Claims

1. An apparatus for generating loudspeaker signals for a plurality of loudspeakers so that an application of the loudspeaker signals at the plurality of loudspeakers renders at least one audio object at an intended virtual position, the apparatus comprising

an interface configured to receive an audio input signal which represents the at least one audio object,

a first panning gain determiner, configured to determine, depending on the intended virtual position, first panning gains for a first set of loudspeakers of the plurality of loudspeakers, which are arranged within a first horizontal layer, the first panning gains defining a derivation of first partial loudspeaker signals from the at least one audio input signal, which are associated with a rendering of the at least one audio object at a first virtual position upon application of the first partial loudspeaker signals onto the first set of loudspeakers,

a vertical panning gain determiner, configured to determine, depending on the intended virtual position, further panning gains for a panning between the first partial loudspeaker signals and one or more second partial loudspeaker signals which is to be applied to a second set of one or more loudspeakers, which is arranged within a second horizontal layer, which is vertically offset relative to the first layer set, and is associated with a rendering of the at least one audio object at a second position so as to pan between the first virtual position and the second position,

wherein the apparatus is configured to compose the loudspeaker signals from the audio input signal using the first panning gains and the further panning gains,
wherein the apparatus is adaptive to different setups of the plurality of loudspeakers and configured to associate the plurality of loudspeakers to a plurality of horizontal layers so that one of the loudspeakers may be associated with different ones of the horizontal layers, and to select the first horizontal layer and the second horizontal layer out of the plurality of horizontal layers so that the intended virtual position is between the first horizontal layer and the second horizontal layer.

2. Apparatus according to claim 1, wherein the second set of one or more loudspeakers comprises more than one loudspeaker, the one or more second partial loudspeaker signals comprise more than one second partial loudspeaker signals and the apparatus further comprises

a second panning gain determiner, configured to determine, depending on the intended virtual position, second panning gains for the second set of loudspeakers, the second panning gains defining a derivation of the second partial loudspeaker signals from the at least one audio input signal, and

wherein the apparatus is configured to compose the loudspeaker signals from the audio input signal using the first and second panning gains and the further panning gains.

3. Apparatus according to claim 2,

wherein the second set of loudspeakers are within a second layer set of one or more horizontal layers and the first and second layer sets are vertically offset to each other.

4. Apparatus according to any of claims 2 to 3,

wherein the second set of loudspeakers are within a second layer set of one or more horizontal layers and the first and second layer sets are vertically offset to each other with the intended virtual position being vertically therebetween.

5. Apparatus according to any of claims 2 to 4,

wherein the second set of loudspeakers are within a second layer set of one or more horizontal layers and the first and second panning gain determinersare configured to select the first and second sets of loudspeakers of the plurality of loudspeakers so that the first and second layer sets are, among horizontal layers which the plurality of loudspeakers are distributed onto, vertically nearest to the intended virtual position and vertically offset to each other with the intended virtual position being vertically therebetween.

6. Apparatus according to any of claims 2 to 5, wherein the first and second panning gain determinersare configured to derive the first and second panning gains so that the first virtual positionand the second positioncoincide in a vertical projection.

7. Apparatus according to claim 6, wherein

the spectral shaping mimics properties of a Head Related Transfer Function, HRTF, along a perception direction from the second position.

8. Apparatus according to any one of claims 6 to 7, configured

so that the second position is vertically above the second layer set and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio input signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges between 1000 and 10 kHz, or

so that the second position is vertically below the second layer set and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz.

9. Apparatus according to any one of claims 6 to 8, configured

so that the second position is vertically above the second layer set and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio input signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges between 1000 and 10 kHz, or

so that the second position is vertically below the second layer set and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz with an intermediate reduction of the dampening within a spectral subrange within the spectral range, located between 5 and 10 kHz, and amplified between 500 Hz and 1 kHz.

10. Apparatus according to any one of claims 6 to 9, configured to

if the intended virtual position is vertically above the second layer set, position the second position to be vertically above the second layer set, perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges Between 1000 and 10 kHz, and

if the intended virtual position is vertically below the second layer set, position the second position to be vertically below the second layer set, perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz.

11. Apparatus according to any one of claims 6 to 10,

wherein the plurality of loudspeakers forms a setup in which the loudspeakers are associated with horizontal layers, and the apparatus is configured to be responsive to a change of the intended virtual position so as to

if the intended virtual position is between two horizontal layers,

select the first layer set to be a first of the two horizontal layers and the second layer set to be a second of the two horizontal layers, and the first set out of loudspeakers associated with the first horizontal layer and the second set out of loudspeakers associated with the second horizontal layer, wherein the first and second panning gain determinerare configured to determine, depending on the intended virtual position, the first and second panning gains, and the spectral shaping is switched off, so that the first virtual position is within the first horizontal layer and the second virtual position is within the second horizontal layer, and

if the intended virtual position is vertically offset to all horizontal layers towards above or below the horizontal layers,

select the first layer set and the second layer set to be an outmost layer of the horizontal layers nearest to the intended virtual position, and the first set and the second set out of loudspeakers associated with the outmost layer, wherein the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains and the spectral shaping being used, so that the second position is a virtual position vertically offset relative to the outmost layer towards a direction at which the intended virtual position lies.

12. Apparatus according to claim 11,

wherein the apparatus is configured to be responsive to a change of the intended virtual position so as to

if the intended virtual position is between two horizontal layers,

the first and second panning gain determinerare configured to determine, depending on the intended virtual position, the first and second panning gains

so that the first virtual positionand the second positioncoincide in a vertical projection, and the spectral shaping is switched off, and/or

if the intended virtual position is vertically offset to all horizontal layers towards above or below the horizontal layers,

the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains so that the first virtual position coincides in a vertical projection, with the intended virtual position.

13. Apparatus according to any one of claims 6 to 12,

wherein the plurality of loudspeakers forms a setup in which the loudspeakers are associated with one or more horizontal layers, and the apparatus is configured to be responsive to a number of the one or more horizontal layers and a change of the intended virtual position so as to

if the number of one or more horizontal layers is larger than one,

if the intended virtual position is between two horizontal layers,

select the first layer set to be a first of the two horizontal layers and the second layer set to be a second of the two horizontal layers, and the first set out of loudspeakers associated with the first horizontal layer and the second set out of loudspeakers associated with the second horizontal layer, wherein the first and second panning gain determinerare configured to determine, depending on the intended virtual position, the first and second panning gains, and the spectral shaping is switched off, so that the first virtual position is within the first horizontal layer and the second virtual position is within the second horizontal layer, and

if the intended virtual position is vertically offset to all horizontal layers towards above or below the horizontal layers,

select the first layer set and the second layer set to be an outmost layer of the horizontal layers nearest to the intended virtual position, and the first set and the second set out of loudspeakers associated with the outmost layer, wherein the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains and the spectral shaping is

used, so that the second position is a virtual position vertically offset relative to the outmost layer towards a direction at which the intended virtual position lies, and

if the number of one or more horizontal layers is one,

if the intended virtual position is within the one horizontal layer,

compose the loudspeaker signals purely from the first partial loudspeaker signals, and

if the intended virtual position is vertically offset to the one horizontal layer,

select the first layer set and the second layer set to be the one horizontal layer, and the first set and the second set out of loudspeakers associated with the one horizontal layer, wherein the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains and the spectral shaping is used, so that the second position is a virtual position vertically offset relative to the one horizontal layer towards a direction at which the intended virtual position lies.

14. Apparatus according to claim 13,

wherein the apparatus is configured to be responsive to a number of the one or more horizontal layers and a change of the intended virtual position so as to

if the number of one or more horizontal layers is larger than one,

if the intended virtual position is between two horizontal layers,

the first and second panning gain determiner are configured to determine, depending on the intended virtual position, the first and second panning gains so that the first virtual position and the second position coincide in a vertical projection, and/or

if the intended virtual position is vertically offset to all horizontal layers towards above or below the horizontal layers,

the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains so that the first virtual position coincides in a vertical projection, with the intended virtual position, and/or

if the number of one or more horizontal layers is one,

if the intended virtual position is vertically offset to the one horizontal layer,

the first panning gain determiner is configured to determine, depending on the intended virtual position, the first panning gains so that the first virtual position coincides in a vertical projection, with the intended virtual position.

15. Apparatus according to any of claims 1 to 14,

wherein the first set of loudspeakers is included in the second set of one or more loudspeakers, and/or

wherein the second set of one or more loudspeakers is included in the first set of loudspeakers, and/or

. wherein the first set of loudspeakers and the second set of one or more loudspeakers coincide, and/or
wherein the first set of loudspeakers and the second set of one or more loudspeakers partially overlap, and/or

wherein the first set of loudspeakers and the second set of one or more loudspeakers are disjoint sets.

16. Apparatus according to any of claims 1 to 15,

configured to select the first set of loudspeakers out of the plurality of loudspeakers depending on a horizontal component of the intended virtual position or depending on the horizontal component of the intended virtual position and a vertical component of the intended virtual position, and/or

configured to select the second set of one or more loudspeakers out of the plurality of loudspeakers depending on a vertical component of the intended virtual position or depending on the horizontal component of the intended virtual position and the vertical component of the intended virtual position.

17. Apparatus according to any of claims 1 to 16 wherein the second set of one or more loudspeakers comprises one or more loudspeakers at, or horizontally surrounding, the second position, and horizontally arranged between the first set of loudspeakers.

18. Apparatus according to any of claims 1 to 17,

wherein the first and/or second panning gain determiners are configured to determine the first and/or second panning gains further depending on a listener position.

19. Apparatus according to any previous claim,

wherein the plurality of loudspeakers refer to any one of, or a combination of, one or more loudspeaker arrays, one or more soundbars, one or more smart speakers, one or more stereo speakers, one or more surround sound setups, or one or more sets of individual loudspeakers.

20. Apparatus according to any previous claim,

wherein the audio input signal is one of a channel-based audio signal, object-based audio signal, and/or scene-based audio signal.

21. Apparatus according to any previous claim,

configured to derive the intended virtual position from the audio input signal.

22. Apparatus according to any previous claim,

wherein the panning gains are amplitude panning gains.

23. Apparatus according to any one of claims 1 to 22,

wherein the audio input signal is a channel-based audio signal defining an audio signal for each of signal-specific loudspeaker positions,

wherein the apparatus is configured to treat each of a selection of one or more (or all) out of the audio signals for the signal-specific loudspeaker positions as one of the at least one audio object.

24. Apparatus according to claim 23, configured to

derive the intended virtual position of the one audio object from the loudspeaker position of the respective audio signal.

25. Apparatus according to claim 24, configured to

wherein the intended virtual position of the one audio object is derived from the loudspeaker position of the respective audio signal in a manner so that a mutual positional relationship between the signal-specific loudspeaker position is maintained.

26. Apparatus according to any one of claims 1 to 25,

wherein the audio input signal is an object-based audio signal defining one or more renderable audio objects,

wherein the apparatus is configured to use a selection of one or more (or all) out of the one or more renderable audio objects as one of the at least one audio object.

27. Apparatus according to any previous claim,
configured to receive information on a change of the plurality of loudspeakers in terms of loudspeaker position and to take the change into account in subsequent generation of the loudspeaker signals and / or

configured to receive information on a change of the plurality of loudspeakers in terms of number of loudspeakers and to take the change into account in subsequent generation of the loudspeaker signals.

28. An apparatus for generating loudspeaker signals for a plurality of loudspeakers so that an application of the loudspeaker signals at the plurality of loudspeakers renders at least one audio object at an intended virtual position, wherein the plurality of loudspeakers are distributed onto one or more horizontal layers, the apparatus comprising

an interface configured to receive an audio input signal which represents the at least one audio object,

a first loudspeaker signal set determiner, configured to determine, depending on the intended virtual position, first panning gains for a first set of loudspeakers of the plurality

of loudspeakers, and use the first panning gains to derive first partial loudspeaker signals from the at least one audio input signal, which are associated with a rendering of the at least one audio object at a first virtual position upon application of the first partial loudspeaker signals onto the first set of loudspeakers,

a second loudspeaker signal set determiner, configured to, by spectral shaping and by panning gains, derive second partial loudspeaker signals from the at least one audio input signal, the second partial loudspeaker signals being associated with a rendering of the at least one audio object at a second virtual position upon application of the second partial loudspeaker signals onto a second set of loudspeakers) of the plurality of loudspeakers, wherein the panning gains are selected so that the second virtual position is above or below the one or more horizontal layers and corresponds to a horizontal position which coincides with a listener position along a vertical projection, and

a vertical panning gain determiner configured to, depending on the intended virtual position, determine further panning gains for the first and second partial loudspeaker signals so as to pan between the first and second virtual positions, and

a composer configured to compose the loudspeaker signals from the first and second partial loudspeaker signals using the further panning gains.

29. Apparatus according to claim 28,

wherein the first set of loudspeakers is within one or more horizontal layers which is/are, among the one or more horizontal layers, vertically nearest to the intended virtual position.

30. Apparatus according to claim 28 or 29,

wherein the first loudspeaker signal set determiner is configured to select the first set of loudspeakers of the plurality of loudspeakers so that the first set of loudspeakers is within one or more horizontal layers which is/are, among the one or more horizontal layers, vertically nearest to the intended virtual position.

31. Apparatus according to claim 28 or 29,

wherein the first loudspeaker signal set determiner is configured so that the first set of loudspeakers is within one horizontal layer and to determine the first panning gains

further depending on positions of the first set of loudspeakers within the one horizontal layer.

32. Apparatus according to any of claims 28 to 31,

wherein the first loudspeaker signal set determiner is configured so that the first panning gains implement a pure amplitude panning so that the first virtual position is between positions of the set of first loudspeakers.

33. Apparatus according to any of claims 28 to 32,

wherein the first loudspeaker signal set determiner is configured to determine the first panning gains further depending on a listener position.

34. Apparatus according to any of claims 28 to 33,

wherein the second loudspeaker signal set determiner is configured so that the spectral shaping mimics properties of a Head Related Transfer Function, HRTF, along a perception direction from the second virtual position.

35. Apparatus according to any of claims 28 to 34,

wherein the second loudspeaker signal set determiner is configured to derive the second partial loudspeaker signals from the at least one audio signal

so that the second partial loudspeaker signals are generated from the at least one audio signal using an amplitude gain factor which is equal for all of the second partial loudspeaker signals, or

by panning using panning gains which correspond to a horizontal central position or sweet spot position in-between the second set of loudspeakers, or

.

36. Apparatus according to any of claims 28 to 35,

wherein the first set of loudspeakers is included in the second set of loudspeakers, and/or

wherein the second set of loudspeakers is included in the first set of loudspeakers, and/or

wherein the first set of loudspeakers and the second set of loudspeakers coincide, and/or

wherein the first set of loudspeakers and the second set of loudspeakers partially overlap, and/or

wherein the first set of loudspeakers and the second set of loudspeakers are mutually exclusive.

37. Apparatus according to any of claims 28 to 36,

configured to select the first set of loudspeakers out of the plurality of loudspeakers depending on a horizontal component of the intended virtual position or depending on the horizontal component of the intended virtual position and a vertical component of the intended virtual position, and/or

configured to select the second set of loudspeakers out of the plurality of loudspeakers depending on a vertical component of the intended virtual position or depending on the horizontal component of the intended virtual position and the vertical component of the intended virtual position.

38. Apparatus according to any one of claims 28 to 37,

wherein the second loudspeaker signal set determiner is configured so that the second virtual position is vertically above the one or more horizontal layers and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges between 1000 and 10 kHz, or

wherein the second loudspeaker signal set determiner is configured so that the second virtual position is vertically below the one or more horizontal layers and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz.

39. Apparatus according to any one of claims 28 to 38,

wherein the second loudspeaker signal set determiner is configured so that the second virtual position is vertically above the one or more horizontal layers and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges between 1000 and 10 kHz, or

wherein the second loudspeaker signal set determiner is configured so that the second virtual position is vertically below the one or more horizontal layers and to perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz with an intermediate reduction of the dampening within a spectral subrange within the spectral range, located between 5 and 10 kHz, and amplified between 500 Hz and 1 kHz.

40. Apparatus according to any one of claims 28 to39,

wherein the second loudspeaker signal set determiner is configured to,

if the intended virtual position is vertically above the one or more horizontal layers, position the second virtual position to be vertically above the one or more horizontal layers, perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a notch spectral range between 200 and 1000 Hz and amplified within one or more in peak spectral ranges Between 1000 and 10 kHz, and

if the intended virtual position is vertically below the one or more horizontal layers, position the second virtual position to be vertically below the one or more horizontal layers, perform the spectral shaping so that the second partial loudspeaker signals are, relative to the at least one audio signal, dampened in a spectral range above 1000 Hz.

41. Apparatus according to any one of claims 28 to 40,

wherein the composer is configured to be responsive to a change of the intended virtual position from an in-layer position, which is vertically within or in-between the one or more layers, to a position vertically offset from the one or more horizontal layers, by

controlling the further panning gains so as to fade from composing the loudspeaker signals purely from the first partial loudspeaker signals to composing the loudspeaker

signals from the first and second partial loudspeaker signals so that the further panning gains pan from the first virtual position towards the second virtual position.

42. A system comprising:

a plurality of loudspeakers, and

an apparatus according to one of the preceding claims.

43. Method for generating loudspeaker signals for a plurality of loudspeakers so that an application of the loudspeaker signals at the plurality of loudspeakers renders at least one audio object at an intended virtual position, the method comprising

receiving an audio input signal which represents the at least one audio object,

determining, depending on the intended virtual position, first panning gains for a first set of loudspeakers of the plurality of loudspeakers, which are arranged within a first layer set of one or more first horizontal layers, the first panning gains defining a derivation of first partial loudspeaker signals from the at least one audio input signal, which are associated with a rendering of the at least one audio object at a first virtual position upon application of the first partial loudspeaker signals onto the first set of loudspeakers,

determining, depending on the intended virtual position, further panning gains for a panning between the first partial loudspeaker signals and one or more second partial loudspeaker signals which is to be applied to a second set of one or more loudspeakers, which is vertically offset relative to the first layer set, and is associated with a rendering of the at least one audio object at a second position so as to pan between the first virtual position and the second position,

composing the loudspeaker signals from the audio input signal using the first panning gains and the further panning gains.

44. Method for generating loudspeaker signals for a plurality of loudspeakers so that an application of the loudspeaker signals at the plurality of loudspeakers renders at least one audio object at an intended virtual position, wherein the plurality of loudspeakers are distributed onto one or more horizontal layers, the method comprising

receiving an audio input signal which represents the at least one audio object,

determining, depending on the intended virtual position, first panning gains for a first set of loudspeakers of the plurality of loudspeakers, and use the first panning gains to derive first partial loudspeaker signals from the at least one audio input signal, which are associated with a rendering of the at least one audio object at a first virtual position upon application of the first partial loudspeaker signals onto the first set of loudspeakers,

by spectral shaping, deriving second partial loudspeaker signals from the at least one audio input signal, the second partial loudspeaker signals being associated with a rendering of the at least one audio object at a second virtual position upon application of the second partial loudspeaker signals onto a second set of loudspeakers, the second virtual position being above or below the one or more horizontal layers, and

depending on the intended virtual position, determining further panning gains for the first and second partial loudspeaker signals so as to pan between the first and second virtual positions, and

composing the loudspeaker signals from the first and second partial loudspeaker signals using the further panning gains.

45. Computer readable digital storage medium having stored thereon a computer program having a program code for performing, when running on a computer, a method according to claims 43 or 44.