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Cold and Austere Beauty in Harbin, China

DIRK HUYLEBROUCK

Does your hometown have any mathematical tourist attractions such as statues, plaques, graves, the café where the famous conjecture was made, the desk where the famous initials are scratched, birthplaces, houses, or memorials? Have you encountered a mathematical sight on your travels? If so, we invite you to submit an essay to this column. Be sure to include a picture, a description of its mathematical significance, and either a map or directions so that others may follow in your tracks.

“Mathematics, rightly viewed, possesses not only truth, but supreme beauty—a beauty cold and austere” is a famous statement by British mathematician and winner of the 1950 Nobel Prize in Literature Bertrand Russell (1872–1970). Beautiful and cold for sure is the world’s biggest ice sculpture festival, in Harbin, China. It mainly features illuminated artistic sculptures up to the size of real palaces, but for the past two winters, the mathematical tourist has also been able to admire a smaller annual exhibition of more mathematical ice structures at the Harbin Institute of Technology.

Harbin is a town of 8.7 million inhabitants in the north of the People’s Republic of China. Because of its Russian past, it has an Orthodox cathedral, a temple that is even more remarkable because it hosts a copy of Leonardo da Vinci’s *Last Supper*. Harbin is most famous for its winter ice sculpture festival, attracting up to 300,000 visitors each year. Of course, we often associate paper lanterns with China, but in Harbin, traditional lanterns were also made of ice. Over the years, this practice of carving ice lanterns grew into an ice festival, a kind of frozen Disney World. Giant blocks of ice are cut out of the Songhua River and carved with swing saws, chisels, and ice picks. But the Institute of Technology has been developing new techniques, including one by which reinforced ice is sprayed on balloons, and an even more recent one that pours ice as is done in a rapid prototyping printing machine.

Several years ago, Professor Arno Pronk, of the Eindhoven University of Technology, Netherlands, developed a technique for spraying ice on balloons, inspired by methods for covering curved surfaces with concrete. For greater strength, inspired by the sawdust mixture called Pykrete invented by the Englishman Geoffrey Pyke (1893–1948) during WWII, he added cellulose to water. Pronk often has to explain that this was done as a research exercise with pedagogical advantages, since ice is cheap and reusable, but “off the record,” he honestly confesses that the building of Disney World-like ice structures is his main motivation. This dream resulted in the creation of the world’s largest ice dome (2015), a set of towers based on the Sagrada Familia Basilica in Barcelona (2016), and a Leonardo da Vinci bridge (2017), all in Juuka, Finland. In 2018, Pronk moved his operations to Harbin, where there are fewer periods of thaw than in Finland. Also, there is already the world-renowned ice festival, and Professor Luo Peng, of the Harbin Institute of Technology, was eager to set up an international collaboration with the Pronk. In 2017, this resulted in the creation of a kind of pseudosphere (see Figure 2).

In 2018, a larger collaborative project was set up by Professor Peng in which the Harbin Institute of Technology and the Eindhoven University of Technology were joined

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71 by Tsinghua University Beijing (China), Kent State University (USA), and the University of Cambridge (UK). The first
72 two had already experimented with ice constructions in
73 Harbin, in 2017, but for Cambridge, it was their first foray
74 into the frigid world of Harbin. To involve the Harbin
75 students even more, a series of talks was held in an evening
76 program, with topics ranging over general information
77 about university collaboration, techniques of ice construction,
78 and mathematical advances in geometry.

80 John Orr, university lecturer in concrete structures and
81 fellow of Magdalene College at the University of Cambridge,
82 encouraged his students to design and build the
83 world's first hyperboloid in ice. They arrived at their final
84 design through a series of structural stability studies and

geometric ideas. A net formed by cables and ropes was
hung from a hexagonal timber structure and was initially
prestressed by the temporary use of a crane. It was sprayed
with an ice and cellulose mixture over a period of days to
create a structure able to stand by itself. It was all carried
out methodically by the student team under the leadership
of Cam Millar (see Figure 3).

Mark Mistur and Rui Liu, of Kent State University, presented an improved version of their previous year's two cones project, appropriately calling it "Tw-ice." Ice was sprayed onto two cones with vertical axes formed by fabric hanging on tall wooden pillars. To make them more attractive, the surfaces of the cones weren't perfectly round, but gracefully draped. They intersected along a vertical parabola and had openings at the top that were seen as perfect circles when looked at from a viewpoint along the cones' axes (see Figure 4).

In his 2018 project, Pronk used an even newer technique. Instead of spraying, his team of students "printed" an ice truss dome 1.80 meters tall and about four meters wide, mimicking concrete rapid prototyping printing. They did the printing by hand while standing on a scaffolding, pouring ice out of a kind of large whipped cream bag on ropes stretched over a balloon. Pronk used a soon to be patented mix of ice, cellulose, guar gum, and xanthan gum to ensure good lubrication of the spray head and better adhesion of the water. He believes that he can omit the rope next time and even automate the process, since it is quite similar to concrete rapid prototyping printing, in which his university specializes (see Figure 5).

In December 2018, the three previously described shapes stood in front of the headquarters of the Harbin Institute of Technology, along a major avenue, Xidazhi Street, so that many passersby saw these mathematical shapes and took pictures of them. On the campus of the

Figure 1. Location of Harbin, China.

Figure 2. Pronk's 2017 pseudospherical construction, in Rhino modeling software and in ice.

Figure 3. Orr and Millar's student team's hyperboloid.

120 School for Architecture, two more icy realizations could be
121 admired: a Möbius strip and part of a surface of revolution.
122 The Möbius strip, with a diameter of 10 meters and a height
123 of 3.8 meters, was conceived by Professor Weixin Huang,
124 of the School of Architecture at Tsinghua University, in
125 Beijing. Other artworks carrying the name of Möbius, such
126 as the Sarajevo Möbius Bridge, aren't really Möbius strips at
127 all, and only abuse the name, but Professor Huang's Mö-
128 bius strip was the real thing. Moreover, unlike Max Bill's
129 Infinity Ring and other Möbius-themed artworks, Professor
130 Huang carried out structural studies to see whether his
131 construction, based on fiberglass-reinforced plastic rods,
132 would hold up. Professor Huang invented a "bending
133 active weaving structure system," which can adapt to dif-
134 ferent freeform geometric constructions. It uses the so-
135 called Kagome lattice, also called a hexadeltile structure,
136 by John Conway. Because of the light effects, the geometric
137 properties of the constituent hexagons and triangles

138 become clearly visible. This made it the world's first
139 structurally thought-through Möbius strip (see Figure 6).

140 Professor Luo Peng, of the organizing Harbin Institute of
141 Technology, made a surface of revolution cut along two
142 planes through the axis of revolution, so that an observer
143 could walk inside and through the icy solid. It was built by
144 spraying water onto a balloon that was removed afterward.
145 Because of his experience in this construction technique,
146 Peng was invited to design a set of seven large halls at the
147 Harbin Ice Festival. This was a first, proving that structural
148 and mathematical designs continue to find their way to a
149 broad audience (see Figure 7).

150 Of course, by the time this paper is published, the
151 models will have long since melted away. Yet the ice
152 models project is an annual event. For instance, in 2019,
153 Pronk intends to build a large grid shell with internal
154 polyhedra, as masterfully drawn by Leonardo da Vinci in
155 Luca Pacioli's 1509 book *Divina Proportione*. In 2019, it will

Figure 4. Mistur and Liu's parabolic intersection of two cones, with openings on the top that project vertically like circles.

Figure 5. Pronk's 2018 grid shell.

Figure 6. Huang's Möbius strip.

Figure 7. Peng's surface of revolution on the Harbin Institute of Technology campus (above and middle left) and his seven halls for the Harbin Ice Festival.

Figure 8. An inspiration for a future model of polyhedra in ice and a group picture of the ice heroes (front row, from left to right: Huang, the author, Pronk, associate dean of the School of Architecture Wei Dong, director of the international cooperation department Xunyi Liu, Mistur, Orr, visiting professor Sophie Giles, and Liu; the main organizer, Peng, is standing in the second row, behind Giles).

be five hundred years since the death of Leonardo, that great Italian polymath, and thus a tribute would be most appropriate in a Chinese city that displays a copy of his *Last Supper*. Moreover, Pronk envisions a Weaire–Phelan structure like the one in the Beijing Water Cube used in the 2008 Olympic Games, a suitable reference to the forthcoming 2022 Winter Olympics in China (see Figure 8). Thus for several years, the mathematical tourist in Harbin can expect an annually renewed feast of cold and austere beauty.

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