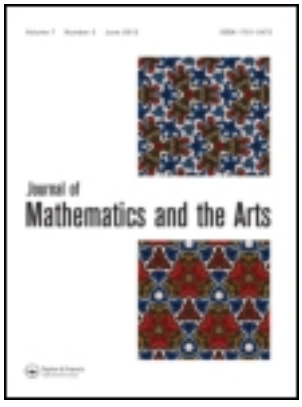

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REPORT

The Bridges Enschede 2013 Exhibition of Mathematical Art

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How to begin to describe the diversity of work on display at the Bridges 2013 art exhibition? I will take inspiration from the last two lines of Rumi's poem *What's Not Here*, and begin with atmosphere.

The work filled a large rectangular room on the ground floor of the Hogeschool of Saxion University, in the city of Enschede, The Netherlands. One long wall was glass, looking out on a courtyard of green and benches. The wall across from this had two pairs of double doors, on opposite ends, both opening onto a long hallway. This bustling hallway, with tables for registration, hands-on activities, and vendors, was a main thoroughfare connecting the entrance of the Hogeschool with the staircases that led to the vast range of Bridges events: talks, film screenings, Zometool construction, the FabLab open house, math-theatre rehearsal, etc. Thus, a constant flow of participants and visitors found themselves weaving through the art exhibition, en route to a talk, waiting for their lunch party, or winding down on the way home. The room of the exhibition became a space of initiation, of contemplation and processing, and of follow-up conversation. It contextualized the theoretical talks transpiring on the floors above, and became a context for new interactions and fresh ideas.

Within the exhibition room, tables with three-dimensional (3D) works ringed the perimeter and dotted the centre, and two-dimensional (2D) works hung on wire-frame wall partitions densely spread throughout. The challenge to fit all submissions into one room was met valiantly and successfully by curator Robert Fathauer, a difficult task given that many 3D works seemed to exceed the recommended size limitations of $24'' \times 24'' \times 24''$.

The average visitor experience seemed to consist of an observant meander, often accompanied by a helpful exhibition catalogue consultation, and perhaps a chat or two. Curiosity was on display throughout, with many ponderous expressions, furrowed brows, and unpretentious discussions. People seemed to find what they were looking for, judging by the smiles, laughs, and satisfied reflective gazes. Compared to the museum-like stillness and isolation in a private art gallery, the Bridges art exhibition was humble, friendly, and light.

Before surveying the range of work, and describing some specific pieces in detail, I wish to comment on my experience of a typical Bridges art object.

Standing in front of it, engaged in viewing, the first impression is that *something mathematical is going on here*. There may be a significant degree of symmetry, as with the many polyhedral sculptures on display; there may be uniform patterning, as in tilings or many woven pieces. Maybe it's all the straight lines. In any case, there is a perceptibly high level of small- and medium-scale detail, accompanied by a uniformity of concept, that seems to trigger the analytic and pattern-finding mental faculties.

Of course, there almost always *is* something mathematical going on in a Bridges piece. To fully appreciate the work, then, the viewer must either decipher the mathematical signature hidden within that work, or consult the exhibition catalogue for a description. In this sense, Bridges pieces are quite contemporary. The 2013 Venice Biennale, titled The Encyclopedic Palace, explored the connection between creative work and the information behind it, presenting new pieces alongside historical works and found objects. 'Blurring the line between professional artists and amateurs, outsiders and insiders, the exhibition takes an anthropological approach to the study of images', according to the Biennale's curator Gioni [2]. Exemplified in the current trend of research-based art, many contemporary art pieces cannot be said to be fully appreciated without an understanding of the story behind their creation.

The delightful conundrum of the viewer – shall I ignorantly enjoy this visual information, or go hunting for its explanation? – is captured well by the lines from Rumi alluded to earlier:

> *While intelligence considers options, I am somewhere lost in the wind.*

With 154 artists exhibiting 295 pieces, this was the largest Bridges art exhibition yet. If my count is correct, artists

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Figure 1. Friedhelm Kürpig, *Worm eaten sphere*, 2010. Stainless steel sheet, thickness 1.5 mm, 360 × 300 × 300 mm.

came from 30 different countries, ranging from Finland to Argentina, Portugal to Japan. There were 152 3D works, including five displayed videos and animations. Twenty-six pieces were created using 3D printing technology. Other media included wood, paper, beads, metal, ceramics, wire, and plastic tubing. Of the 122 2D works, 79 were digital prints of computer-generated images and/or photography, and 43 were created wholly or partially by hand. Twenty-one quilted or woven works were on display. This report will survey only a small fraction of all the pieces, chosen with some amount of personal bias. For more, consult the Bridges Art Exhibition Catalogue [1], which is also available online at http://gallery.bridgesmathart.org/exhibitions/2013-bridges-conference. I would like to thank all the artists for their permission to reproduce the copyrighted images shown here.

At this, the 16th iteration of Bridges, the mathematics behind the pieces could be quite elaborate and sophisticated: rotationally symmetric non-periodic rhombic tilings, compound perfect squared squares, even a Petrie projection onto the Coxeter plane of the eight-dimensional root system of the exceptional Lie group E_8.

For the second year, Bridges visitors were given the chance to vote on favourite works, in four categories. The award for Best Craftsmanship went to Friedhelm Kürpig's *Worm eaten sphere*, created by layering 29 separated stainless steel sheets. The circular laser-cut sheets create a sphere, which is at the same time carved into by two helicoids (Figure 1). The object seemed untouchable and majestic.

The Most Innovative award went to *Triple Gear* by mathematicians Saul Schleimer and Henry Segerman, three

Figure 2. Saul Schleimer and Henry Segerman, *Triple Gear*, 2013. PA 2200 Plastic, Selective-Laser-Sintered, with motorized base, 19.8 × 11.3 × 13.0 cm.

plastic interlocking circular gears perpetually turned by a motor in the base (Figure 2). Throughout the Bridges conference, a small flock of visitors gathered around the churning gears, entranced and lulled by its inevitable stasis in movement.

Roberto Giardili's *Triangular Wriggle*, a welded sculpture of iron tubes ricocheting upwards in two angled lines to meet at a point, was awarded Most Effective Use of Mathematics (Figure 3). The lines and angles are determined by a hidden initiator shape, 'a pair of four-pieced ascending helices out of phase 180° that converge to the centre in the top point', and its interaction with a generating curve 'inspired by the von Koch curve but extended to 3D'.[1] The award for Best In Show was given to Mike Naylor's *Human Platonic Transform*, which will be discussed in more detail below.

With so many artists presenting work, and some artists presenting multiple pieces, certain mathematical themes were explored quite thoroughly. One could peruse a diversity of perspectives, expressed through a range of media, on a single idea.

For example, consider the icosahedron, a platonic solid formed by 20 equilateral triangles. George Hart's trio of hanging paper sculptures *Trio* aims to 'highlight the three types of rotational symmetry in the icosahedral symmetry group'. Complementing this, one of Andrea Hawksley's pieces in *Seeing Stars* is an icosahedron made of plastic star-shape-framed sunglasses, 'symmetrically coloured such that the edges around the structure are accentuated'.

Raymond Aschheim's printed *Platon Archimede and Kepler* includes a 'platonic ball', in which all five platonic solids are nested; Stephen Wilmoth also nests all five in *Crystal Morphohedron*, but using optical clear acrylic (Figure 4).

Figure 3. Roberto Giardili, *Triangular Wriggle*, 2012. Welded Iron Tubing, $21'' \times 12'' \times 12''$.

Platonic Water of H-Fractal 5-3, by Hongtaek Hwang and Gyungsoo Woo, is an icosahedron constructed with yellow and red tubes and aims to symbolize water. Also using tubes and wire, Martin Levin exhibits a duality between icosahedra and dodecahedra, repeatedly nesting one within the other, in *As Above So Below* (Figure 5). Chern Chuang's elaborate glow-in-the-dark beaded $C60 \otimes C60$ uses the fact that both the buckyball C_{60} and the Zometool ball exhibit icosahedral symmetry. The beaded *Disco Ball Explosion* by Laura Shea puts an icosahedron at the end of each of 12-beaded columns emerging from a central dodecahedral shape.

Bringing the icosahedron to life in his piece *icosaeder/water*, Ton Oostveen figured out how to fill one in with transparent surf sail, so that it would fly as a kite. The icosahedron is pushed into two dimensions by Curtis Palmer, for example, in *Hessians on Edge*. In fact, he simultaneously projects three polyhedra – an icosahedron, a dodecahedron, and an icosidodecahedron – onto a plane, generating a 2D image that is then selectively coloured in. By changing the orientation of the plane, three different images are created. Roland Gagneux's plywood *Expanded Propello Truncated Icosahedron* has 902 faces.

Figure 4. Stephen Wilmoth, *Crystal Morphohedron*, 1970. Optical clear acrylic, $6'' \times 6'' \times 6''$ closed, $6'' \times 15'' \times 6''$ opened.

Apparently, all five platonic solids can be constructed by starting with the 30-face rhombic triacontahedron and selecting appropriate vertices. Bob Rollings shows this comprehensively with *In The Search For Vertices*, building the central shape on a lathe out of bubinga and cocobolo woods, and then selectively inserting brass rods (Figure 6).

These elaborate, clever, and sincere meditations on the icosahedron, spread throughout the Bridges exhibition space, were contrasted nicely by some playful and bizarre pieces. Again, Rumi: *While intelligence considers options, I am somewhere lost in the wind.*

Tiffany Inglis' painted papier-mâché sculpture of a coffee cup melded with a doughnut, *A Homeomorphic Breakfast*, is flawlessly executed (Figure 7). She explains:

> This sculpture is an homage to the age-old joke that a topologist cannot distinguish between a doughnut and a coffee mug, since the two spaces are homeomorphic.

Inglis is a PhD candidate in the Computer Science department at the University of Waterloo, Canada. Her PhD advisor Craig Kaplan is a professor in that department, and was also playing on inside jokes when he created *'Bunny' Bunny* with Henry Segerman, a printed sculpture of a bunny whose surface is made out of the word 'Bunny'.

Less frivolous but more bizarre is Françoise Beck's *Horses enjoy wider viewing than Humans*. Apparently horses, goats, and sheep have rectangular pupils. The pupil of a cat is a vertical sliver, and human pupils are round.

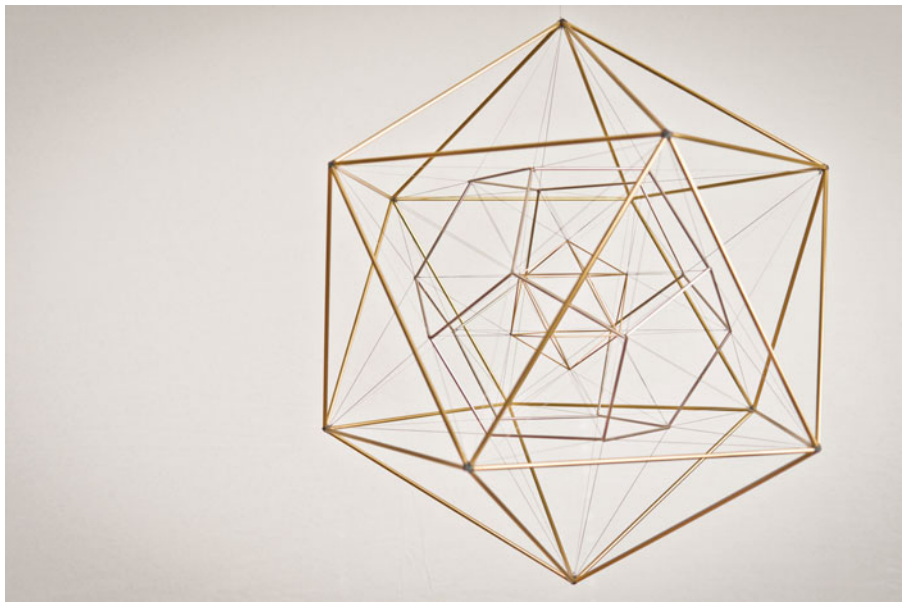

Figure 5. Martin Levin, *As Above So Below*, 2013. brass and aluminium tubing, beading wire and string, and 3D printed nylon joints, $17'' \times 17'' \times 17''$.

The three geometric shapes are superimposed on a colour pencil drawing of one left eye.

Perhaps most bizarre is Samuel Verbiese's collage *Twisted Super Cretan Labyrinth*, in which he elaborately constructs a circular labyrinth from a piece of plastic trash, then glues crackers to it. He explains:

> I was 'automatically' munching on the last crackers left during a pre-New Year party cleanup. Suddenly my attention was caught by the regular ridges of the plastic container's bottom: 'WOW!, isn't that a Cretan labyrinth seed?' Cleanup was left for another day, as the precious thing needed an immediate response . . . Couldn't the twists represent my wanderings through the labyrinth, crawling once on my belly, then on my back and reverse?

Finally, Nathan Selikoff's piece this year, *Mini Marionette*, successfully bridges the rigorous and the playful. The fully functional puppet has an icosahedron for a head, and limbs made of cardboard cylinders (Figure 8). Visitors to the exhibit were invited to operate the marionette,

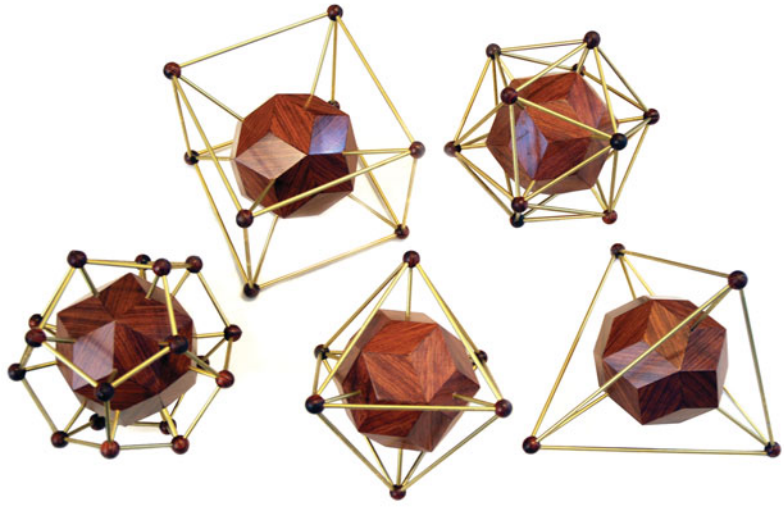

Figure 6. Bob Rollings, *In The Search For Vertices*, 2013. Bubinga and Cocobolo Wood and Brass Rods, $6'' \times 16'' \times 16''$.

Figure 7. Tiffany Inglis, *A Homeomorphic Breakfast*, 2013. Acrylic paint on macaroni and papier-mâché, 12″ × 24″ × 8″.

marching it around the room to view mathematically inspired art. While most pieces in the art exhibition focused on mathematical content or characteristics of that content, Selikoff's piece was one of few at Bridges that directly referenced the mathematical process and the human body that *does* mathematics. (*I am somewhere...*) These works deserve mention, as they present an alternate vision of the common ground to be found between mathematics and art.

One of the most explicit is Nick Sayers' *Giant Pantograph*, a large device of struts and hinges 'used by draughtsmen and engravers to enlarge or reduce drawings before the advent of computer aided design'. At Bridges, Sayers exhibited a photograph of the device, as it is being used to

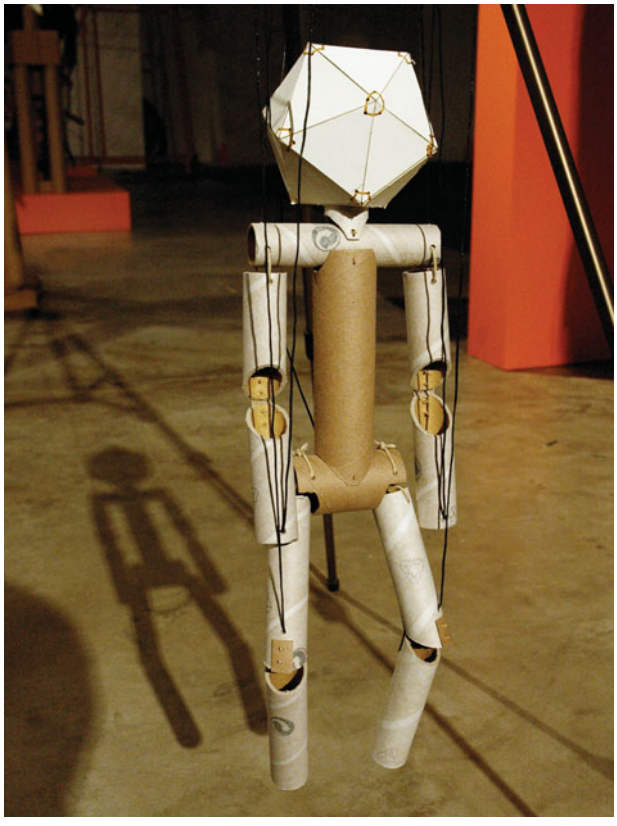

Figure 8. Nathan Selikoff, *Mini Marionette*, 2013. Recycled cardboard, toothpicks, string, imitation sinew, 16.5″ × 5″ × 3.5″ (not including strings).

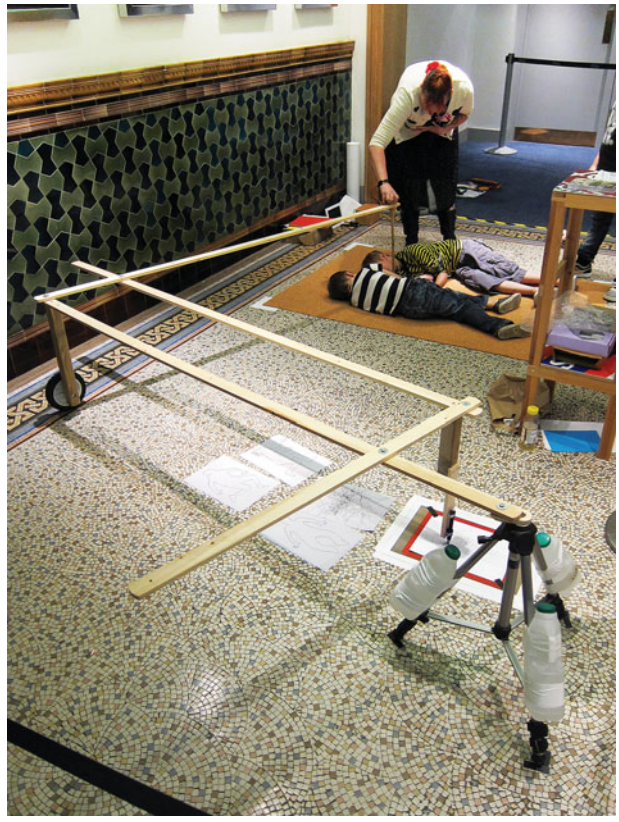

Figure 9. Nick Sayers, *Giant Pantograph*, 2011. Photograph of 2-m pantograph body drawing machine, Wood, nuts and bolts, photographic tripod, art paper, mechanical pencil.

create miniature silhouettes of several children sprawled out on a tile floor (Figure 9) – a sort of mathematical modelling.

With *Hidden Pentagram* and *Hexagonal Flower*, Francesco De Comité continued his exploration of anamorphoses, interactive objects that reveal a secret symmetry when viewed from the right perspective, an accurate invocation of mathematical discovery. James Mai captured the process of translation between mathematical domains, one of the most useful tools in research mathematics, with his 'studies in colour contingency'. In *Circuitous*, a pink band travels between regions of red, yellow, and violet, inducing shifts in colour perception along the way.

The computer-assisted embroidery of *Complex Functions Quilt*, created by Ricardo Nemirovsky and J. Brooke Ernest, with the students in the Spring 2010 Technology in Teaching Mathematics course at San Diego State University, includes artist testimonies directly. An accompanying iPad allows viewers to watch videos of students explaining their work and process. The object, the physical quilt, is presented as an artefact of doing, merely a signifier for the woven-together stories of mathematically inspired creation. And it's hard to disagree with student Whitney Niceswanger when she says, 'Seeing mathematics as an art form facilitates just the kind of creative thinking that is a requirement for a good mathematician'.

Figure 10. Loe Feijs and Marina Toeters, *Drapely-o-lightment*, 2012. Polyester fabric, OLEDs, Arduino, 60 × 30 × 30 cm.

There is also the textile works of Loe Feijs and Marina Toeters, displayed on mannequins that greeted visitors as they entered the Bridges art exhibition room. Interesting tessellations of triangles and quadrilaterals on the skirt *Drapely-o-lightment* (Figure 10) were 'designed around the themes of drapability and light'. Incorporating organic light-emitting diodes in an intriguing way, the garment brings the mathematics to life, while also seeming quite comfortable.

Anna Ursyn's prints of collages, *Selections* and *Quartus*, are accompanied by concise descriptions that could be either Confucian aphorisms, or learning goals for an introductory course on mathematical thinking: 'Small parts of available material can construct a new shape' and 'Dividing and organizing aids communication'.

Perhaps the richest invocations of mathematical process are the Musical Flocks pieces by Ruslan Kamolov and Penousal Machado. Each of three pieces follows a common methodology. Starting from a given musical composition of Kevin MacLeod, music visualization software generates real-time animations 'by simulating the behaviour of agents that react to the sound of music. Swarm-like behaviour is attained by following rules of separation, alignment and cohesion'. The piece is presented threefold: music, animation, and three well-chosen stills. For example, *Jackhammer* (Figure 11) depicts stunning point-and-line fields of clustered depth and confusion. In these pieces, I see the doing of math. With music as the intangible muse, the mental symphony accompanying a flight through some given mathematical landscape, a mathematician uses the tools of 'separation, alignment and cohesion' to extract new representations and data. This flow of visions across the mind's eye is frozen, captured, and communicated by scribbles and scratchmarks on paper. There is no guarantee of structure or insight or order, only transmission.

In this vein, perhaps I may be permitted some critical reflection on the art exhibition. I would yet again point to the Rumi quote, but this time as capturing what I see as a disconnect between some Bridges pieces and their larger societal context. While intelligence considers the piece as created in a culture, with a history and established symbolism, the artist is somewhere lost in the wind. To a small degree this disconnect is present in many pieces, in their mild ignorance of previous Bridges pieces, not to mention wider Art History. But in a more specific way, I saw this disconnect in two works, by Mike Naylor and by Kuiper's Math Art.

Naylor's *Human Platonic Transform* is a looping digital animation presented in a digital frame. The animation consists of six idealized female bodies – not to say Barbie dolls – floating in space, their limbs and torsos spread to

Figure 11. Ruslan Kamolov and Penousal Machado, *Jackhammer*, 2013. Inkjet print on Photo Rag Bright White paper / Computer Animation, 84 × 18 cm.

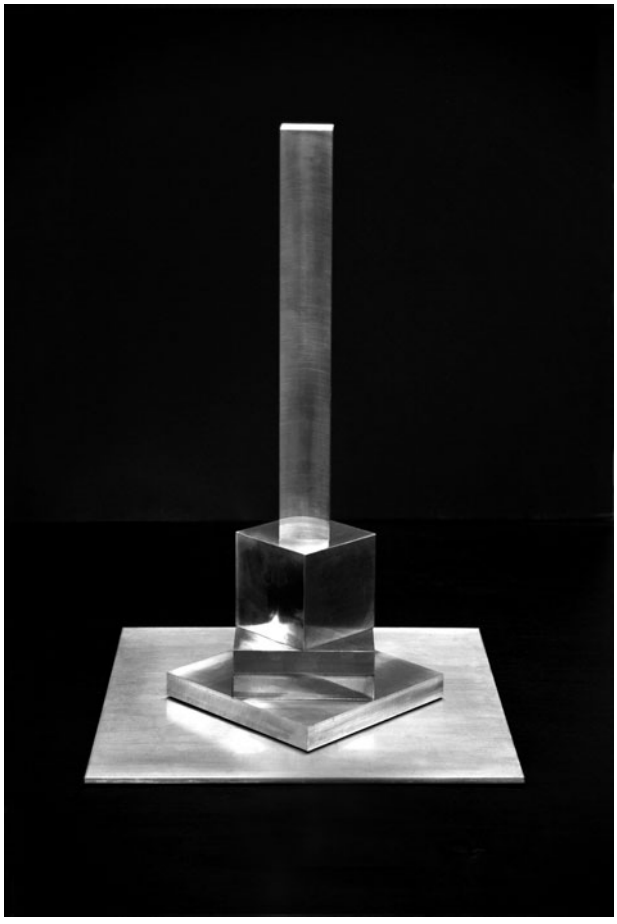

Figure 12. Roger Vilder, *Equivalence 64" cube*, 1999. Aluminium, 41 × 41 × 60 cm.

form the edges of various polyhedra. Naylor's past work has also used such digital models, as well as their male counterparts, and he told me, 'I consider the gender of the figures to be peripheral to the mathematics in the animation'. Yet my impression of this piece, one shared by several other Bridges visitors that I spoke with, was of the unthoughtful and literal *objectification* of women. With so few Bridges pieces even giving a tangential reference to the human body that does mathematics, and with gender bias and female attrition within the mathematics community such prominent, often-discussed issues, I don't think it safe to assume that viewers will consider the gender and form of these figures to be peripheral to the mathematics. A more thoughtful piece would allow the possibility that the piece would be approached from this perspective, and consider what statement it would then be making.

No better is *Kiss*, by Kuiper's Math Art. This is a low-quality digital print, an imitation of an Escher tessellation of symmetry group *P*2 redone with crudely positioned naked women kissing each other. It displays no mathematical or artistic novelty, and in my opinion should not have been included in the exhibition.

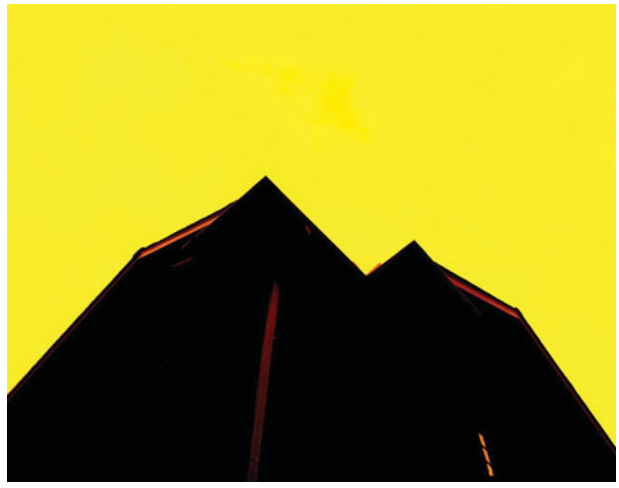

Figure 13. Andrea Jones, *Architectural Screen II*, 2009. Digital photograph, 24″ × 30″.

Mathematics and art both have the ability to mean different things, on different levels; this gives them their richness and power. That *Human Platonic Transform* won Best In Show this year, in my opinion, indicates that most Bridges viewers approach pieces as objects that describe or illustrate mathematical content. Another possibility, as explored in pieces like *Giant Pantograph* or the Musical Flocks series, is that math-art work can say something about mathematical or artistic context: How is it done? Who are the people doing it? What are they like? What do they care about?

To conclude, I would like to point out a way in which Rumi's quote does *not* apply to the Bridges art exhibition. A naïve reading might map the first clause to mathematics, and the second to art. It can be tempting to dichotomize math-versus-art as that eternal dialogue between mind and body, Apollonian and Dionysian, spirit and flesh, the monk and the lush.

However, the work on display at the Bridges art exhibition refutes this, again and again. French artist Roger Vilder's *Equivalence 64″ cube* exudes a serenity and purity that is rare in the life of a working mathematician (Figure 12). Professor of Art Chris Bartlett skillfully encodes self-reference and the golden ratio into his painting *Greek Island House*. Andrea Jones' careful choice of colours and use of light in *Architectural Screen II* (Figure 13) finds a resonant sweet spot. Conversely, many mathematicians exhibiting at Bridges, whether students, high school teachers, or university lecturers, are motivated by a desire to express their emotional connection to the subject, ranging from Dallas Clement's coloured Cayley tables *I told you groups were pretty Trisha!*, to Frédéric Vayssouze-Faure's hypnotising videos of sinusoidal oscillation, to Gabriele Meyer's hyperbolic crocheting.

Mathematical objects carry an inherent emotional weight, and artistic creation requires a certain measure of

discipline and rigor. We are not just creating new bridges, but also discovering bridges that are already there.

Note

1. Unless specified or originating from Rumi, quotes are from artist statements in the exhibition catalogue [1].

References

[1] R. Fathauer and N. Selikoff (eds.), *Bridges Enschede 2013 Art Exhibition Catalog*, Tessellations Publishing, Phoenix, AZ, 2013.

[2] M. Gioni, *The Encyclopedic Palace*, La Biennale di Venezia. Available at http://www.labiennale.org/en/art/exhibition/gioni/.