Shaped Embroidered Musical Instruments

Sound Sculpture Pyramid [*]

The *Sound Sculpture Pyramid* was designed to be the ultimate in interdependent and intuitive instruments, letting players use a natural squeezing to play and explore different combinations of eight sensors, as opposed to one-to-one, finger-based control over specific sensors. In its final incarnation, this instrument allows players to explore timbre through the different combinations of eight different audio filters. The DSP musical software for this instrument (by Tristan Jehen) lets players explore the interaction of many different audio filters and the different timbres those interactions create. The physical design of the *Pyramid* reflects the need for filter mixing and timbral exploration software by emphasizing both the interdependency of the sensors, and an intuitive playing style that lets players use *natural squeezing* to play all the sensors at once. This design allows players to explore audio software in ways impossible with a mouse or a series of sliders and knobs. Most people can only control two knobs, or few a sliders at once. This instrument lets players control eight continuous sensors at once, and use the geometry of the instrument to navigate different sensor combinations. These combinations are determined not only by the player's choices, but by the geometry and layout of the sensors. Careful placement of the ground

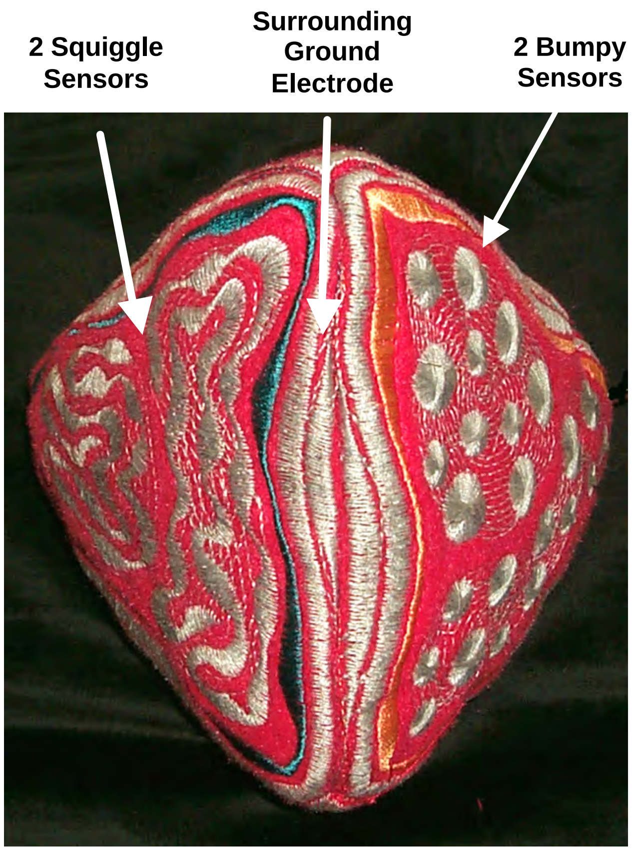

Figure 12. 9 The *Sound Sculpture Pyramid.*

[*] Music software by Tristan Jehan.

electrode around the edges of the instrument guarantees that the player is immediately well grounded when he or she picks up the instrument. I am particularly satisfied with this instrument and its software because its musical output often seems an aesthetic and sensuous reflection of the gestural, squeezing input. The *Pyramid* is also the first instrument to explore the possibility and importance of tactile variety in the embroidered electrodes.

Physically, the *Pyramid* creates sensor interdependency in many ways. Its design encourages interdependent exploration by allowing players to touch all the sensors simultaneously, and preventing them from playing any one sensor at a time. The instrument is shaped like a four-sided pyramid to reflect the four sides of a person's cupped hands. By cupping his or her hands, a player can touch the entire surface of the instrument, playing eight continuous sensors at once. The *Pyramid* has two sensors per side, for a total of eight sensors. (Originally the *Pyramid* was designed to allow control of sixteen small sensors, but the small size of kids' hands made it important to make the sensors bigger.) The two sensors on each side are designed to visually and tactilely appear as one, making it difficult for the player to isolate them. Consequently, the two parameters controlled by the two sensors on each side are almost always played interdependently. If the ball is cupped in one hand, the player must touch two surfaces of the *Pyramid*, and usually four sensors.

While the shape of the instrument is symmetrical, i.e. with no up or down, the *Pyramid* has other design cues

Figure 12.10 The four sides of the *Pyramid* reflect the four sides of cupped hands.

that allow players to use it geometry to navigate and explore different sensor and filter combinations. Each side of the *Pyramid* is marked with a non-conducting embroidered band. There are two blue bands and two yellow bands. The *Pyramid* also has two bumpy sides and two smoother squiggle sides. There is one blue and one yellow bumpy side and one blue and one yellow squiggle side. Players can squeeze the two blue sides, the two yellow sides, the two bumpy sides, or the two squiggles sides. Players can also grab the *Pyramid* by the corners, exploring the relationship of the three sensors that meet there.

An intuitive squeezing or playing style is also emphasized by the physical design of the *Pyramid*. The placement of the ground electrode on the outside edges of the *Pyramid*, and the sewing of it on the same fabric piece as the sensors, guarantees that the player is well grounded as soon as the *Pyramid* is picked up. (This was made possible by the wrapped bobbin thread.) Immediate grounding of the player when the ball is squeezed, makes generating an immediate musical response with simple hand squeezing intuitive and easy. The symmetric shape of the *Pyramid* (no top, bottom, right or left), encourages players to navigate with their ears and explore the timbral relationships, rather than the shape of the instrument.

The *Sound Sculpture Pyramid* was the first instrument to explore the tactility of the embroidered sensors. Before the *Pyramid*, all the electrodes on a single instrument possessed the same tactile qualities. In the *Pyramid*, the tactile differences between different sensors and the ground electrode help the player

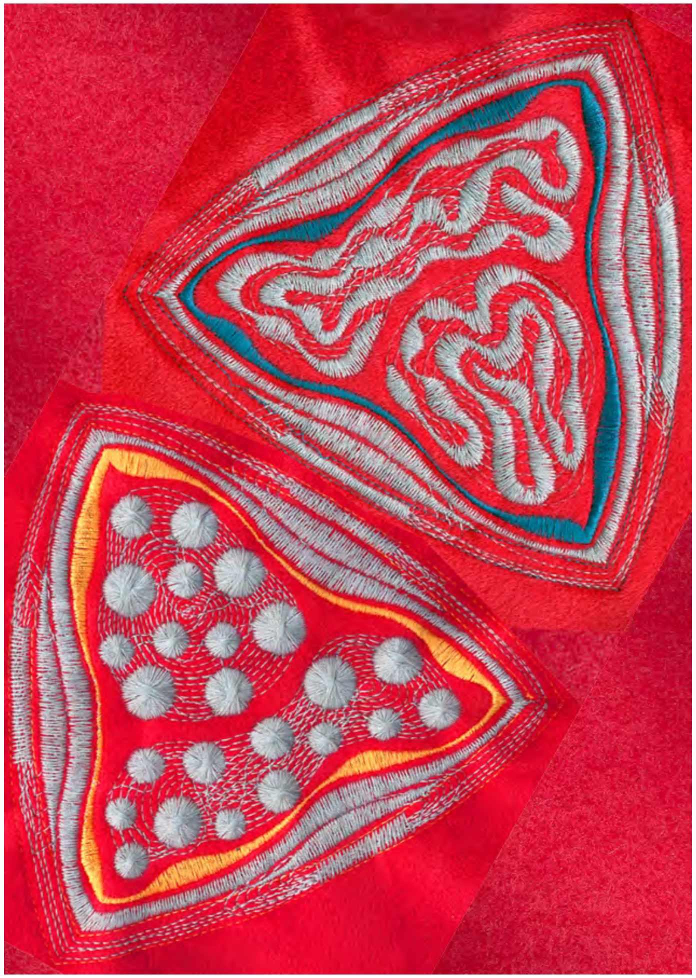

Figure 12.11 Flat design of the *Pyramid* sides, with yellow and blue bands, and bumpy and squiggle sensors.

navigate the instrument. The *Pyramid* has two sides with bumpy sensors, two sides with satin stitched squiggle sensors, and a more evenly stitched satin, ground electrode. The more tactile stitching of the sensor electrodes indicates that these are the places to touch. Players can also use the different textures to navigate the instrument. They can squeeze all the bumpy sides at once, or all the squiggly sides at once.

One major goal for the sensors of the *Pyramid* was to keep their sensitivity, (which, I empirically observed, required both high conductivity and surface area), but at the same time reduce the density and stiffness of the embroidery. For the *Generic Musical Ball*, I had created stable and highly conductive electrodes by densely sewing a continuous satin stitch. While this worked well, it was very stiff. The *Pyramid* used a new sewing method that combines a loose contour under-stitch (to provide a stable electrical plane that was flexible), with denser, well-spaced objects. The contour-stitched under plane created electrical continuity and redundancy; the dense objects on top provided something for the player's hand to electrically couple to, and the spacing of the objects kept the electrode flexible. For instance, in the *Pyramid,* each bumpy sensor is made up of a group of very tactile, stiff bumps sewn over an underlying, loose and soft contour stitch. The contour stitch provides the denser bumps with a soft, single electrical plane to rest on. Using the contour stitch and the wrapped bobbin thread allowed me to create sensors with many different shapes and textures while maintaining their soft qualities. The bumps make these sensors particularly sensitive, because their surface rises above the surface of the fabric to meet

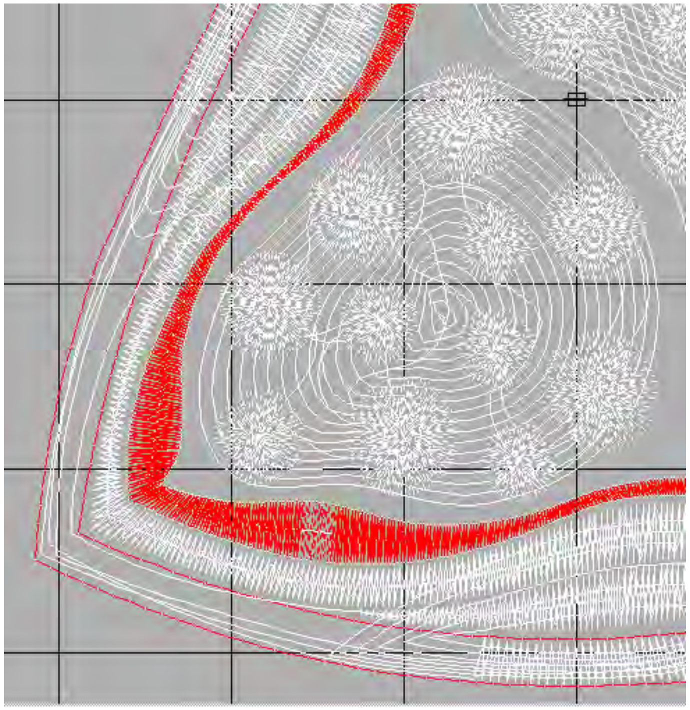

Figure 12.12 CAD file of bumpy sensors sewn over contour under-stitch base.

the surface of the hand, and they give the player something relatively stiff to push against.

The intimate link between the visual design and the electronic/sensing needs of the bumpy sensors is an excellent example of highly developed *functional ornament*. I started out creating many bumps as a way to let players feel the sensors and also as a way to make the two sensors on a single surface tactilely linked and inseparable. I wanted to cover the surface with a series of bumps in a way that prevented the player from distinguishing between one bump and another. These bumps were also essential to making the sensor reactive. The design of the electrical contour plane is both necessary for conductive and visual reasons. In this way, the visual design of the electrode is closely linked to its electrical function.

Using embroidered sensors and textiles allowed me to iterate on this instrument literally dozens of times. Numerous experiments were performed on the sensor design, perfecting both the bumpiness and the electrical properties. Ground design and placement was also experimented with many times. The ground needed to be very conductive, as big as possible and not accidentally short out the sensing electrodes adjacent to it. Ultimately, I wanted the ground electrode to be tactilely different than the sensing electrodes. I experimented with a tatami stitch that creates an even fill that is not particularly bumpy. However, at that point I could not figure out how to make it conductive enough for good grounding.

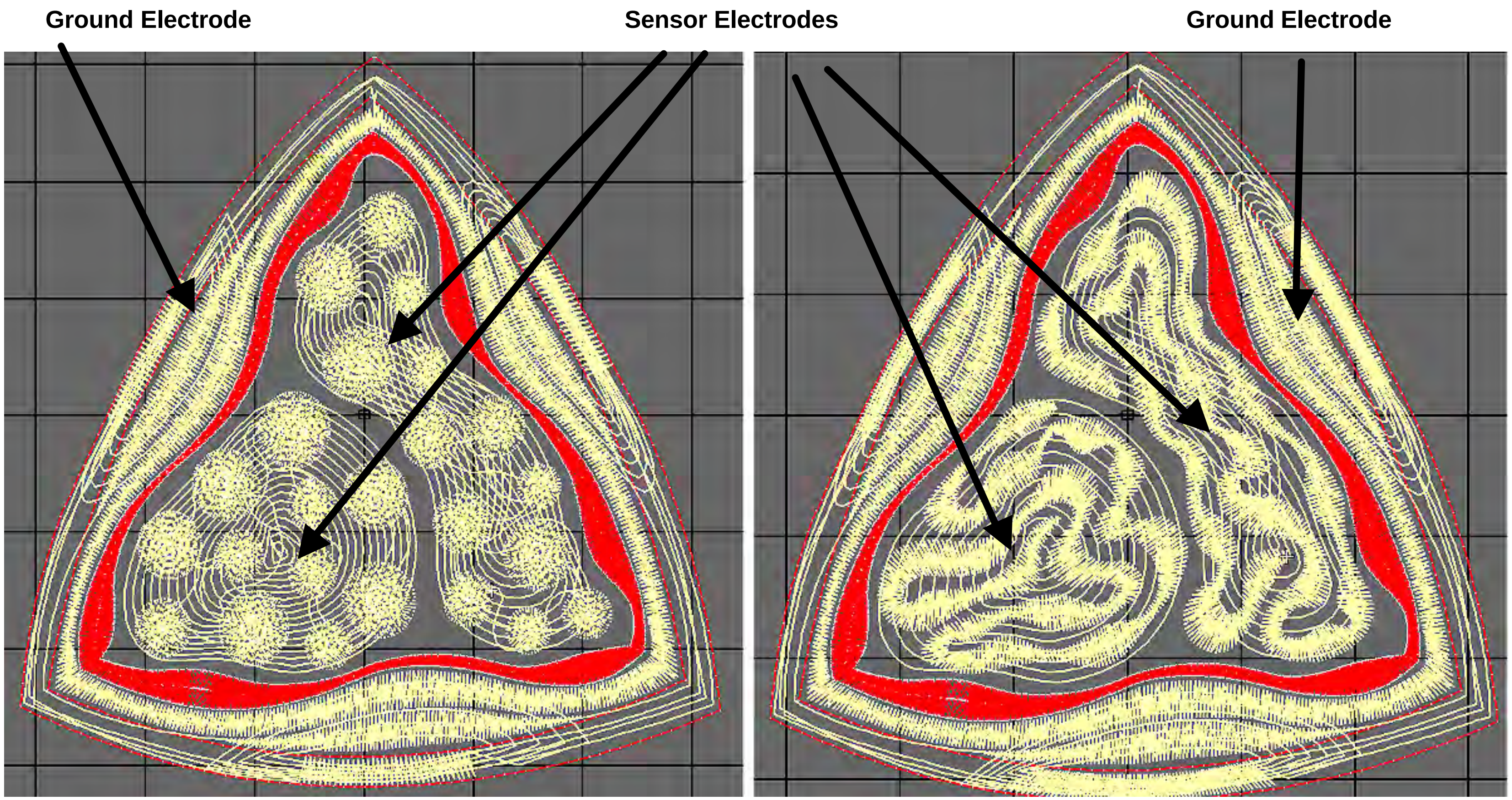

Figure 12.13 CAD files of two separate sides of *Pyramid.*

Melody Butterfly*

This instrument was my first attempt at designing an instrument that would let players create two complementary melody lines. Each melody line is determined by four continuous sensors that are mapped to volume, tempo, pitch/contour and note length. This butterfly-shaped, two-sided instrument was designed to let players control each melody line with a single hand. The four sensors per side were placed so that players could control each sensor with a single finger, like a piano. The instrument was asymmetric so players could orient top and bottom and front and back, being sure of which finger was controlling which musical parameter.

After many sensor designs it became apparent that hand-held, stuffed *Embroidered Musical Instruments* were not meant for one-to-one finger to sensor control. Many problems emerged when I tried to create this type of one-to-one control. It was ergonomically difficult to design an instrument that would fit any size hand and guarantee a good ground connection and finger-by-finger control. An important element of complex impedance sensing is the DC electrical connection between a player's hand and the sensors and ground electrodes. The squeezy balls let players explore, and find out how to best couple their hands to different instruments. The *Butterfly* forced EVERY person to use the tips of their fingers to play the sensors. Because different people have calluses and different skin thicknesses on different parts of their hands, not

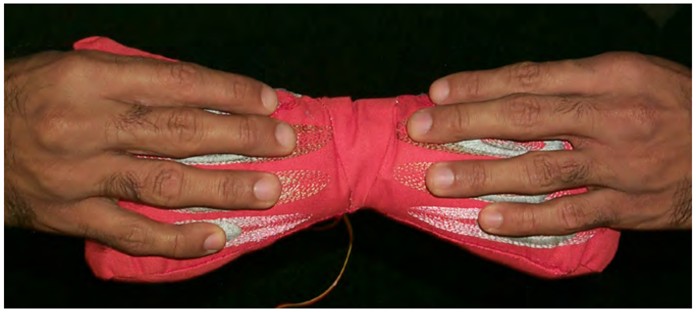

Figure 12.14 *Melody Butterfly* designed for piano-like finger–by-finger control.

Figure 12.15 *Melody Butterfly*. Top, the front with four sensors. Bottom, the back with circle ground electrodes.

* Music software by Gili Weinberg.

everyone's fingertips worked equally well. Moreover, getting good contact with ground involves being able to press your hand against the electrode. I found that when players tried to use this sort of finger-by-finger control they tend to lift the rest of their hand away from the instrument, or hold it lightly. This meant that they were poorly grounded. Moreover, getting your hand in good contact with the electrodes involves creating a certain degree of physical pressure. But the fabric is squishy, so it provides no rigid surface to squeeze against (like a piano does). In the *Pyramid*, two hands could push against each other. In the *Butterfly*, each hand needed to be able push against itself to create the necessary pressure to play it well. But the soft touch required by individual finger control prevented the use of opposing force when squeezing the *Butterfly*.

I went through many sensor designs for the *Butterfly* trying to fix this problem. None of them worked. In the mean the time, we started pairing the melody software with highly interdependent *Pyramid* instrument. Our experiments playing the Melody software on the *Pyramid* were surprisingly successful. This is because creating any satisfying musical response with the instrument requires that the tempo and volume parameter of each line must be triggered together. This interdependent *need* of the software was reflected in the physical design of the *Pyramid*, whose design forced them to be played together. In addition, squeezing the *Pyramid* generally triggered enough sensors to create an interesting melody. But the *Pyramid* design still had some drawbacks. Because it was possible to squeeze only four sensors at a time (with one hand), and because there was little clear orientation about which four you were squeezing, it was possible to squeeze the ball with one hand and get little musical results if you got the wrong combinations of sensors.

Melody Tube

The experimentation with the *Pyramid* and melody software led to a new physical design, the *Melody Tube*. The final *Melody Tube* combines the intuitive squeezing properties and interdependent sensors of the *Pyramid,* with the two-sided nature of the *Butterfly*. The final instrument is a long tube with two halves. Each half has four sensors that control the two melody lines. The sensors are designed diagonally to let plays play all four at once with a single hand. The diagonal design of the sensor electrodes forces interdependency by guaranteeing that players cannot trigger the inner sensors, or the unnecessary sensors, without triggering the outer ones. By sliding their hands to the end of the *Tube*, players can trigger only the two sensors necessary to create a musical output. Thus as long one hand is squeezing one half of the tube the player is getting a musical response. The tube-like shape allows players to create opposing hand pressure for good sensor and ground contact. It also lets players explore to see which parts of their hands work better.

In this instrument, I used bumpy sensors, a wide satin stitch, and a contour over-stitch to create the sensing electrodes. The bumpy and satin stitches are highly tactile so the player can easily feel them. Tactility is something I look for when making a sensor electrode. The bumpy dots also give the player's hand something

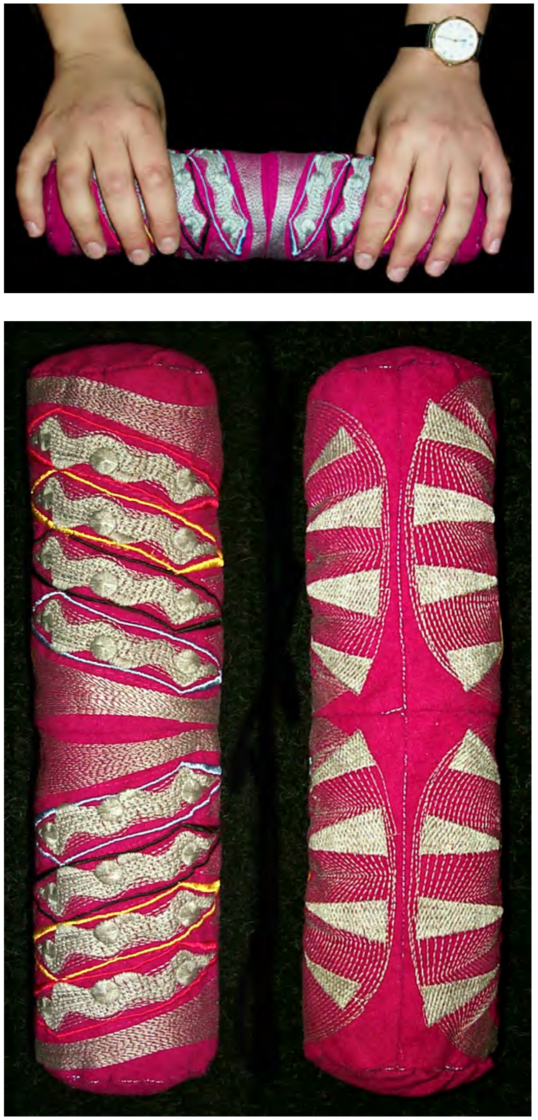

Figure 12.16 *Melody Tube*. Top shows relationship of sensors to player's hands. Below left, sensor design. Below right, ground electrode design.

to push against. The light contour overstitch is the final piece of my new sewing style for highly conductive electrodes. I empirically found that by overstitching any filled object with a light contour stitch, it substantially increased its conductivity. Overstitching tacks down the threads of a wide satin stitch. It also works to electrically improve and connect the relatively smooth tatami triangles in the ground electrode.

Problems with this instrument still remain. Having the four sensors in a line or row means that there is a very specific order or grouping in which they are triggered. For instance, the two middle sensors have a tendency to be triggered all the time. I have also found that it is easier to reach the maximum value on the outer sensors than the inner sensors because of the pressure your hand creates while squeezing. Ultimately, I would like to redesign these sensors in a more circular pattern, on the end of the tube.

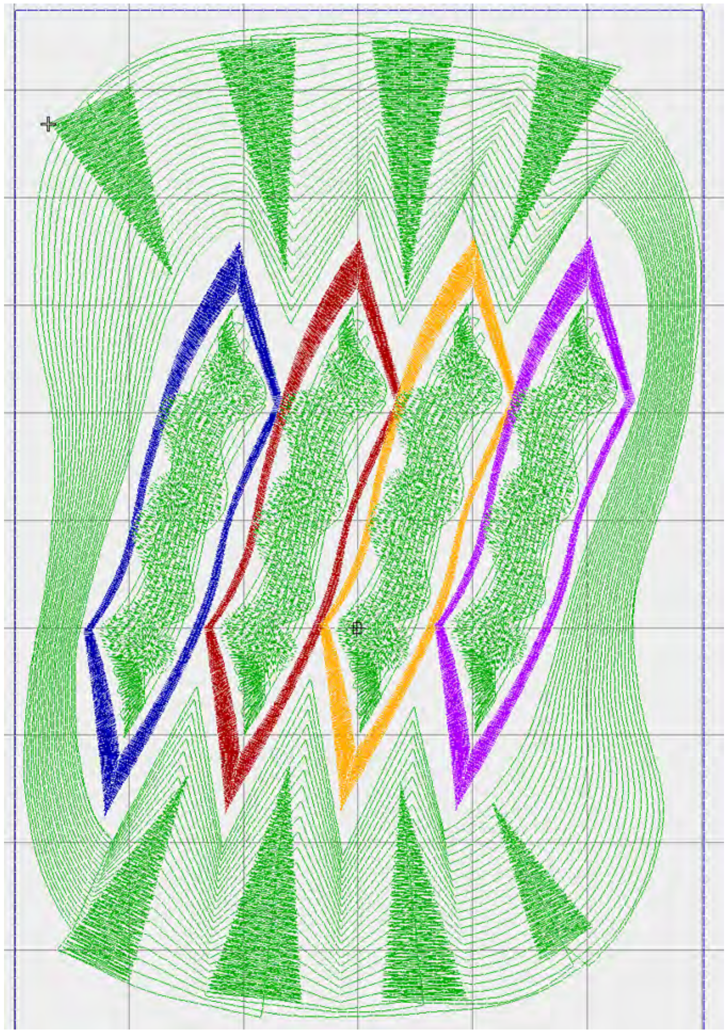

Figure 12.17 CAD file of *Melody Tube* design.

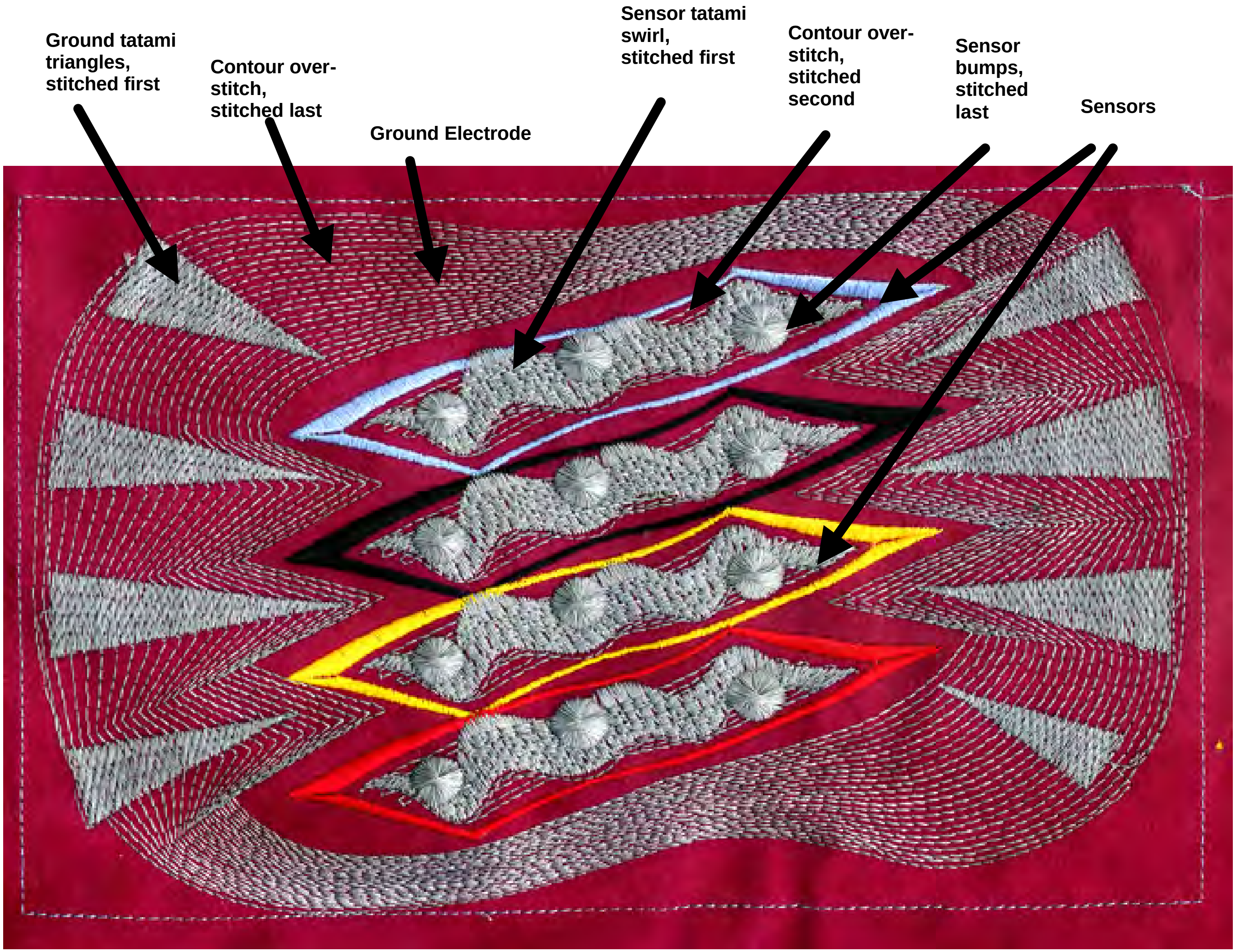

Figure 12.18 Flat panel of *Melody Tube* design.

Big Ring for Re-Composing Music[*]

Both the software and physical form of this instrument were designed to take advantage of what had been seen as a bug in the *Generic Musical Ball*: the limited number of sensors players can touch at a time. The music for the *Big Ring* is eight tracks of pre-composed music. If played at once, these tracks sound like a cacophony. The size and placement of the sensors on the ring force players to select and blend just a few (no more than four) tracks at a time. This process is designed to let players “recompose” the music.

The *Big Ring’s* sensors are wide, allowing players to cover only one at a time with a single hand. By designing the ends of the sensors to diagonally overlap, players can also trigger two at time. The bumps at each end of the sensor let players know tactilely when they are about to touch two sensors. The placement of the sensors on the outside edge of the *Ring* guarantees that the player’s hand contacts the sensors when it is first grabbed. The large ground on the top and bottom of these sensors is easy to reach. But while this design may seem almost identical to the *Generic Ball,* it is not. The ring around the ball is sized so that it can be grabbed with one hand and squeezed. This allows players to use the opposing pressure in a single hand grab to make a strong electrical contact to the ground and sensors simultaneously. In the *Generic Ball*, opposing hand pressure with a single hand could not be used because of the round shape.

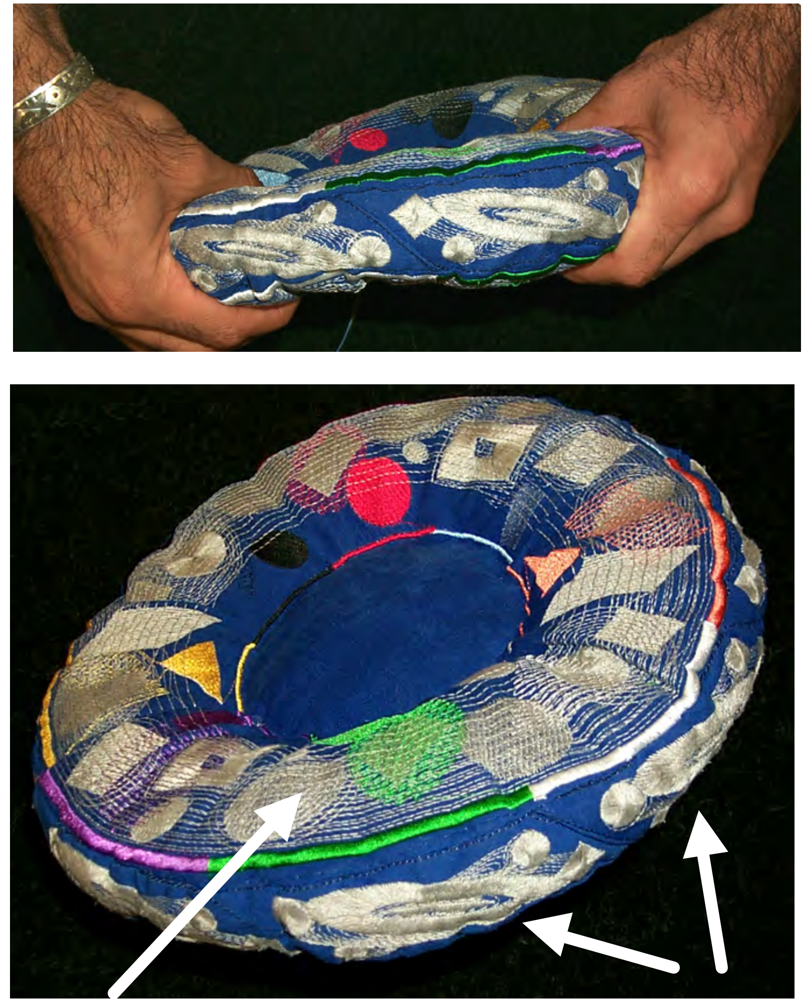

Figure 12.19 *Big Ring*. Top, relationship of hands to sensors and ground. Bottom, ground and sensor design.

[*] Music software by Gili Weinberg.

With this instrument I was able to really experiment visually because of a new sewing technique that made it even EASIER to make highly conductive electrodes from the less dense tatami stitch. Using a loose contour both *under and over* the primary shapes of the electrode, (in the past I only used it under the objects), dramatically increased the conductivity and allowed me to use far less conductive, but more creative, stitches and object shapes. The result of this process is the visual layering of objects with different densities in the ground electrode of the *Big Ring*. Because of the new possibilities that this layered sewing process the ornate design of this ground electrode may have gotten away from me. I had observed that people playing the balls were drawn to touching ornate areas. Players who touch this instrument often think that the ornate ground electrode is the sensitive part of the instrument and attempt to touch the squares and circles to make music. But this was the first time I got to really visually experiment with different stitch styles and layering, so I was a little too excited to restrain myself.

Soft and pliable ultra-suede is the substrate of this instrument. Ultra-suede is thin enough that it does not add thickness and stiffness to the sewn electrodes. In the past I had tried to work with polar fleece, but found it became too stiff when embroidered. This fabric is water repellent (good for preventing sweat from shorting things out), and at the same time it has a velvet-like quality that makes it tactilely appealing.

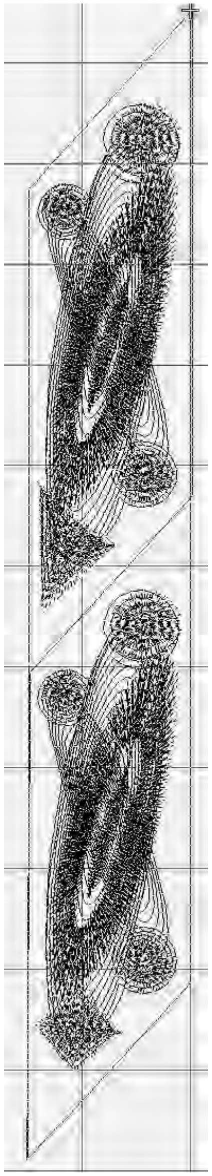

Figure 12.20 Sensor electrodes of the *Big Ring*. The diagonal design makes it easy for one hand to play two at a time.

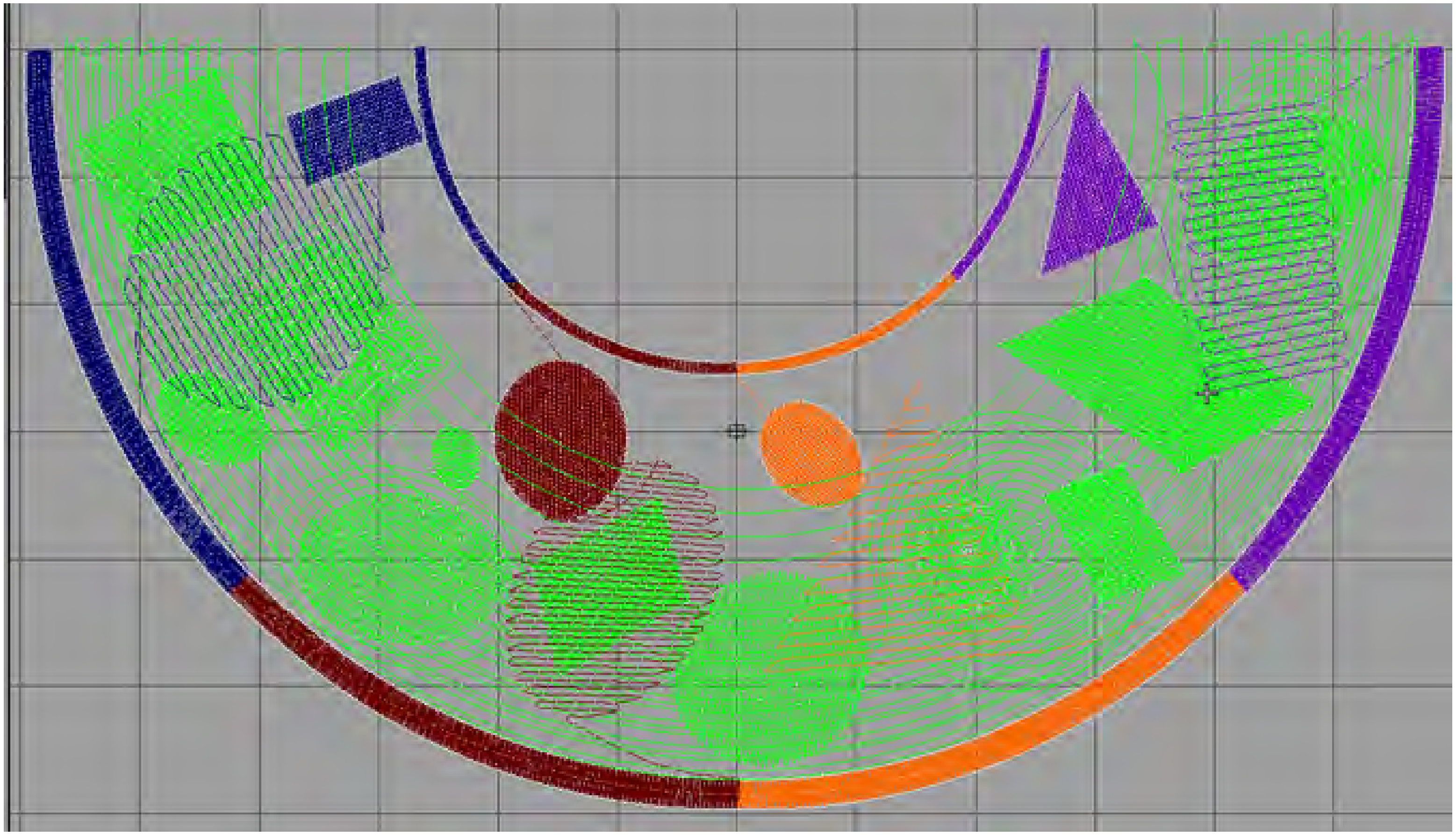

Figure 12.21 *Big Ring* ground electrode.

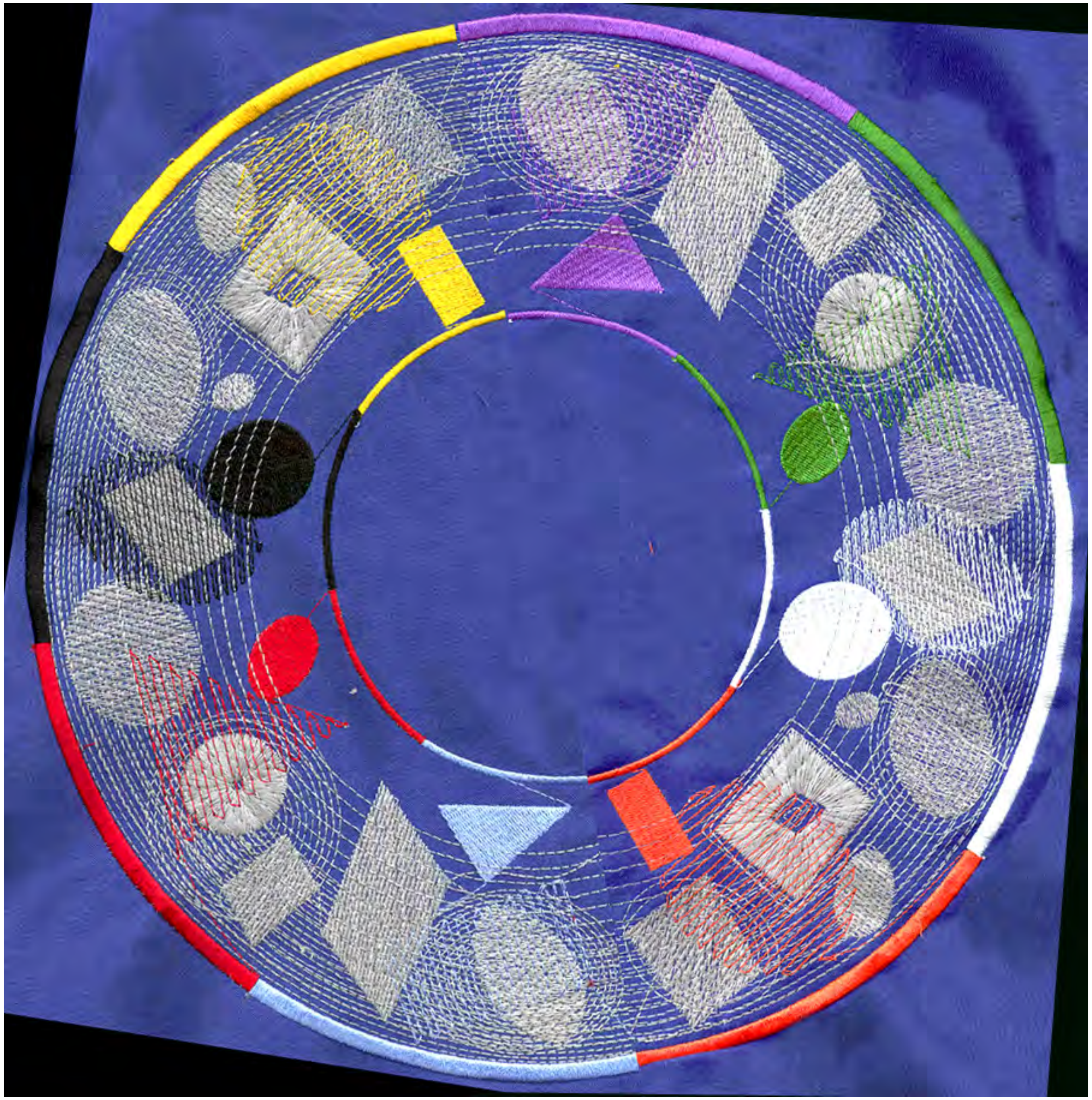

Figure 12.22 Flat version of complete *Big Ring* ground electrode.