EVALUATION OF DISTANCE BASED AMPLITUDE PANNING FOR SPATIAL AUDIO

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ABSTRACT

Distance-Based Amplitude Panning (DBAP) has recently been proposed as a new technique for panning sound sources in two and three dimensional spaces spaces. In this paper, DBAP is compared with two established alternatives, Ambisonics and Vector-Based Amplitude Panning, both objectively in terms of speaker gains and their variation with source position, and subjectively using listening tests to estimate apparent source position.

Index Terms— Spatial Audio, Vector Distance Panning, Ambisonics, Vector Based Amplitude Panning, Distance- Based Amplitude Panning

1. INTRODUCTION

Two of the most common techniques for spatial audio reproduction are Vector-Based Amplitude Panning (VBAP) [1] and Ambisonics [2]. They share the ability to place sound sources anywhere on a surface represented by the loudspeaker array. They have advantages over 5.1 surround and related formats, which assume the listener's attention is focused towards the front and have limited resolution of sources placed behind. Nor do they require the large number of speakers needed for wave field synthesis. Thus, both techniques are appealing in their ability to offer improved spatialisation in a consumer environment.

However, both VBAP and Ambisonics suffer several limitations. They both assume that the position of the listener is known, fixed and restricted to a small area. Although both techniques may be modified [3, 4], neither is intended for placing sources inside the speaker array (as opposed to on the surface). Furthermore, Ambisonics typically requires that the speakers are surrounding the listener either on a two-dimensional ring or a three-dimensional sphere.

To address these issues, Distance-Based Amplitude Panning (DBAP) was recently proposed in [5], and independently in [6] (where it was referred to as Vector Distance Panning). This spatialization technique makes no assumptions as to where the listeners are situated, and has no requirements regarding the speaker arrangement. In this work we evaluate DBAP and compare it with VBAP and Ambisonics, both objectively in terms of speaker gains and their variation with source position, and subjectively using listening tests.

2. DISTANCE-BASED AMPLITUDE PANNING

Consider a source placed in a Cartesian coordinate system at position P, where there are N loudspeakers placed at positions speaker S_1, S_2,… S_N, each at a distance D_1, D_2,… D_N from the intended source position. As with stereo panning and VBAP, we assume that the gains on the speakers are normalized in order to have a balanced system with constant energy.

$$\sqrt{\sum_{n=1}^{N} {g_n}^2} = 1 \qquad (1).$$

The gain for each speaker is then found by assuming that it is inversely proportional to the distance between the speaker and the source position.

$$g_n = c / D_n \qquad (2)$$

As noted in [5], c may be dependent on the exact nature of the inverse distance law for sound propagation. But this is unimportant, since (1) and (2) may be combined to give,

$$g_n = \frac{1}{d_n \sqrt{\sum_{i=1}^{N} 1/{d_i}^2}} \qquad (3)$$

Several benefits of this technique are immediately apparent. The number of speakers is not restricted, and the speakers may be placed in any arrangement. This technique is similar to VBAP, where gain factors are also derived from speaker's position. But rather than using directional components of the vectors, with DBAP we use the distance as a whole to calculate the gains. The gains for each speaker are independent of the listener's position. Only the distances to the virtual sound source are important.

However, if the listener position is known, then further improvements can be made. To assure that the sound from each speaker will arrive at the same time to the listener, the proper delay should be added to each speaker output. Eq. (4) can be used to calculate the delay in samples, d_n, added to speaker n's output.

$$d_n = (\max(D_{L,1}, D_{L,2}, \ldots D_{L,N}) - D_{L,n})\, f_s / v_s \qquad (4)$$

where $D_{L,n}$ is the distance from speaker n to the listener's position, v_s is the speed of sound and f_s is the sampling frequency.

3. SPEAKER GAINS IN VBAP AND DBAP.

VBAP requires a triplet of speakers to pan a sound source. Thus, for direct comparison, we will also apply DBAP with 3 speakers. In the following 3 tests we will show the differences in gain values between VBAP and DBAP by changing the listener's position. We randomly choose 3 speakers with radius, azimuth angle and elevation angle of (1,0,28.3), (1,0,0) and (1,41.9,0) for speakers 1, 2 and 3, respectively. The azimuth angle goes clockwise from 0 in front of the listener to 180 degrees behind the listener, and elevation angle goes from 0 degrees in front of the listener to -90 degrees directly below and 90 degrees directly above the listener. For VBAP, we assume the listener is 1 meter away, at the origin.

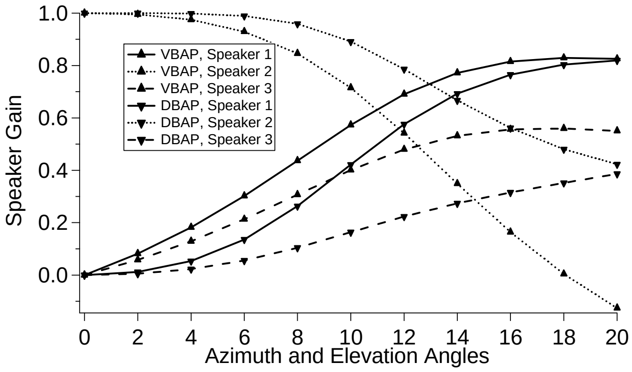

Figure 1. Gain differences between VBAP and DBAP. Sound position elevation angle and azimuth angle are changed simultaneously from 0 to 20 degrees.

Figure 1 depicts the gain values for VBAP and DBAP when a sound source is panned by changing both elevation and azimuth angle from 0 to 20 degrees It can be seen here that we have more smooth changes in DBAP than VBAP. This is because VBAP is sensitive to directional component changes, whereas DBAP is sensitive to distance only. Similar results were found when only the azimuth or only the elevation angle was changed.

4. SPEAKER GAINS IN AMBISONICS AND DBAP

In this section we compare gain values from 3rd order ambisonics and DBAP using 16 speakers over 3 tiers, as configured in the Centre for Digital Music at Queen Mary University of London's Listening Room. Table 1 shows the speaker positions in polar coordinates.

Figure 2 depicts the speaker gains for ambisonics and DBAP with various sound source positions. Ambisonics and DBAP are very different in their approaches. Ambisonics is a technique based on spherical harmonics for reproduction of the sound field. In contrast, DBAP does not intend to reproduce the sound field, but simply to place the source in a preferred location. Thus the speaker gains that are produced are very different.

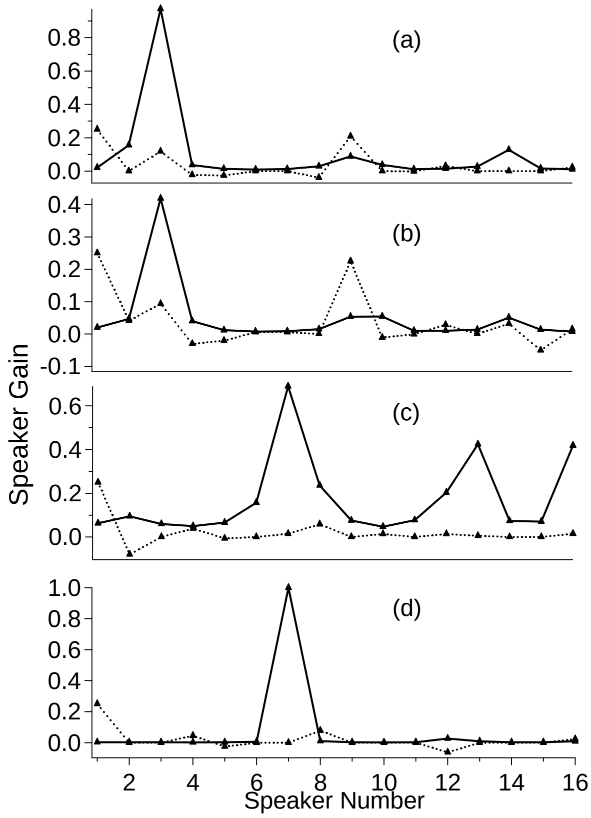

Figure 2. Speaker gains for ambisonics (dashed curve) and DBAP (solid curve) for 4 source positions; (a) Azimuth=30º Elevation=0º, (b) Azimuth=45º Elevation=15º, (c) Azimuth=270º Elevation=-30º, (d) Azimuth=270º Elevation=0º.

Speaker number	Azimuth angle	Elevation angle
1	90	0
2	0	0
3	41.9	0
4	94.6	0
5	150.6	0
6	-152.4	0
7	-94.5	0
8	-44	0
9	0	28.3
10	90	27.2
11	180	26.7
12	-90	27.5
13	-45	-29
14	45	-30
15	135	-25.9
16	-135	-27.8

Table 1. The speaker array positions.

5. SUBJECTIVE EVALUATION

For performing the tests below 5 different sound sources in the 3D speaker array was chosen. Twelve candidates were involved in the tests, 7 of them with previous experience of research in the audio field, 2 with little experience, and 3 with no experience. The speaker array listed in Table 1 was used.

Candidates were asked to locate the sound source. Five different sound clips were played; 3 bands, 1 woman voice and 1 instrumental. For all of the DBAP and VBAP tests, delay was added to each speaker using (4) in order for the sound to reach the listener at the same time.

5.1. Comparing DBAP and VBAP

Three different sound sources with locations given in Table 2 (radial distance is fixed at 1 meter), positions 1 to 3, were chosen to compare VBAP and DBAP. The positions and techniques were played in random order.

Position No	Azimuth	Elevation	Music type	Speaker No
1	25^0	10^0	guitar	2,3,9
2	130^0	0^0	woman voice	4,5,10
3	-20^0	-20^0	band	2,8,13
4	45^0	30^0	band	all
5	160^0	45^0	band	all

Table 2. Different sound source positions for subjective evaluation of VBAP, DBAP, and ambisonics.

Three speakers were used for panning the sound source. The speakers used in each test are given with their numbers in the last column of Table 2. For position 1, participants were asked to move 1m back from their original position and then again to point the location of the sound. Figure 3 shows the answers of each participant.

The average results are shown in Table 3 for each position. Both VBAP and DBAP performed similarly, including when the listener moved away from the sweet spot. Overall, DBAP performs slightly worse in terms of average results, but slightly better in terms of standard deviation.

	DBAP Angle		VBAP Angle	
Position	azimuth	elevation	azimuth	elevation
1	26.29	8.58	26.33	5.9
1, 1m back	33.75	7.75	27.68	4.36
2	140.636	4.54	131.79	5.17
3	-10.75	7.5	-10.96	-2.9

Table 3. Average results for perceived source position with DBAP and VBAP.

5.2. Comparing DBAP and Ambisonics

Two different sound sources were chosen for comparison with 3rd order ambisonics, given by positions 4 and 5 in Table 2. In each case, all speakers were used, and the music was multi-voice (rock band). A different sound clip was played from each location.

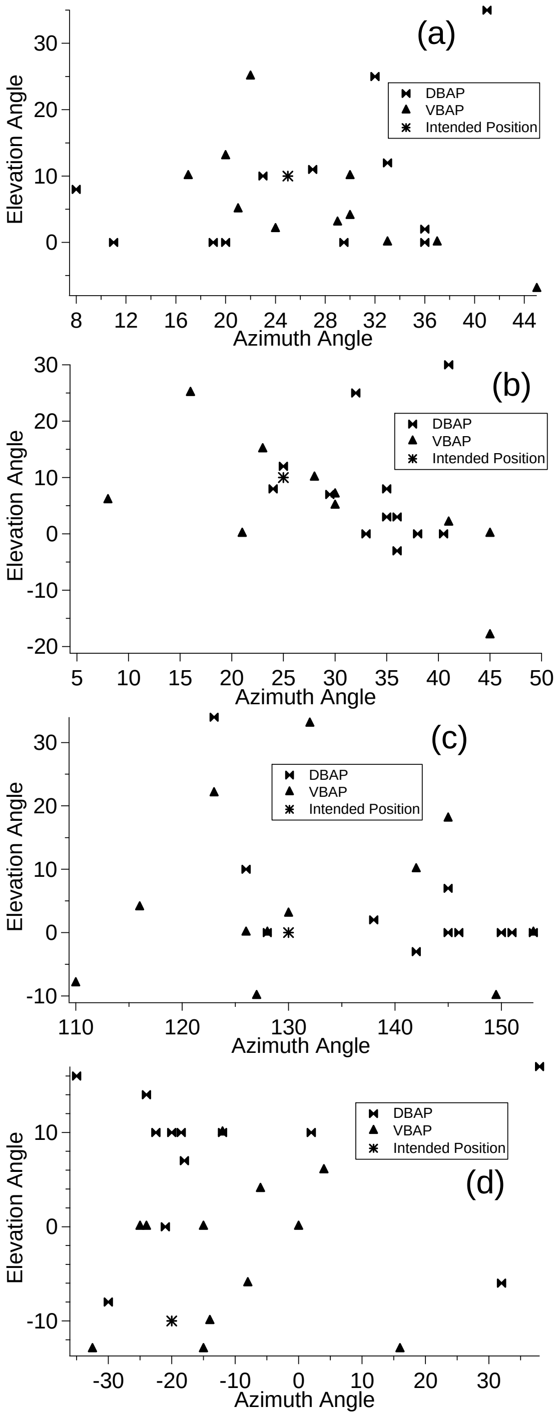

Figure 3. Subjective evaluation results for VBAP and DBAP with 3 different sound source positions. (a) Position 1, (b) Position 1, 1 meter back, (c) Position 2, (d) Position 3.

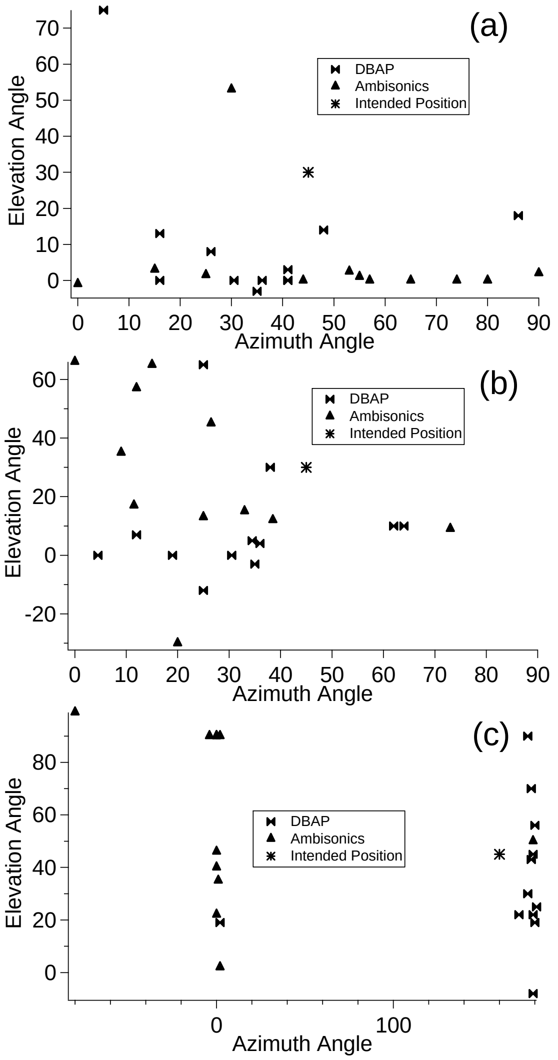

Figure 4. Subjective evaluation results for 3rd order ambisonics and DBAP with 2 different sound source positions. (a) Position 4, (b) Position 4, 1 meter back, (c) Position 5.

In Figure 4, 3rd order ambisonics without Fu-Ma weights was compared with DBAP. For both positions the results with ambisonics are not good. Ambisonics is very sensitive to speakers' arrangement. In this particular arrangement, there was no speaker from below, which made sound coming from above dominant for the listener. For Figure 4b, participants were asked to move 1 meter to the left. When the listeners were away from the center, they estimated the sound source more accurately, although it is known that away from the center ambisonics does not give good results. The test cannot give authoritative results for comparison between DBAP and 3rd order ambisonics, but it indicates that DBAP results are robust to speaker configurations. This gives a promising direction for further evaluation and investigation of DBAP with many speakers.

The test was successful for DBAP which showed very good results for both positions. The averages results are shown in Table 4. It can be seen that DBAP is not sensitive to the listener's position, as mentioned previously.

	DBAP Angle		Ambisonics Angle	
Position	azimuth	elevation	azimuth	elevation
4	35.125	10.67	5.16	49
4, 1m back	32.125	9.67	23.95	25
5	163.25	36.08	8.33	62

Table 4. Average results for perceived source position with DBAP and 3rd order ambisonics.

6. CONCLUSIONS AND FUTURE WORK

DBAP is a technique which can be used with an arbitrary number of speakers in almost any arrangement. The gain values can be calculated easily. This gives the technique a lot of flexibility and simplicity. The results with sound localization are closer to VBAP, but the ability to use more than 3 speakers at once gives DBAP advantages in some applications. It is not sensitive to the listener's position, whereas ambisonics is. The idea of DBAP is universal and the method can be used both in 2D and 3D. This makes it suitable for home movie or game systems.

The authors consider this work as ongoing and realize that evaluating DBAP with only 1 speaker arrangement and 5 different sound sources does not give authoritative results. Further evaluation is need with various speaker arrangements. Using sources between the listener and the speakers is essential next step. Investigating the contribution of the speakers away from the sound source with lower gains is also needed for future comparison with ambisonics.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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