

固定波束

学习目标

仿真实验: 用RIR仿真生成数据, 设计固定波束验证去混响的效果, 绘制指向因子和白噪声增益图;

实测波束: 利用真实麦克风阵列数据, 分析不同麦克风数量和目标方位对设计波束的增强结果的影响。

实验设置

1. 使用rir_generator生成数据
2. 8 mic 均匀线阵, 间距 3cm
3. 延迟相加波束
4. 目标方向与线阵垂直

实验内容

1. 声源与阵列垂直, 主观听测去混响效果, pesq
2. 声源与阵列共线, 主观听测去混响效果, pesq
3. 声源与阵列垂直, 麦克风数量减少为4个, 主观听测去混响效果, pesq
4. 绘制波束模式、指向因子、白噪声增益

代码

全部代码及测试数据: <https://github.com/RRRRwys/dasp-homework>

- cal_pesq.py : 用于计算 pesq 取值

```

1 from scipy.io import wavfile
2 from pesq import pesq
3 def cal_pesq(f1,f2):
4     rate, ref = wavfile.read(f1)
5     rate, deg = wavfile.read(f2)
6     print(f1,f2)
7     print('wb', pesq(rate, ref, deg, 'wb')) # 宽带pesq
8     print('nb', pesq(rate, ref, deg, 'nb'))
9
10 cal_pesq('./speech.wav', './speech_rev_ds_90_4.wav')

```

- dir_vec.m : 计算导向矢量

```

1 function dfc = dir_vec(f, tar_angle, angle, M, dis, c)
2 % 计算均匀线阵导向矢量
3 % Input:
4 %   f 频率 Hz
5 %   angle 目标方向 弧度
6 %   M 麦克风数量
7 %   dis 间距 m
8 %   c 声速 m/s
9 % Output:
10 %   dfc 导向矢量
11
12 dfc = zeros(M,1);
13 dt = dis / c;
14 cosd = cos(angle+pi/2-tar_angle);
15 for p = 1:M
16     dfc(p) = exp(-1i*2*pi*f*dt*(p-1)*cosd);
17 end
18 end

```

- fix_beam_DS.m : 延迟相加波束计算波束模式，指向因子，白噪声增益

```

1 clc;close all;clear;
2
3 %%%%%%%%%%%%%%
4
5 % dir_vec
6

```

```

7  M = 8;
8  f = 8000;
9  dis = 0.03;
10 c = 340;
11 tar_angle = pi/2;
12
13 angles = 0: pi/1000 : pi*2.0;
14 g = zeros(length(angles),1);
15
16 for i = 1:length(angles)
17     angle = angles(i);
18     dirv = dir_vec(f, tar_angle, angle, M, dis, c);
19     h = dirv;
20     g(i) = abs(sum(h))/M;
21 end
22
23 figure
24 polar(angles', 20*log10(g) - min(20*log10(g)));
25 title('波束模式');
26
27 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
28 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
29 fq = 20:1000:20000;
30 wng = zeros(4,length(i));
31 for i = 1:length(fq)
32     f = fq(i);
33     d = dir_vec(f, tar_angle, tar_angle, 2, dis, c);
34     h = d/2;
35     wng(1,i) = abs(h'*d)^2/(h'*h);
36
37     d = dir_vec(f, tar_angle, tar_angle, 4, dis, c);
38     h = d/4;
39     wng(2,i) = abs(h'*d)^2/(h'*h);
40
41     d = dir_vec(f, tar_angle, tar_angle, 6, dis, c);
42     h = d/6;
43     wng(3,i) = abs(h'*d)^2/(h'*h);
44
45     d = dir_vec(f, tar_angle, tar_angle, 8, dis, c);
46     h = d/8;
47     wng(4,i) = abs(h'*d)^2/(h'*h);
48 end

```

```

49
50 figure;
51 hold on;
52 plot(fq, 10*log10(wng(1,:)), '-r*');
53 hold on;
54 plot(fq, 10*log10(wng(2,:)), '-g*');
55 hold on;
56 plot(fq, 10*log10(wng(3,:)), '-bo');
57 hold on;
58 plot(fq, 10*log10(wng(4,:)), '-m+');
59 hold on;
60 ylabel('WNG(dB)');
61 xlabel('f(hz)');
62 title('白噪声增益');
63
64 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
65
66 % 指向因子 DF
67
68 fq = 20:200:20000;
69 DF = zeros(4,length(i));
70 for i = 1:length(fq)
71     f = fq(i);
72
73     M = 2;
74     gama = zeros(M);
75     dt = dis/c;
76     for ii = 1:M
77         for jj = 1:M
78             if(ii ~= jj)
79                 gama(ii,jj) = sin(2*pi*f*(jj-ii)*dt)/(2*pi*f*
(jj-ii)*dt);
80             else
81                 gama(ii,jj) = 1.0;
82             end
83         end
84     end
85     d = dir_vec(f, tar_angle, tar_angle, M, dis, c);
86     h = d/M;
87     DF(1,i) = abs(h'*d)^2/(h'*gama*h);
88
89     M = 4;

```

```

90     gama = zeros(M);
91     dt = dis/c;
92     for ii = 1:M
93         for jj = 1:M
94             if(ii ~= jj)
95                 gama(ii,jj) = sin(2*pi*f*(jj-ii)*dt)/(2*pi*f*
(jj-ii)*dt);
96             else
97                 gama(ii,jj) = 1.0;
98             end
99         end
100     end
101     d = dir_vec(f, tar_angle, tar_angle, M, dis, c);
102     h = d/M;
103     DF(2,i) = abs(h'*d)^2/(h'*gama*h);
104
105     M = 6;
106     gama = zeros(M);
107     dt = dis/c;
108     for ii = 1:M
109         for jj = 1:M
110             if(ii ~= jj)
111                 gama(ii,jj) = sin(2*pi*f*(jj-ii)*dt)/(2*pi*f*
(jj-ii)*dt);
112             else
113                 gama(ii,jj) = 1.0;
114             end
115         end
116     end
117     d = dir_vec(f, tar_angle, tar_angle, M, dis, c);
118     h = d/M;
119     DF(3,i) = abs(h'*d)^2/(h'*gama*h);
120
121     M = 8;
122     gama = zeros(M);
123     dt = dis/c;
124     for ii = 1:M
125         for jj = 1:M
126             if(ii ~= jj)
127                 gama(ii,jj) = sin(2*pi*f*(jj-ii)*dt)/(2*pi*f*
(jj-ii)*dt);
128             else
129                 gama(ii,jj) = 1.0;

```

```

130         end
131     end
132 end
133 d = dir_vec(f, tar_angle, tar_angle, M, dis, c);
134 h = d/M;
135 DF(4,i) = abs(h'*d)^2/(h'*gama*h);
136 end
137
138 figure;
139 hold on;
140 plot(fq, 10*log10(abs(DF(1,:))), '-r*');
141 hold on;
142 plot(fq, 10*log10(abs(DF(2,:))), '-g*');
143 hold on;
144 plot(fq, 10*log10(abs(DF(3,:))), '-bo');
145 hold on;
146 plot(fq, 10*log10(abs(DF(4,:))), '-m+');
147 hold on;
148 ylabel('DF(dB)');
149 xlabel('f(hz)')
150 title('指向因子');
151
152 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
153 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

- cancel_rev.m : 基于阵列实现延迟相加波束，观察其对于去混响的影响

```

1 clear; close all; clc;
2
3 % position
4 c = 340;
5 fs = 16000;
6 % M = 8; % number of mic
7 M = 4;
8 r = [
9     %2.00 1.5 2;
10    %2.03 1.5 2;
11    2.06 1.5 2;
12    2.09 1.5 2;
13    2.12 1.5 2;
14    2.15 1.5 2;

```

```

15     %2.18 1.5 2;
16     %2.21 1.5 2
17 ];
18
19 s = [2.105 2 2]; % 90
20 % s = [2.71 1.5 2]; % 0
21
22 tar_angle = pi/2;
23
24 L = [5 4 3];
25 beta = 0.69;
26 n = 4096;
27 h = rir_generator(c, fs, r, s, L, beta, n);
28
29 [x,fs] = audioread('speech.wav');
30 y = [];
31 for i = 1:M
32     tmp = filter(h(i,:),[1.],x);
33     filename = sprintf('speech_rev_%d_90_4.wav',i);
34     audiowrite(filename, tmp, fs);
35     y = [y ; tmp'];
36 end
37
38 % pi / 2
39 y1 = zeros(1,length(y(1,:)));
40 for i = 1:M
41     y1 = y1 + y(i,:);
42 end
43
44 filename = 'speech_rev_ds_90_4.wav';
45 audiowrite(filename, y1, fs);
46

```

实验结果

1. 声源与阵列垂直，主观听测去混响效果，pesq

- 主观听测，有一定的效果；
- pesq 测试结果如下，可以看到pesq有了明显提升；

音频	宽带 PESQ
channel1 带混响	1.961

音频	宽带 PESQ
channel2 带混响	1.999
channel3 带混响	1.975
channel4 带混响	1.882
channel5 带混响	1.913
channel6 带混响	1.989
channel7 带混响	1.989
channel8 带混响	1.965
DS波束 去混响	2.301

2. 声源与阵列共线，主观听测去混响效果，pesq

- 主观听测，效果不好，混响甚至更严重了；
- pesq 测试结果如下，可以看到pesq出现下降；

音频	宽带 PESQ
channel1 带混响	1.716
channel2 带混响	1.708
channel3 带混响	1.702
channel4 带混响	1.698
channel5 带混响	1.696
channel6 带混响	1.777
channel7 带混响	1.752
channel8 带混响	1.760
DS波束 去混响	1.635

3. 声源与阵列垂直，麦克风数量减少为2和4，主观听测去混响效果，pesq

- 去除了2侧的个2个mic，保留中间 4 个
- 主观听测，效果没有明显下降；
- pesq 测试结果如下，可以看到pesq相对去混响前有一定提升，但是比 8mic 时，效果有一定下降；

音频	宽带 PESQ
channel1 带混响	1.975
channel2 带混响	1.882

音频	宽带 PESQ
channel3 带混响	1.913
channel4 带混响	1.989
DS波束 去混响	2.112

4. 绘制波束模式、指向因子、白噪声增益



