Virtual Sound Source Positioning Using Vector Base

The listener is situated equidistant to each speaker. If each speaker has a base angle of $\Phi_0 = 45^\circ$ The panning span is [-45 45] degrees from right to left speaker.

Contents


```
phi0 = 45 * pi/180;
```

Seen from the listener a pan angle Φ. is shifted to be the angle $\Theta = \Phi + \Phi_0$ from the listeners position to the virtual sound positioning.

```
panAngle = 30
phi = panAngle * pi/180;
theta = phi + phi0;
```

```
panAngle =
    30
```

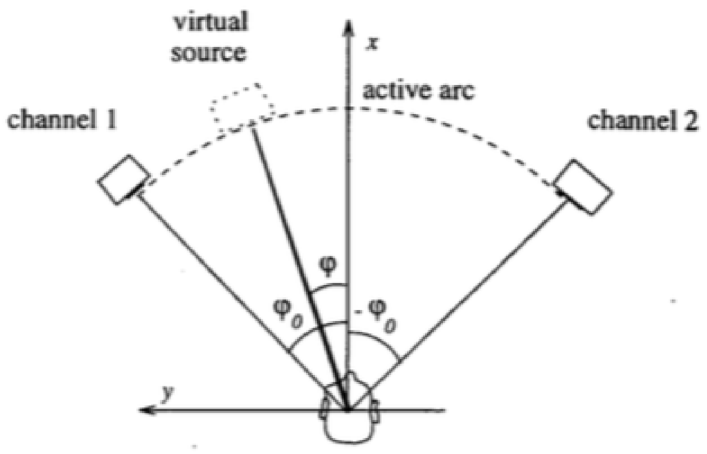


Fig. 1. Two-channel stereophonic configuration.

The trigonometric functions are most often used for panning gain since their power is unity as $1 = \cos^2 x + sin^2 x$

```
g1 = cos(theta);
g2 = sin(theta);
g = [g1 g2]';
```

If the source is moving during playback the sound power can be set to a constant as $C = g_1^2 + g_2^2$.

```
C = 1;
gScaled = sqrt(C)*g/sum(g.^2)
```

```
gScaled =
    0.2588
    0.9659
```

Vector definition

The base Vectors are defined by unit-length vectors. l_1 and l_2, which are pointing toward loudspeakers 1 and 2, respectively.

```
l1 = [-cos(phi0) sin(phi0)]';
l2 = [ cos(phi0) sin(phi0)]';
```

The unit-length vector p is pointing toward the virtual sound source position The virtual source can be treated as a linear combination of loudspeaker vectors with gains g1 and g2 by multiplying the gain g and the L matrix

```
% $p^T = g^TL$
L = [l1 l2];
pT = gScaled'*L
```

```
pT =
    0.5000    0.8660
```

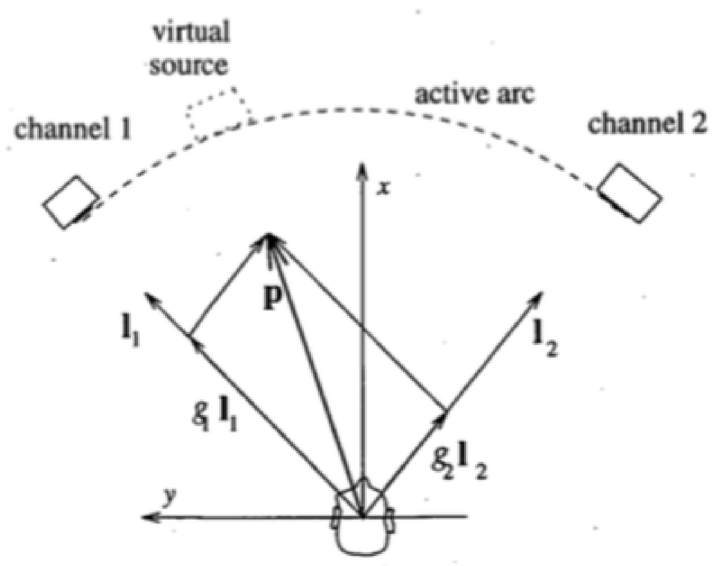


Fig. 3. Stereophonic configuration formulated with vectors.

Under these assumptions for a given panning angle Θ is found as: $\Hat{\Theta} = \Arctan{p_1/p_2}

```
estimatedAngle = atan(pT(1)/pT(2))*180/pi
```

```
estimatedAngle =
   30.0000
```

The described panning model is based on http://lib.tkk.fi/Diss/2001/isbn9512255324/article1.pdf by Ville Pulkki)

EXAMPLE with two simulated harmonic signals.

We simulate a signal with two sources with natural guitar amplitudes

```
clear all;
trueAngle1 = 23.45
trueAngle2 = -32.46
fs = 44100;
duration = 0.04;

load('/Users/home/Documents/MATLAB/code/test_programs/source_separation/betaMean_Martin_40ms.mat');
load('/Users/home/Documents/MATLAB/code/test_programs/source_separation/a_hat_file_used_in_test_on_L.mat');
s500 = smc_sum_of_sines(smc_beta_model(500,0,18), abs(aHat(:,1,3)), 18, duration, fs );
s1500 = smc_sum_of_sines(smc_beta_model(700,0,7), abs(aHat(:,1,3)), 7, duration, fs );
```

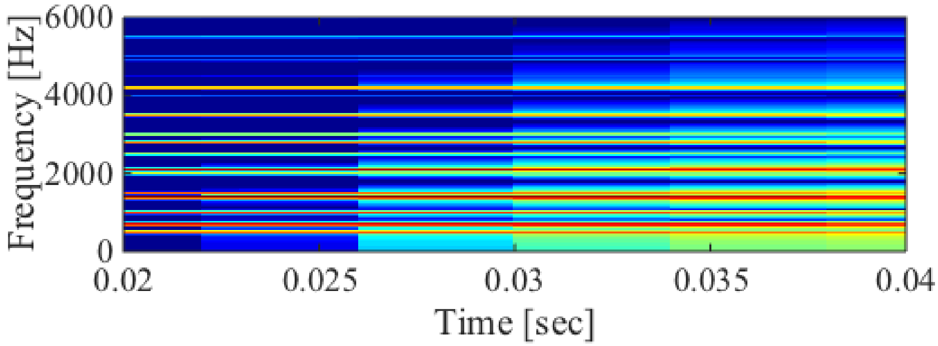
```
trueAngle1 =
   23.4500
trueAngle2 =
  -32.4600
```

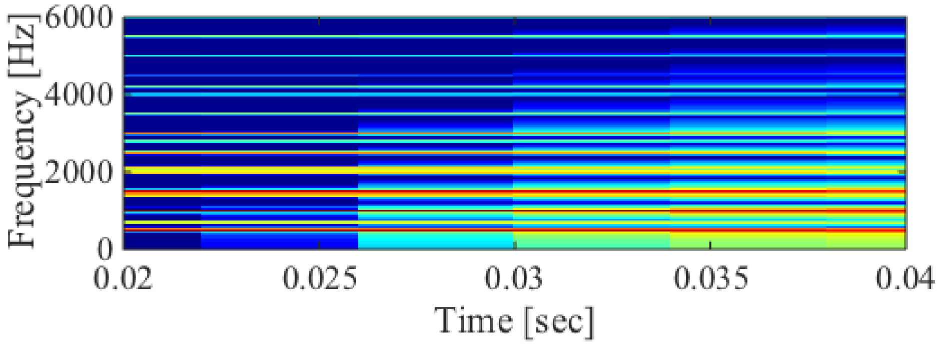
We pan the signals to each side

```
[g1] = VBAP2(trueAngle1);
[g2] = VBAP2(trueAngle2);

s1 = s500*g1(1) + s1500*g2(1);
s2 = s500*g1(2) + s1500*g2(2);
s = [s1 s2];

    figure;
        subplot(211); smc_spectrogram(s1,fs); xlim([0.02 0.04]); ylim([0 6e3]);
        subplot(212); smc_spectrogram(s2,fs); xlim([0.02 0.04]); ylim([0 6e3]);
```





Pitch and complex amplitude estimation

Transform to analytic

```
x1 = analytic(s1); fs2=fs/2;
x2 = analytic(s2); fs2=fs/2;
```

estimate the first pitch with joint ANLS

```
[w0,L] = joint_anls(x1, [1e-3 0.25],2^12);
pitchEstimateJointANLS = w0*fs/4/pi;
```

```
L =
     6
w0 =
    0.1994
```

```
Refine the pitch estimates
```

```
[f, X1] = smc_fft(s1,fs,2^22);
[pitchEstimateL CL]= smc_ANLS(X1, pitchEstimateJointANLS*[0.97 1.03], L, fs);
[f, X2] = smc_fft(s2,fs,2^22);
[pitchEstimateR CR] = smc_ANLS(X2, pitchEstimateJointANLS*[0.93 1.03], L, fs);
if CR>CL
    pitchEstimate = pitchEstimateR
else
    pitchEstimate = pitchEstimateL
end
```

```
pitchEstimate =
  699.9572
```

Estimate complex amplitudes for each side from estimated pitch and model order using LS.

```
Z = smc_Z(pitchEstimate, length(x1), fs2, L);
aLeft  = inv(Z'*Z)*Z'*x1;
aRight = inv(Z'*Z)*Z'*x2;
```

Angle Estimation

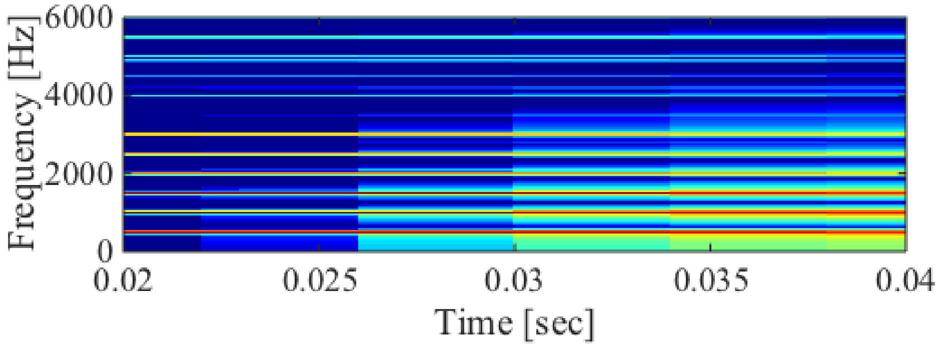
finally we can estimate the angle from the estimated energy contained in the amplitudes.

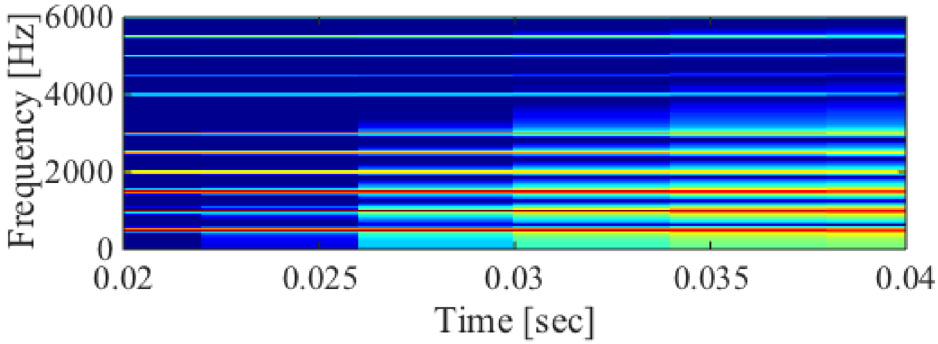
```
g1 = sum(abs(aLeft));
g2 = sum(abs(aRight));
phi0 = 45 * pi/180;
l1 = [-cos(phi0) sin(phi0)]';
l2 = [ cos(phi0) sin(phi0)]';
L = [l1 l2];
g = [g1 g2]'; C = 1;
gScaled = sqrt(C)*g/sqrt(g1^2+g2^2);
pT = gScaled'*L;
estimatedAngle1 = atan(pT(1)/pT(2))*180/pi;
```

Subtract estimate from source and iterate

We model the signals in real space time domain and subtract them from the given input.

```
x1Hat = Z*aLeft;
x2Hat = Z*aRight;
sL = ianalytic(x1-x1Hat);
sR = ianalytic(x2-x2Hat);
%
    figure;
        subplot(211); smc_spectrogram(sL,fs);xlim([0.02 0.04]); ylim([0 6e3]);
        subplot(212); smc_spectrogram(sR,fs);xlim([0.02 0.04]); ylim([0 6e3]);
```



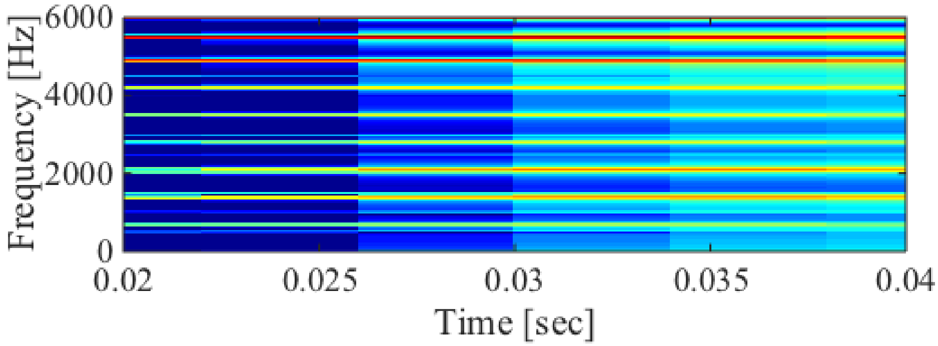


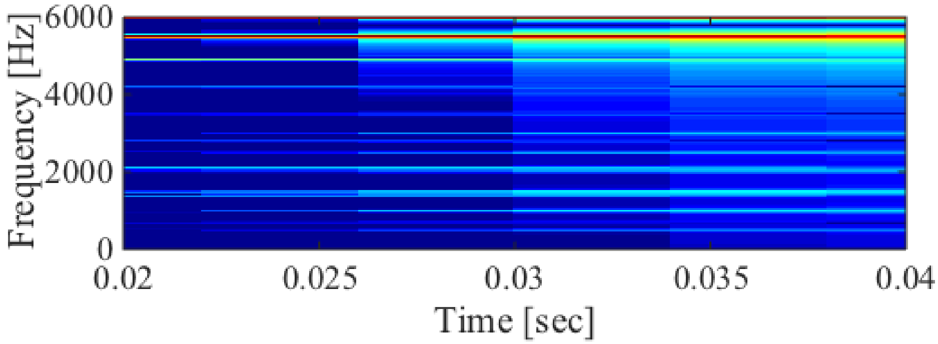
We estimate the next source with the same procedure.

```
[estimatedAngle2 , sL, sR] = smc_angle_estimator([sL sR],fs);

    figure;
        subplot(211); smc_spectrogram(sL,fs);xlim([0.02 0.04]); ylim([0 6e3]);
        subplot(212); smc_spectrogram(sR,fs);xlim([0.02 0.04]); ylim([0 6e3]);
```

```
L =
    10
w0 =
    0.1427
g =
    0.4113
    1.0414
```





Finally we have estimated the two panning angles

```
error1 = abs(estimatedAngle1-trueAngle2)
error2 = abs(estimatedAngle2-trueAngle1)
```

```
error1 =
    0.1768
error2 =
    0.0020
```

Published with MATLAB® R2014b