

CLAIMS

1. A method comprising:
 - producing an acoustic field from a transducer array having known relative positions and orientations;
 - defining a control point wherein the control point has a known spatial relationship relative to the transducer array;
 - assigning an amplitude to the control point;
 - generating a mid-air haptic effect for a virtual object on a human body part by moving the control point in a single closed curve, wherein the single closed curve comprises a plurality of curve segments;
 - wherein the single closed curve traverses at least one location where the human body part intersects with the virtual object; and
 - after moving a control point in the single closed curve, designing a second closed curve in response to a change in the virtual object.
2. The method as in claim 1, wherein the movement of the control point in the single closed curve is faster when the control point does not traverse the at least one location where the human body part intersects with the virtual object than when the control point traverses the at least one location where the human body part intersects with the virtual object.
3. The method as in claim 1, wherein when control point reaches the at least one location where the human body part intersects with the virtual object, the control point avoids traversing the human body part that intersects with the virtual object.
4. A method comprising:
 - a user interacting with virtual three-dimensional content using the user's hands;
 - a tracking system monitoring the user's hands;
 - a physics engine updating the properties of the virtual three-dimensional content;
 - a mid-air haptic feedback system providing haptic information to the user;

applying a first haptic impulse to at least one of the user's hands when the at least one of the user's hands contacts the virtual three-dimensional content;

forming the at least one of the user's hands into a skeletal model having a plurality of bones;

wherein the first haptic impulse is applied to the plurality of bones of the at least one of the user's hands that contacts the virtual three-dimensional content; and

wherein the first haptic impulse applied to at least one of the user's hands ceases when the at least one of the user's hands maintains contact with the virtual three-dimensional content.

5. The method of claim 4 wherein the skeleton of the at least one of the user's hands has a first side and a second side, wherein the contact of the at least one of the user's hands occurs on the first side and the haptic impulse occurs on the second side.

6. The method as in claim 4, wherein the first haptic impulse applied to at least one of the user's hands follows the at least one of the user's hand using decaying amplitude when the at least one of the user's hands terminates contact with the virtual three-dimensional content.

7. A method comprising:

producing an acoustic field from a transducer array having known relative positions and orientations;

defining a control point wherein the control point has a known spatial relationship relative to the transducer array; and

generating a sound having a sound waveform by moving the control point in a trajectory that encodes the sound waveform;

wherein the trajectory comprises a closed curve path.

8. The method as in claim 7, wherein the closed curve path is parametrized into in-phase and quadrature components.

9. A method comprising:
- producing an acoustic field from a transducer array having known relative positions and orientations;
 - defining a control point wherein the control point has a known spatial relationship relative to the transducer array; and
 - generating a sound having a sound waveform by moving the control point in a trajectory that encodes the sound waveform;
- wherein the trajectory comprises an open curve path.