

Appendix - Normalized Orthogonal Projection

The normalized orthogonal projection op of a memorized sibilant's position \vec{x} in the three-dimensional DCT-space onto the dimension between the speaker-specific phonological classes /s/ and /ʃ/ is calculated as follows:

$$op(\vec{x}) = 1 - 2 \frac{(\vec{x} - \vec{c}_f) \odot (\vec{c}_f - \vec{c}_s)}{(\vec{c}_f - \vec{c}_s) \odot (\vec{c}_f - \vec{c}_s)}$$

with:

\vec{x} : position of agent's sibilant in three-dimensional DCT-space

\vec{c}_f : centroid (mean) of all <ʃ>-word sibilants of the agent in three-dimensional DCT-space

\vec{c}_s : centroid (mean) of all <s>-word sibilants of the agent in three-dimensional DCT-space

\odot : scalar (inner) product of two vectors

op is the orthogonal projection of a sibilant's position in the three-dimensional DCT-space on the line passing through the agent's centroids calculated from the agent's sibilants in <s> and <ʃ>-words respectively. Thus, op expresses the relative position of the sibilant within the agent's /s/ -> /ʃ/ space.

op is normalized by two times the distance of the centroids and then shifted, so that:

$op = -1$: sibilant's position is on a orthogonal plane through the /ʃ/ centroid

$op = 1$: sibilant's position is on a orthogonal plane through the /s/ centroid

$op = 0$: sibilant's position is on an orthogonal plane in the middle between the /ʃ/ and the /s/ centroid