
Df.last = -148.7541 dB
For remaining 298 values:
Df.max = -143.6353 dB
Df.p75 = -145.5665 dB
Df.median = -153.5253 dB
Df.p25 = -Inf dB
Df.min = -Inf dB
Diffrogram file:
ref_sine1k_44.wav(44)__ref_sine1k_44.wav(44)__mono_100-Inf-153.5253-143.6353.png
Done.
```



Diffrogram file: ref_sine1k_44.wav(44)__ref_sine1k_44.wav(44)__mono_100-Inf-153.5253-143.6353.png

Diffrogram image file name consists of output and input sound file names, mode of operation, width of Df window WDIFF (ms), min/median(red)/max of all computed Df values (dB) except for the first and the last ones.

In this example the input and output signals are identical, no warping was applied, the diffrogram shows errors of Difference Level computation without warping; Grey bars correspond to perfectly identical waveforms when Df = -Inf (dB).

2. Output file with small deviation from 1000Hz (1000.002Hz); without time warping

Preparing the test signals

Reference (input) sound signal is from example 1. Output signal with deviation is generated as follows:

```
% Sin wave 1000.002 Hz
% 30s, -10 dBFS (rms), 2 channels, 44100 Hz, 32 bit
Fs = 44100; % [Hz] +1Hz
L = 30; % [s]
G = -10; % [dB]
F = 1000.002; % [Hz]
Ls = round(L*Fs);
t = (0:Ls-1)';
x = 10^(G/20) * sin(t*2*pi/(Fs/F));
x = [ref,ref];
audiowrite('out_sine1k+_44.wav', x, Fs, 'BitsPerSample',32)
```

Computing the diffrogram

```
diffrogram('ref_sine1k_44.wav', 'out_sine1k+_44.wav', 100, 'Mono NoWarp');
```

Results

```
*****
***          Diffrogram V2.3          ***
***          soundexpert.org          ***
*****
FileRef: ref_sine1k_44.wav, 2 channel(s), 44100 Hz
FileOut: out_sine1k+_44.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: no
Low-pass filtering of OUT: no
Warping: no
Computing Df values .....
Resulting Df statistics (300 values):
Df.first = -65.8002 dB
Df.last = -11.5495 dB
For remaining 298 values:
Df.max = -11.5782 dB
Df.p75 = -14.0306 dB
Df.median = -17.5172 dB
Df.p25 = -23.4704 dB
Df.min = -57.3476 dB
Diffrogram file:
out_sine1k+_44.wav(44)___ref_sine1k_44.wav(44)___mono_100-57.3476-17.5172-11.5782.png
Done.
```



Diffrogram file: out_sine1k+_44.wav(44)___ref_sine1k_44.wav(44)___mono_100-57.3476-17.5172-11.5782.png

Even small deviation of frequency of the output file results in erroneous Df measurements; time warping of the output signal is necessary (see example 3).

3. Output file with small deviation from 1000Hz (1000.002Hz); with time warping

Preparing the test signals

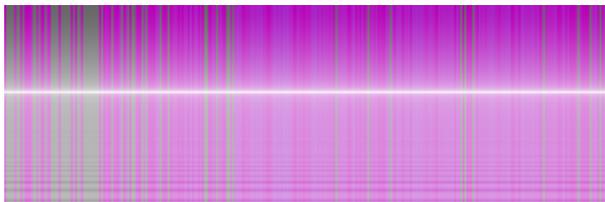
Input and output sound signals are from example 2.

Computing the diffrogram

```
diffrogram('ref_sine1k_44.wav', 'out_sine1k+_44.wav', 100, 'Mono');
```

Results

```
*****
***          Diffrogram V2.3          ***
***          soundexpert.org          ***
*****
FileRef: ref_sine1k_44.wav, 2 channel(s), 44100 Hz
FileOut: out_sine1k+_44.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: x4
WarpMargin: 5 samples
Warping: frame-wise (100 ms)
Number of frames: 300
Time warping ..... (may take a long time)
Frame: 1/300 Df: -151.0949 SCL: 3.999992 TAU: -0.0000
Frame: 2/300 Df: -Inf SCL: 3.999992 TAU: +0.9648
.....
Frame: 299/300 Df: -Inf SCL: 3.999992 TAU: +2.4866
Frame: 300/300 Df: -68.0112 SCL: 3.999992 TAU: +2.4513
Computing Df values .....
Resulting Df statistics (300 values):
Df.first = -151.0949 dB
Df.last = -68.0112 dB
For remaining 298 values:
Df.max = -141.9116 dB
Df.p75 = -146.7584 dB
Df.median = -149.1320 dB
Df.p25 = -154.7747 dB
Df.min = -Inf dB
Diffrogram file:
out_sine1k+_44.wav(44)__ref_sine1k_44.wav(44)__mono_100-Inf-149.1320-141.9116.png
Done.
```



Diffrogram file: out_sine1k+_44.wav(44)__ref_sine1k_44.wav(44)__mono_100-Inf-149.1320-141.9116.png

Time warping was applied and it compensated frequency deviation of the output signal; the diffrogram shows errors of Difference Level computation with time warping.

4. Identical white noise signals as input and output; with time warping

Preparing the test signals

```
% White noise
% 30s, -10 dBFS (rms), 2 channels, 44100 Hz, 32 bit
Fs = 44100; % [Hz]
L = 30; % [s]
PdB = -10; % [dB]
Ls = round(L*Fs);
ref = randn(Ls,1);
Po = sqrt(mean(ref.^2));
Pd = 10^(PdB/20)/sqrt(2);
Kp = Pd/Po;
x = ref .* Kp;
x = [x,x];
audiowrite('ref_wn.wav', x, Fs, 'BitsPerSample',32)
```

Computing the diffrogram

```
diffrogram('ref_wn.wav', 'ref_wn.wav', 100, 'Mono');
```

Results

```
*****
***          Diffrogram V2.3          ***
***          soundexpert.org          ***
*****
FileRef: ref_wn.wav, 2 channel(s), 44100 Hz
FileOut: ref_wn.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: x4
WarpMargin: 5 samples
Warping: frame-wise (100 ms)
Number of frames: 300
Time warping ..... (may take a long time)
Frame: 1/300 Df: -44.8321 SCL: 4.000000 TAU: -0.0000
Frame: 2/300 Df: -148.7541 SCL: 4.000000 TAU: +1.0000
.....
Frame: 299/300 Df: -Inf SCL: 4.000000 TAU: +1.0000
Frame: 300/300 Df: -152.5562 SCL: 4.000000 TAU: +1.0000
Computing Df values .....
Resulting Df statistics (300 values):
Df.first = -44.8321 dB
Df.last = -152.5562 dB
For remaining 298 values:
Df.max = -144.1052 dB
Df.p75 = -148.7541 dB
Df.median = -153.5253 dB
Df.p25 = -Inf dB
Df.min = -Inf dB
Diffrogram file:
ref_wn.wav(44)__ref_wn.wav(44)__mono_100-Inf-153.5253-144.1052.png
Done.
```



Diffrogram file: ref_wn.wav(44)__ref_wn.wav(44)__mono_100-Inf-153.5253-144.1052.png

Df values for white noise are computed with the same accuracy as for sine waves.

5. All-pass filtered white noise as output signal; with time warping

Preparing the test signals

Reference (input) sound signal is from example 4. Filtered output signal is generated as follows:

```
% Allpass filtered white noise
% 30s, -10 dBFS (rms), 2 channels, 44100 Hz, 32 bit
PdB = -10; % [dB]
[x,Fs] = audioread('ref_wn.wav');
a = [1 1/5 1/4 1/3];
b = [1/3 1/4 1/5 1];
% fvtool(b,a)
x = filter(b,a,x);
Pd = 10^(PdB/20)/sqrt(2);
P1 = sqrt(mean(x(:,1).^2));
P2 = sqrt(mean(x(:,2).^2));
Kp1 = Pd/P1;
Kp2 = Pd/P2;
x(:,1) = x(:,1) .* Kp1;
x(:,2) = x(:,2) .* Kp2;
audiowrite('out_wn_af.wav', x, Fs, 'BitsPerSample',32)
```

Computing the diffrogram

```
diffrogram('ref_wn.wav', 'out_wn_af.wav', 100, 'Mono');
```

Results

```
*****
FileRef: ref_wn.wav, 2 channel(s), 44100 Hz
FileOut: out_wn_af.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: x4
WarpMargin: 5 samples
Warping: frame-wise (100 ms)
Number of frames: 300
Time warping ..... (may take a long time)
Frame: 1/300 Df: -8.0199 SCL: 4.000024 TAU: -0.5319
Frame: 2/300 Df: -7.9308 SCL: 3.999982 TAU: +0.5762
.....
Frame: 299/300 Df: -8.0967 SCL: 4.000005 TAU: +0.5289
Frame: 300/300 Df: -8.2013 SCL: 3.999997 TAU: +0.5625
Computing Df values .....
Resulting Df statistics (300 values):
Df.first = -8.0199 dB
Df.last = -8.2013 dB
For remaining 298 values:
Df.max = -7.8717 dB
Df.p75 = -8.0760 dB
Df.median = -8.1572 dB
Df.p25 = -8.2211 dB
Df.min = -8.4315 dB
Diffrogram file:
out_wn_af.wav(44)__ref_wn.wav(44)__mono_100-8.4315-8.1572-7.8717.png
Done.
```



Diffrogram file: out_wn_af.wav(44)__ref_wn.wav(44)__mono_100-8.4315-8.1572-7.8717.png

White noise from example 4 was processed by all-pass filter and compared with the unprocessed one. Original waveform degraded substantially.

6. Glockenspiel sound sample with all-pass filter; with time warping

Preparing the test signals

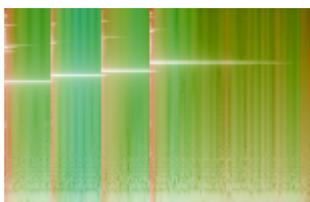
```
% All-pass filtered Glockenspiel sample
% ~15s, -23.7/-24.3 dBFS (rms), 2 channels, 44100 Hz
% 16bit(ref), 32bit(out)
[x,Fs] = audioread('ref_GLK.flac');
Pd1 = sqrt(mean(x(:,1).^2));
Pd2 = sqrt(mean(x(:,2).^2));
a = [1 1/5 1/4 1/3];
b = [1/3 1/4 1/5 1];
x = filter(b,a,x);
P1 = sqrt(mean(x(:,1).^2));
P2 = sqrt(mean(x(:,2).^2));
Kp1 = Pd1/P1;
Kp2 = Pd1/P2;
x(:,1) = x(:,1) .* Kp1;
x(:,2) = x(:,2) .* Kp2;
audiowrite('out_GLK_af.wav', x, Fs, 'BitsPerSample',32)
```

Computing the diffrogram

```
diffrogram('ref_GLK.flac', 'out_GLK_af.wav', 100, 'Mono');
```

Results

```
*****
FileRef: ref_GLK.flac, 2 channel(s), 44100 Hz
FileOut: out_GLK_af.wav, 2 channel(s), 44100 Hz
Channel mode: mono
Df window: 100 ms
Upsampling of OUT: x4
WarpMargin: 5 samples
Warping: frame-wise (100 ms)
Number of frames: 153
Time warping ..... (may take a long time)
Frame: 1/153 Df: -10.6886 SCL: 3.999768 TAU: -1.6557
Frame: 2/153 Df: -13.6612 SCL: 3.999871 TAU: -1.1867
.....
Frame: 152/153 Df: -21.5697 SCL: 3.996772 TAU: -0.7866
Frame: 153/153 Df: -6.5083 SCL: 4.006437 TAU: +0.0003
Computing Df values .....
Resulting Df statistics (152 values):
Df.first = -10.6886 dB
Df.last = -21.5697 dB
For remaining 150 values:
Df.max = -8.1194 dB
Df.p75 = -36.6174 dB
Df.median = -41.8556 dB
Df.p25 = -52.6307 dB
Df.min = -68.3725 dB
Diffrogram file:
out_GLK_af.wav(44)__ref_GLK.flac(44)__mono_100-68.3725-41.8556-8.1194.png
Done.
```



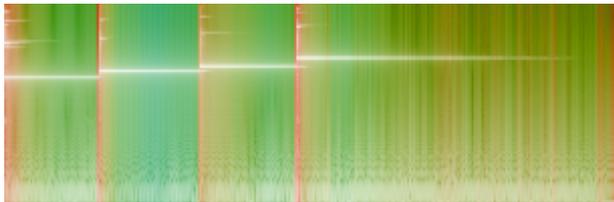
Diffrogram file: out_GLK_af.wav(44)__ref_GLK.flac(44)__mono_100-68.3725-41.8556-8.1194.png

This example is similar to example 5 but with Glockenspiel sample instead of white noise. Some parts of the sample degraded to a greater extent than others.

6.1. The time warped signal `out_GLK_af.wav(44)_warp_mono_100.wav` returned by `diffrogram` can be used to compute `diffrogram` with different time window `WDIFF`; no need to perform computationally intensive time warping once again:

```
diffrogram('ref_GLK.flac', 'out_GLK_af.wav(44)_warp_mono_100.wav', 50, 'Mono NoWarp');

*****
FileRef: ref_GLK.flac, 2 channel(s), 44100 Hz
FileOut: out_GLK_af.wav(44)_warp_mono_100.wav, 1 channel(s), 44100 Hz
Channel mode: mono
Df window: 50 ms
Upsampling of OUT: no
Low-pass filtering of OUT: no
Warping: no
Computing Df values .....
Resulting Df statistics (305 values):
Df.first = -10.7029 dB
Df.last = +0.0000 dB
For remaining 303 values:
Df.max = -7.1215 dB
Df.p75 = -35.3282 dB
Df.median = -41.8712 dB
Df.p25 = -52.6654 dB
Df.min = -68.3972 dB
Diffrogram file:
out_GLK_af.wav(44)_warp_mono_100.wav(44)__ref_GLK.flac(44)__mono_50-68.3972-41.8712-7.1215.png
Done.
```



Diffrogram file:
`out_GLK_af.wav(44)_warp_mono_100.wav(44)__ref_GLK.flac(44)__mono_50-68.3972-41.8712-7.1215.png`

`WDIFF = 50 (ms)` gives more detailed view of the waveform degradation

6.2. The `diffrogram` function also returns vector of `Df` values which can be further analyzed:

```
df = diffrogram('ref_GLK.flac', 'out_GLK_af.wav(44)_warp_mono_100.wav', 400, 'Mono NoWarp');

*****
FileRef: ref_GLK.flac, 2 channel(s), 44100 Hz
FileOut: out_GLK_af.wav(44)_warp_mono_100.wav, 1 channel(s), 44100 Hz
Channel mode: mono
Df window: 400 ms
Upsampling of OUT: no
Low-pass filtering of OUT: no
Warping: no
Computing Df values .....
Resulting Df statistics (38 values):
Df.first = -11.2074 dB
Df.last = -27.3396 dB
For remaining 36 values:
Df.max = -13.1459 dB
Df.p75 = -36.6951 dB
Df.median = -40.7265 dB
Df.p25 = -52.2094 dB
Df.min = -67.6922 dB
Diffrogram file:
out_GLK_af.wav(44)_warp_mono_100.wav(44)__ref_GLK.flac(44)__mono_400-67.6922-40.7265-13.1459.png
Done.
```



Diffrogram file:

out_GLK_af.wav(44)_warp_mono_100.wav(44)__ref_GLK.flac(44)__mono_400-67.6922-40.7265-13.1459.png

df =

-11.2074
-34.4483
-46.6810
-52.5358
-53.3624
-15.5776
-28.7708
-56.7683
-62.8135
-67.6922
-64.7958
-62.2056
-23.7432
-36.8535
-43.9034
-49.5757
-55.9277
-53.3604
-13.1459
-39.3353
-47.9665
-51.8831
-47.9137
-44.3937
-42.2497
-40.7828
-39.4609
-34.7714
-37.9869
-38.5757
-36.9734
-37.4781
-36.9789
-35.7930
-33.5749
-40.6702
-36.5367
-27.3396