Pixie Dust: Graphics Generated by Levitated and Animated Objects in Computational Acoustic-Potential Field

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This is an *easy-read* summary of a **SIGGRAPH**2014 Technical Paper

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… By changing the distribution of the acoustic-potential field (APF)… we can generate graphics using levitated small objects…
In the current system, multiple particles:
-Are levitated together at 4.25-mm intervals.
-The spatial resolution of the position is 0.5 mm.
-Particles move at up to 72 cm/s.
-The allowable density of the material can be up to 7 g/cm3

… We propose in this paper a method to control the spatial position and 3D animation of small objects by utilizing a noncontact manipulation technology. With this method, we can employ real objects as graphical components, such as display pixels … and vector graphics… Compared to magnetic levitation, air jets, and other noncontact levitation technologies, APF has the following advantages: it can be used with a wide variety of available materials, it provides a satisfactory refresh rate, and it has sufficient spatial resolution… we introduce a concept called "computational potential field" (CPF)… When the field is controlled by a computer, we call it a CPF…

[Apart from a] focal point and focal line,.. phased arrays control transducers… can generate other distributions of potential fields… We developed our manipulation system with four modules of phased arrays… The surrounded area is 520 x 520 mm^2… We have two options of phased arrays:… 40 and 25 kHz… The phased array is controlled by a single PC via USB… The PC sends the data, including the coordinates of the focal point and output intensity, to the driving board. The driving board receives the data, calculates adequate time delays for each transducer… and generates the driving signals…

Speed of Manipulation

> … Manipulation along the y-axis [parallel to all arrays] was more stable than along the other axes… particles with diameter 0.6 mm are more stable than those with diameter 2 mm at higher frequencies. This suggests that larger particles tend to fall from the nodes of a standing wave.

Workspace

> In the case of movement along one of the acoustic axes, the manipulated particles could approach the ultrasound array to within 60 mm, but dropped when the distance became smaller. In the case of movement perpendicular to the acoustic axes, the particles at the more distant nodes dropped earlier when they moved away from the center of the system…

Weight Capability

Vertical **F**$_z$ can hold up to 1.09 g and horizontal **F**$_x$ can hold up to 0.66 g…

The levitation and manipulation method used in our study has several characteristics that can prove useful in graphics applications.
These include
1. Simultaneous levitation and manipulation of multiple objects by modification of APF
2. Rapid manipulation of levitated objects resulting in the production of persistence of vision
3. Only dimension and density [are] limitations on levitating objects

[A] wide beam [can be] used for projection screens and raster graphics, whereas [a] narrow beam [can be] used for the levitation of various objects and vector graphics…

Projection Screen

… The movement of the screen has a high refresh rate and high spatial resolution. In our current prototype, the maximum control rate is 1 kHz, the distance between the particles is 4.25 mm, and 85 x 85 particles are held at the maximum… Furthermore… movement vertical to the screen results in volumetric expression and that parallel to the screen achives pseudo high resolution.

Levitated Raster Graphics

First, the APF suspends small particles in all nodes… The system then adequately blows off some of the particles and generates a raster image.

Physical Vector Graphics

By changing the spatial position of the nodes of the APF,… the levitated objects are moved. The movement is fast enough to turn the trajectories of the objects into vector graphics based on persistence of vision… Trajectories are designed as a series of coordinates of control points, which are set up to 1,000 points-per-second… The maximum speed of movement was 72 cm/s… (enough to produce persistence of vision)…

Physical Particle Effects

The movement of the APF produces not only vector graphics, but also [real-world] particle effects…

Animation and Interaction

We combined our levitation and manipulation setup with an IR-based motion capture system. We levitated and manipulated small retro-reflective balls,… tracked by the motion capture system… Another motion capture setup was developed with Kinect. In this setup,… levitated objects are controlled according to the motion of the users' hands…

Material Limitation

There are two factors to consider when choosing objects to manipulate: dimension and density.
Dimension:
The allowable dimension is determined by the geometry of the APF and the allowable density of the material is related to the intensity of ultrasound… 4.25 mm for 40 kHz and 6.8 mm for 25 kHz. A lower frequency leads to larger size.
Density:
The maximum density of a levitated object is theoretically derived as 5 x 103 kg/m3. Further, the shape of the levitated object is limited by the shape of the node.

… Three factors determine the sustainability of the suspension: the heat condition of ultrasonic devices, oscillation of objects inside the nodes, and acceleration in vector graphics:
Heat: The temperatures of devices are equivalent prior to them being turned on. When they are turned on, their temperatures gradually increase… [Because of] difference in temperature, the operating frequencies of the controlling circuits differ,… [which] causes… levitated objects fall off…
Oscillation: … If the intensity of the ultrasound is too high, oscillation grows and finally exceeds the node of the potential field…
Acceleration: … Acceleration acts to throw [objects] off the nodes…

Weight: … More transducers [will] enable us to levitate heavier objects…
Size: … The size of the object is limited by the frequency. In order to retain its non-audible property… We have a scalability limit of up to 8 mm.
Speed: The maximum manipulation speed of physical vector graphics is 72 cm/s… The acceleration [can be increased]… with a higher intensity of ultrasound.
Multiple Controls: … Multiple beams [could be] generated… by separating a single phased array into several regions and controlling them individually…

Get the complete paper:
http://bit.ly/s2014-paper-pixie
Catch the SIGGRAPH 2014 presentation:
Tuesday, 12 August; 345-515 pm
[ballroom A, East Building; VCC]

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