3LD – Library for Loudspeaker Layout Design

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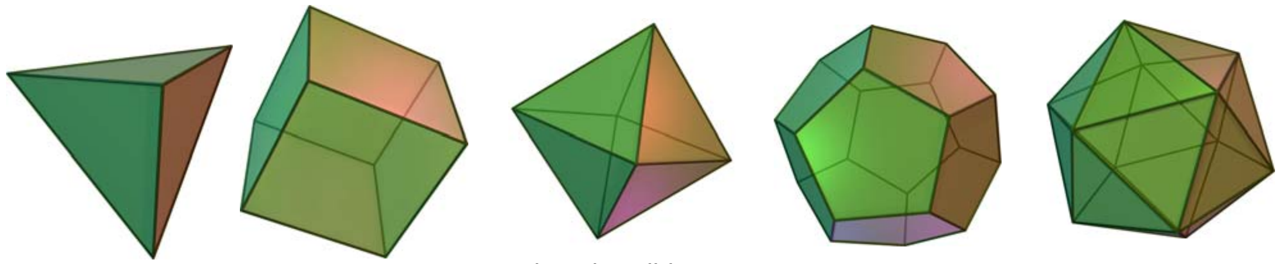
The generation of loudspeaker layouts for periphonic sound spatialization systems is a non-trivial task, just like the underlying mathematical problem: the homogeneous distribution of a number of points on the surface of a sphere. According approaches have a long tradition in mathematics (platonic solids, geodesic spheres) as well as in physics (minimal energy configurations). However, neither of these fullfill all the requirements of periphonic loudspeaker layouts, such as arbitrary choice of the number of loudspeakers, possibility of psychoacoustical optimization (loudspeaker density as a function of the ear's spatial resolution) and the consideration of practical limitations (forbidden and explicitely demanded loudspeaker positions).



Platonic solids

Through a hybrid approach of the strategies mentioned above, it is possible to overcome the limitations of each single method and create a universal tool for the design of three-dimensional loudspeaker layouts. Based on the theoretical background described in [1], this project is concerned with the practical implementation of the developed theory and results in the 3LD Library for Loudspeaker Layout Design [2], which includes features for the generation, visualization and evaluation of periphonic loudspeaker layouts.

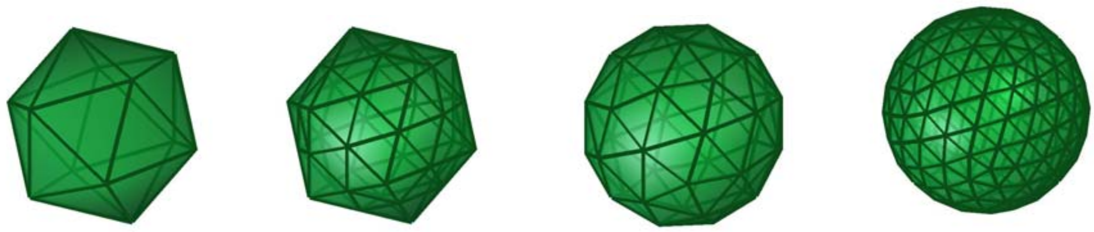
Periphonic Loudspeaker Layouts

The different criteria regarding the design of 3D loudspeaker layouts can be briefly summarized by stating that the design of a periphonic (i.e. 3D) loudspeaker layout has to take into account

- The applied soundfield reconstruction algorithms, e.g. VBAP, Ambisonics, etc.
- The homogeneity of soundfield reconstruction
- The properties of human spatial hearing
- The loudspeaker distribution in the horizontal plane
- The architectural circumstances of a periphonic sound system

Geodesic Spheres

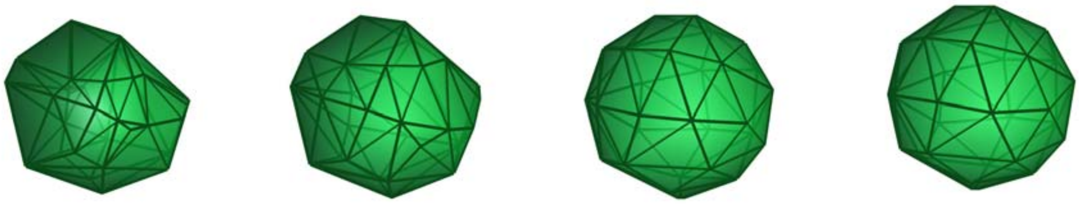
By tessellating the facets of a polyhedron and pushing the such created new vertices out to the radius of the original configuration, *geodesic spheres* can be built from the platonic solids or other polyhedra. The method of geodesic spheres has been generalized in [1] towards maximum flexibility regarding the choice of the number of loudspeakers in a configuration, resulting in a set of tessellation rules. By applying these rules independently onto different facet shapes and different iterations of the process, we achieve significant freedom in the design of periphonic loudspeaker layouts.



Construction process of a geodesic sphere

Minimal Energy Configurations

An approach from physics to the distribution of an arbitrary number of points on a sphere are so-called *minimal energy configurations*, which are generated by a random distribution of electrons on a spherical surface: Due to the repulsion forces among the electrons, they will arrange themselves in a natural equilibrum of minimal potential energy after some time. Note that the elctrons are only allowed to move on the surface of a sphere. The nex figure shows some snapshots of this iterative process, which yields that the homogeneity of the configuration increases with the number of iterations. The obvious advantage of arbitrary numbers of electrons/loudspeakers has to be traded off for a lack of symmetry in the resulting layout.



Electrons distributing themselves towards a minimal energy configuration

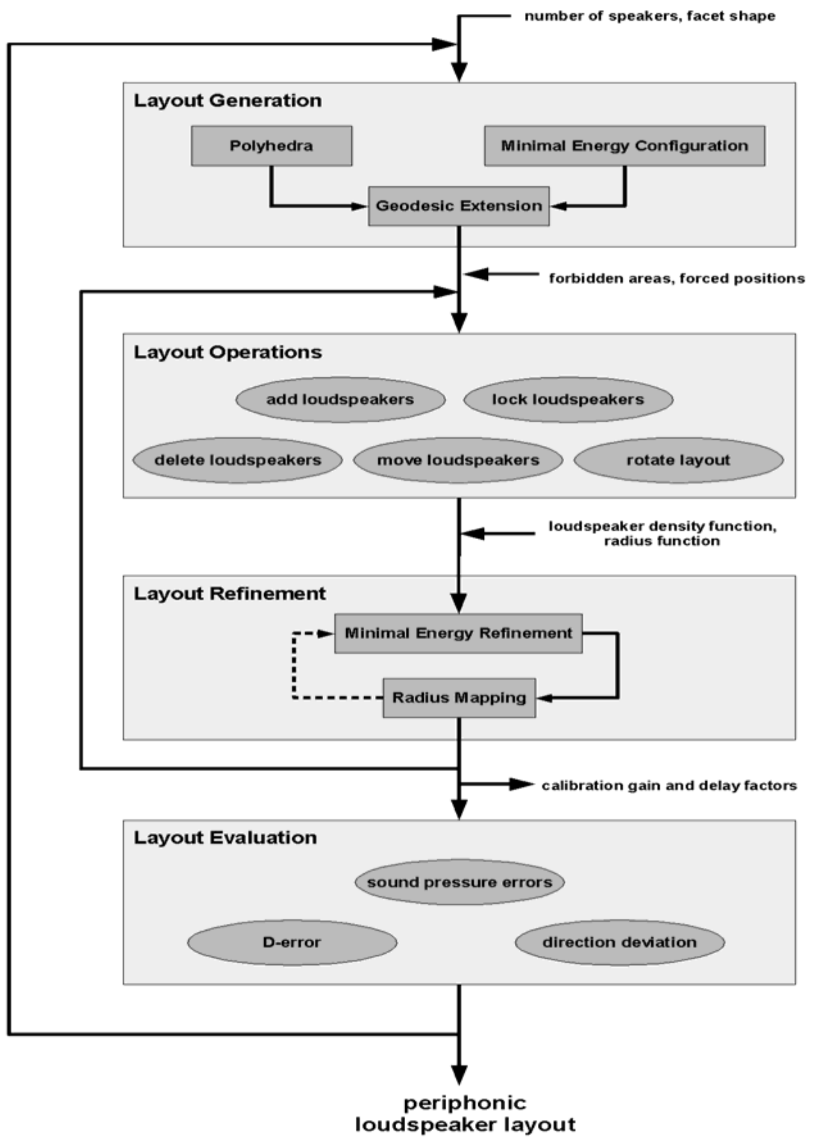
An Extended Loudspeaker Layout Design Strategy

A new hybrid strategy for the design of periphonic loudspeaker layouts presented in [1] is based on the separation of the design process into two stages, the first of which is dedicated to the construction of a homogeneous loudspeaker distribution, which is then psychoacoustically refined in the second stage: The spatial resolution of the human ear is best in the horizontal plane and for the front direction, whereas elevated and lateral sound sources can not be localized as well. By providing higher loudspeaker densities in areas of better auditory resolution, we can optimize a layout regarding the total number of loudspeakers. It has been suggested in [1] to use the charges of the electrons in a minimal energy algorithm for the implementation of spherical loudspeaker density functions: higher electron charges result in higher repulsion forces among the electrons, and thus in lower loudspeaker densities. A spherical loudspeaker density function can thus be derived as the inverse of a function representing direction-dependent electron charges (which do not exist in nature but are introduced here as a useful concept). However, a non-constant electron density also means that we cannot choose the initial electron distribution randomly any more, but rather have to use an initial configuration in which the electrons are already to some degree homogeneously distributed over the sphere. The Platonic solids or their geodesic extensions represent suitable intial layouts for this hybrid approach, which can be further extended in order to account for

- Non-spherical layout surfaces, i.e. a spherical radius function
- Gain and delay calibration due to differing loudspeaker distances
- Areas which do not allow for the mounting of loudspeakers

- Forced loudspeaker positions, i.e. 'locked' electrons

The combination of these considerations results in an *extended loudspeaker layout design strategy* shown in the next figure.



References

[1] Florian Hollerweger: *Periphonic Sound Spatialization in Multi-User Virtual Environments*. Master's thesis, University of Music and Dramatic Arts Graz, Austria, 2006

[2] Florian Hollerweger: *3LD - Library for Loudspeaker Layout Design, A Matlab Library for Rendering and Evaluating Periphonic Loudspeaker Layouts*. – IEM Report 32/06