W-Panning and O-format: Tools for Object Spatialisation

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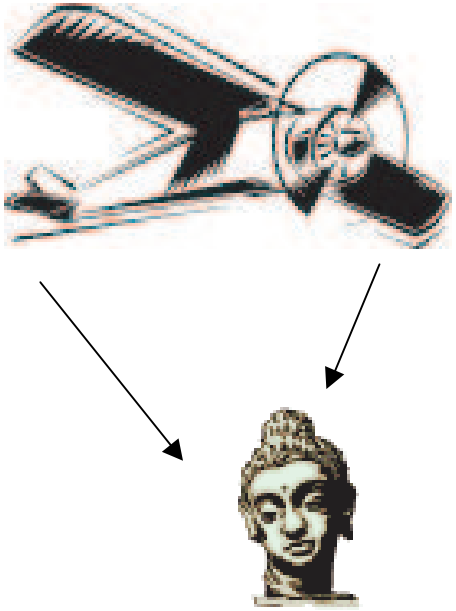
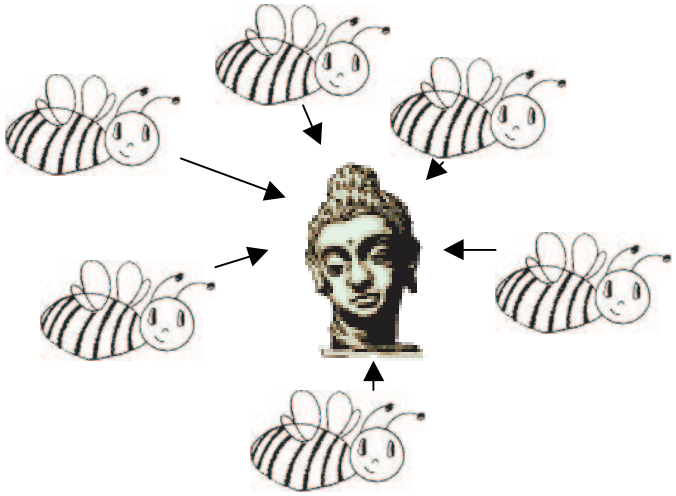
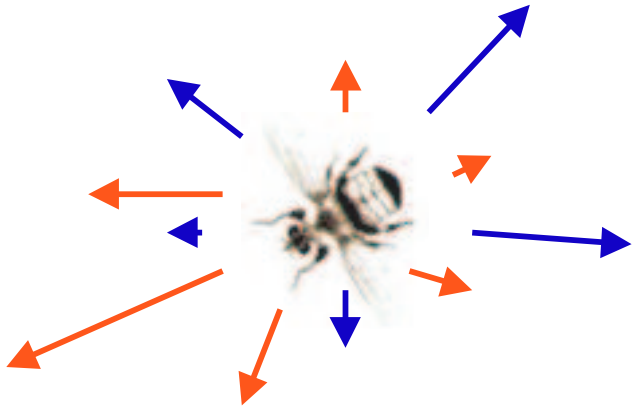
Object Properties



- Objects have width.

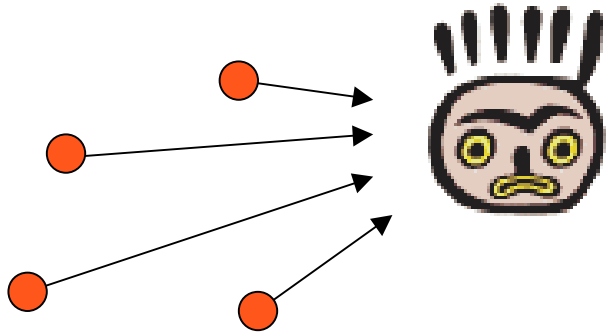


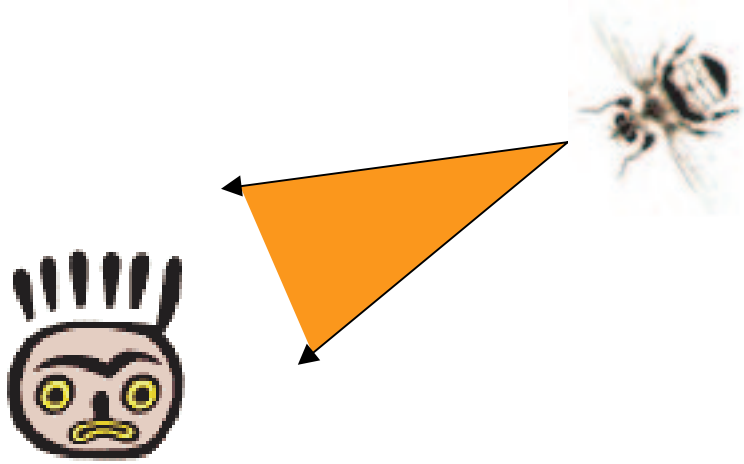
- Some objects are penetrable, eg a swarm.



- Objects have freq-dependent radiation patterns.

Existing Methods





Width : Manybodies

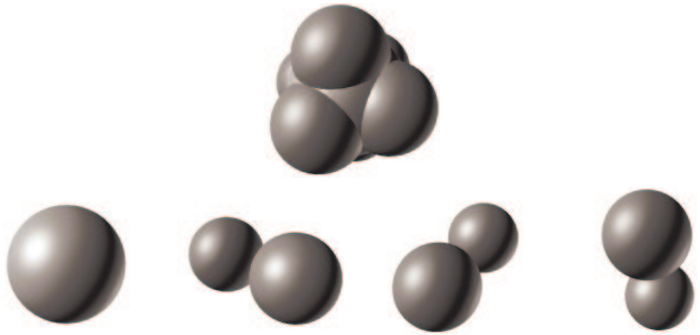
- Simulate width using several points.
- Not smooth when penetrating object, because a point may come close.
- Extra processing required.

Radiation : Soundcones

- Not freq-dependent.
- Need many to get frequency dependent distribution.

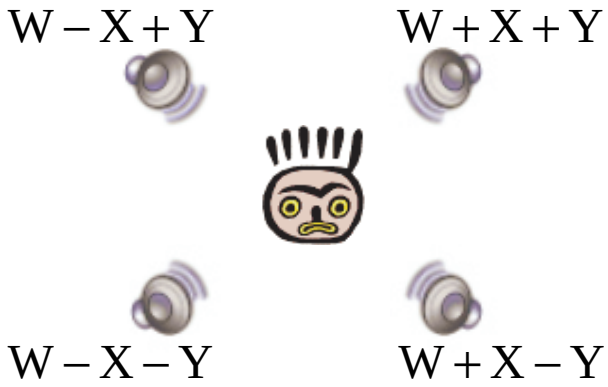
Ambisonics : brief summary

Encoding : Spherical harmonics
1st order is called *B-format*



W **X** **Y** **Z**

Decoding for speaker arrays
Eg - simple 2D 4-speaker



For a signal in one direction:

$$2\mathrm{W}^2 = \mathrm{X}^2 + \mathrm{Y}^2 + \mathrm{Z}^2$$

Easy soundfield rotation
by rotating (X,Y,Z).

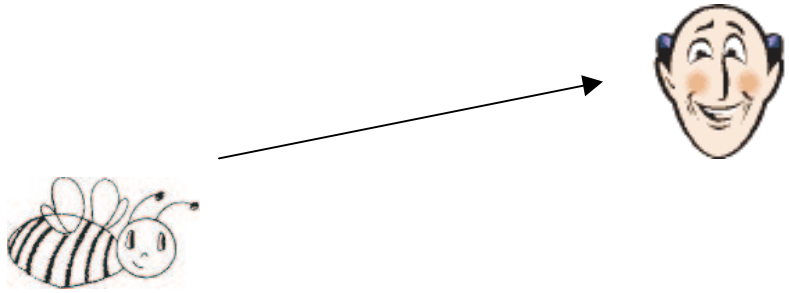
Converting B-format to binaural

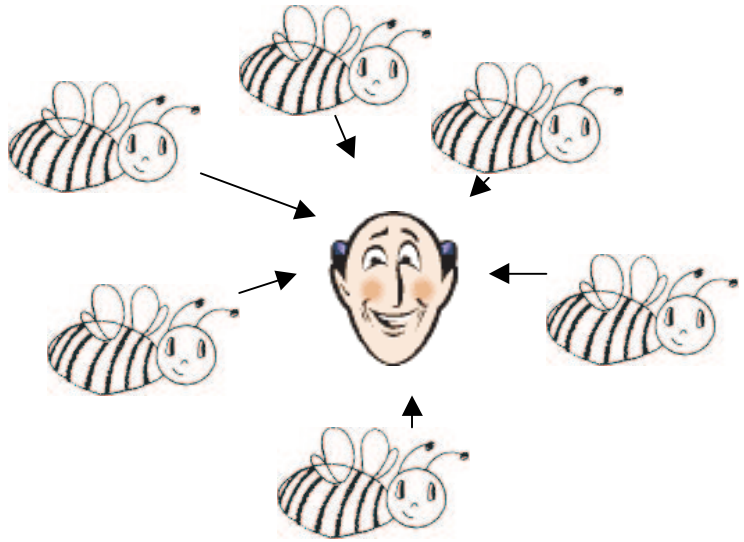
$$F_i = \int d\Omega \, Y_i(\theta,\phi) HRTF_L(\theta,\phi), \; i = W, X, Y, Z$$

$$B_L = F_W(W) + F_X(X) + F_Y(Y) + F_Z(Z)$$

$$B_R = F_W(W) + F_X(X) + F_Y(Y) - F_Z(Z)$$

W-panning : limiting cases





Distant Object

- Narrow apparent width / solid-angle
- W and |(X,Y,Z)| in ratio $1:\sqrt{2}$

Ideal Surround Object

- Assume isotropic sound.
- X,Y,Z all zero, W non-zero.
- W and |(X,Y,Z)| in ratio $1:0$

W-panning : generalized formula

To synthesize the ideal surround object modify single source equation with γ, and introduce overall gain β, from the sum of the spherical harmonic energies :

$$2\gamma W^2 = X^2 + Y^2 + Z^2 \quad 0 \le \gamma \le 1 \qquad\qquad 2W^2 + X^2 + Y^2 + Z^2 = \beta^2$$

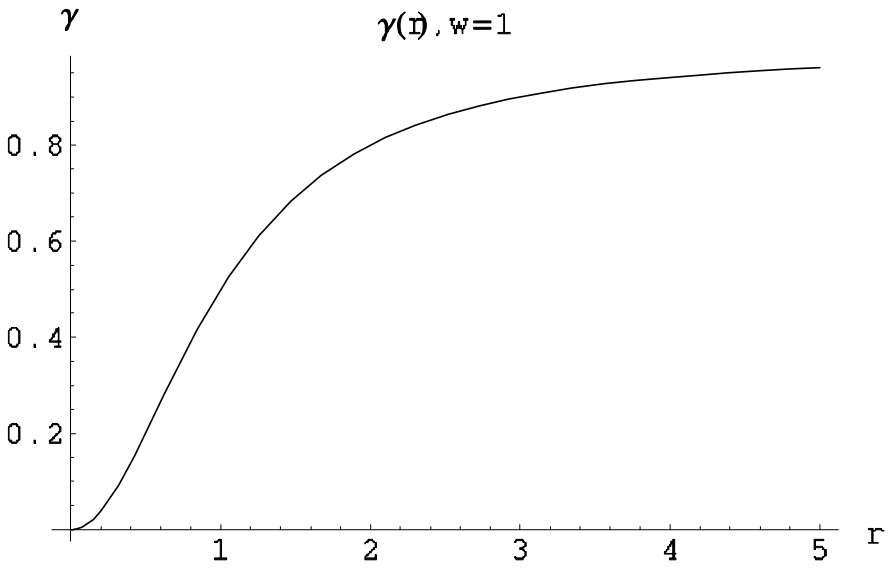
Given γ , β and source direction n, find that :

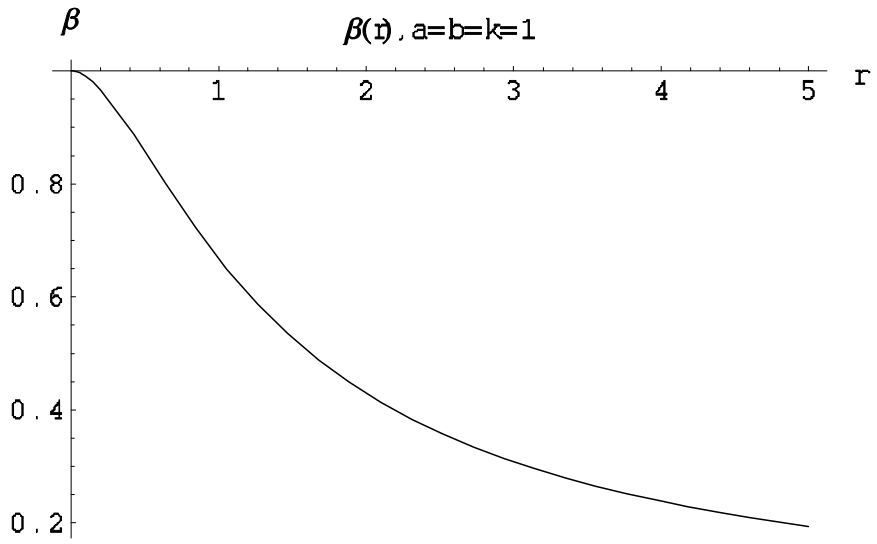
$$W = \beta(2 + 2\gamma)^{-1/2},$$
$$X = \alpha n_x , \quad Y = \alpha n_y , \quad Z = \alpha n_z$$

where,

$$\alpha = \begin{cases} \beta(1+\gamma^{-1})^{-1/2} & 0 < \gamma \le 1 \\ 0 & \gamma = 0 \end{cases}$$

W-panning : fitting γ and β





Conditions

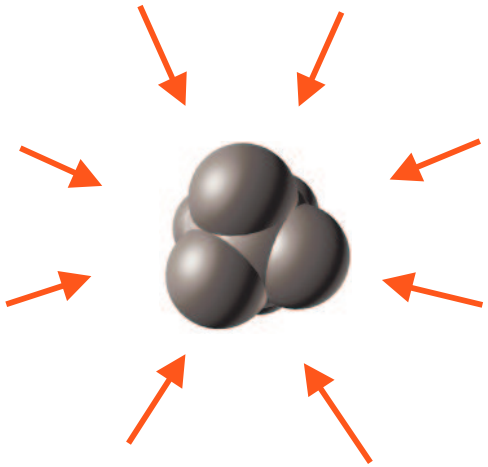
- $\gamma = 0$ at $r = 0$
- $\gamma = 1$ at $r = \infty$
- Smooth at $r = 0$

Conditions

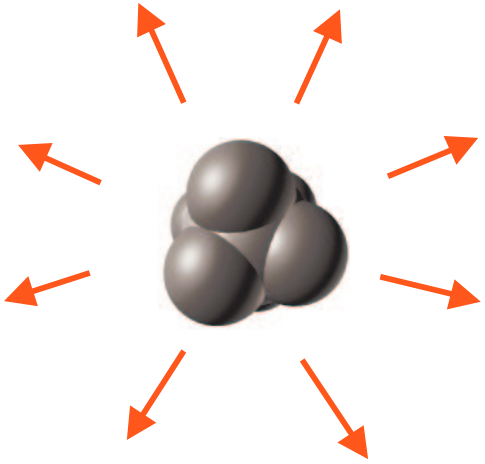
- $\beta = a$ at $r = 0$
- $\beta \to br^{-k}$ as $r \to \infty$
- Smooth at $r = 0$

O-format : spherical harmonic encoding of radiation

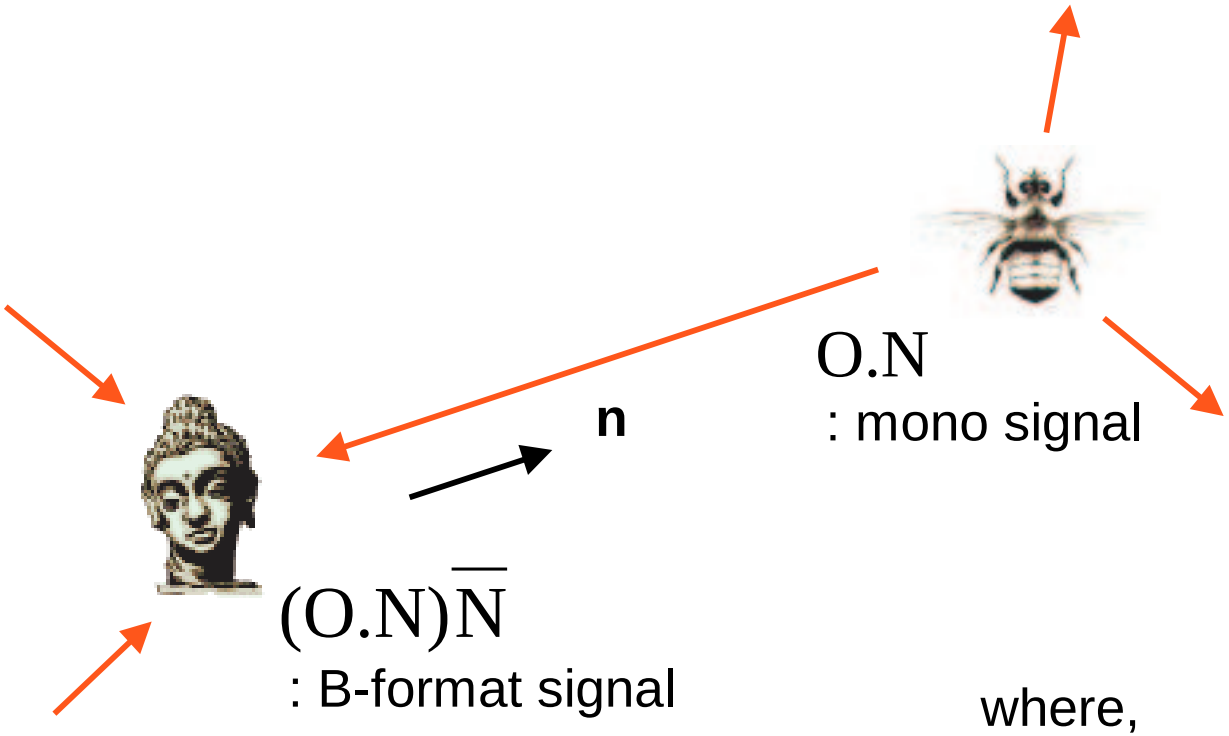
B-format is the 1st order encoding of *incomming* sound waves, from a soundfield.



O-format is the 1st order encoding of *outgoing* sound waves, from a radiating source.



O-format : rendering into B-format



where,

$$\overline{N} = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ n \end{pmatrix} \quad N = \begin{pmatrix} \sqrt{2} \\ -n \end{pmatrix} \quad O = \begin{pmatrix} W \\ X \\ Y \\ Z \end{pmatrix}$$

- Simple into B-format.
- Could render direct into binaural.
- Can rotate O-format like B-format.
- Possible to create width with *dominance.*

Conclusion

- W-panning is simple, cheap and effective.
- It is smoother than existing techniques for penetrable objects.
- W-panning can sometimes be improved with frequency spreading.
- O-format is a cheap way to create a richer source radiation pattern.
- W-panning and O-format objects can be combined to create more complex structures.