Playing in the Lux Dimension

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Abstract

A ninety minute workshop led by Michael Acerra, inventor of the linkage-based Lux construction system. The workshop will familiarize the group with Lux by constructing a series of Platonic and Archimedean polyhedra, a model of a diamond molecule, and dynamic linkages. The workshop will conclude with a question and answer period.

Introduction

My wife Heather and I have long been inspired by the works of Buckminster Fuller and Frank Lloyd Wright. We were intrigued by Wright and Fuller's accounts of how their experiences in the Froebel Kindergartens were foundational in their development. [1] We investigated the 19th Century pedagogue, Frederick Froebel, and his "gifts", as he called them, which he used as teaching materials. For twenty years we worked with children both as teachers and mentors and developed an appreciation for using construction activities as a means of teaching principles of art, engineering, mathematics, and science. In 2009 we employed our fifteen year old neighbor, Daniel Wollin, who was skilled in AutoCAD, to help us in the development of what we called the Lux Project*: our search for the Froebel Gift for the twenty-first century*. The idea was to create a construction system that would engage the user in building using the same principles which nature uses when it creates. Therefore we set out to create what the architect Peter Pearce might describe as a Min/Max or minimum inventory maximum diversity system. [2] Lux are the end result of this journey. In our workshop we will explore how Lux works and how we can use it to find deeper meanings and understandings of our world along with helping us to hone our own perceptions of space, motion, pattern, and design.

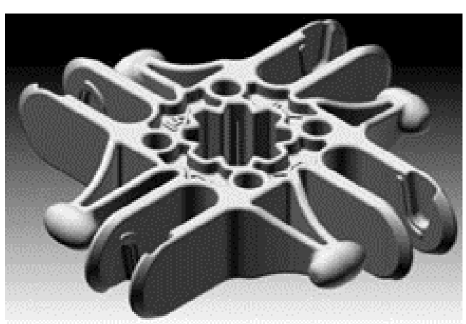

Figure 1: *The single Lux element in isometric view.*

Lux Activity One: Revolute Joints, Kinematic Chains, and Linkages

Lux form revolute joints. When connected together they form linkages, called kinematic chains, with a range of motion of 240 degrees. See Figure 2. When three Lux are connected in a series and closed upon themselves they form a triangular prism structure (linkage is rendered static). Since the triangular top and bottom opening of this prism has three edges each with unused connection points, the prism can serve as a triangular shape element. See Figure 3.

Figure 2 : *Three Lux being joined as a Kinematic chain and folded into a triangular prism*.

Figure 3: *The three Lux make an equilateral triangular prism.*

Many Lux structures utilize prisms as shape-elements in which larger structures can be made. For instance, the three tetrahedral pyramids in Figure 4 show how they are variations of the prism as face-elongations of the central tetrahedron. As the edge length of these structures increase the triangular opening or face begins to become more predominant with respect to the height of its edges. While the structure of these three tetrahedra are organized from the same idea, as they grow, one aspect is increased; the pyramid, while the other decreased; *the four prisms of what can be described as a face-elongated tetrahedron*.

Figure 4: *Three Lux tetrahedrons show how the face-elongated nature of the form is diminished as the length of its sides are increased.*

Figure 5 shows how the octahedron is made with eight triangular Lux prisms. When the prisms are only one Lux long the octahedron's face-elongated nature is very prominent. Interestingly, we can also view these prisms as vertice-elongations of a cube. As the length of the sides increase the octahedron's triangular faces become more apparent than the elongated nature of its construction.

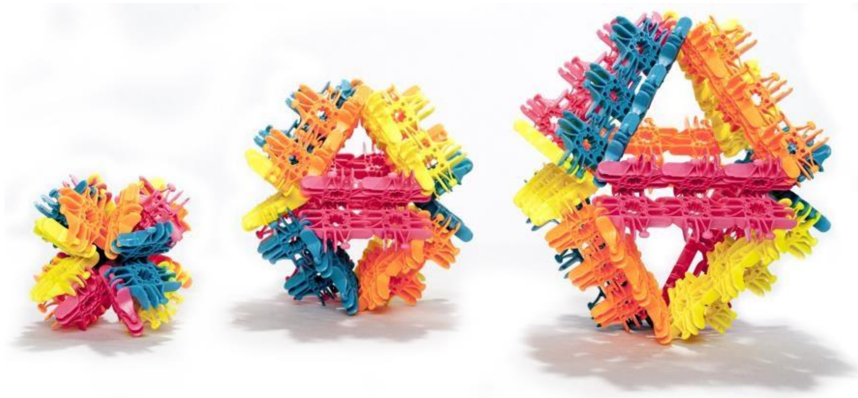

Figure 5: *The three Lux octahedrons demonstrate how as the prism of each side is lengthened its elongated appearance is reduced and the openings or faces of the polyhedra become more apparent.*

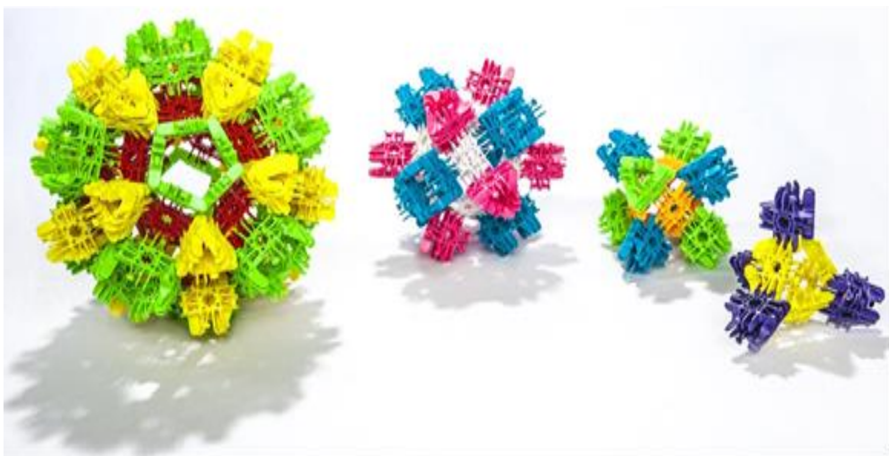

Figure 6: *Platonic/Archimedean hybrids from left to right the Rhomicosidodecahedron, Cube/Rhombic Dodecahdron/ Octahedron, Cuboctahedron, and the Tetrahedron/ Cubotahedron.*

While prisms can serve as the "openings" or "faces" of polyhedra, as seen in the prior example, they can also serve as the corners or vertices of polyhedra, as we saw with the cubo-octahedral relationship in Figure 5. In Figure 6 we see four Platonic/Archimedian hybrid polyhedral structures that are made by connecting prisms with Lux single elements in between. The tetrahedron on the far right accentuates the four-prism elongated vertices over the triangular face openings between each of the prisms. To the left of the tetrahedron is the hexahedron or cube, with eight triangular prisms serving as the vertices and six square elements in between. The next figure shows the relationship of the cube, rhombic dodecahedron, and the octahedron, possessing six square prisms as the vertices of a vertex-elongated octahedron, eight triangular prisms as the vertices of a vertex-elongated cube (hexahedra), and twelve squares which lie in the planes of a rhombic dodecahedron. The figure to the far left, the rhomicosidodecahedron, shows the relationship of the dodecahedron (twelve pentagons), the icosahedron (twenty triangles), and the thirty square faces which lie in the same plane as the rhombic triacontahedron. Twenty triangular prisms can be viewed as either the faces of a face-elongated icosahedron or the vertices of a vertex-elongated dodecahedron. The twelve pentagonal prisms can be viewed as the faces of the dodecahedron or the vertices of the icosahedron.

Lux Activity Two: Diamond Molecule

We can create a face-elongated tetrahedron by connecting four Lux triangular prisms together so they each share an edge. See Figure 7, right. We can also make a compound tetrahedron (left in Figure 7), which is also a face-elongated octahedron and a vertex-elongated cube. We can say that both of these can represent a carbon atom because both of these possess a tetrahedral component. Because of the particular way in which Lux are bonded using left/right, male/female connection ports, and because of the way in which carbon atoms are aligned in the diamond configuration in an up and down framework, it is necessary to create these two variations so they can work in a complimentary fashion. The rule to make this structure is to connect four compound tetrahedrons (blue- left) to the four triangular prisms (red-left) on the face elongated tetrahedron and then four tetrahedrons to the ports across from the corner of the prism (every other prism). So there will always be four free or unused prisms on the (blue) compound tetrahedron.

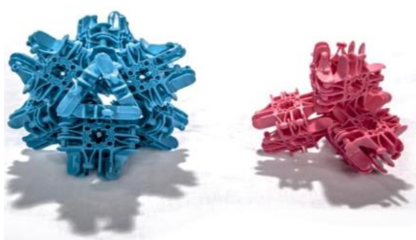

Figure 7: *Compound Tetrahedon and face-elongated Tetrahedron.*

First construct four face-elongated tetrahedrons, Figure 7 right, and seven face-elongated octahedrons (compound tetrahedral) Figure 7, left. Connect each of the four vertices of the tetrahedron to a compound tetrahedron. See Figure 8.

Figure 8: *Four compound tetrahedra around one tetrahedron.*

Next connect six tetrahedra between all of the compound tetrahedra. See Figure 9.

Figure 9: *Diamond lattice.*

Activity Three: Between States of Structure and Machine – Exploring Kinematic Linkages by Making a Gimbalgus, a Flexcube and a Flux

Lux connections allow angular freedom and make kinematic linkages. When we begin to limit that freedom with various patterns of assembly we can witness very beautiful and exotic motions. Three such motions we will create are that of the gimbalgus, the flex cube, and the flux. For the gimbalgus, construct six square prisms and connect them together to make a face-elongated cube. Alternatively you can make a gimbalgus from elongating the square sides of a triangular prism. See Figure 10 (right). The linkages we are seeing in the gimbalgus is a series of four bar linkages.

Figure 10: *The gimbalgus (Left) is a face-elongated cube that has an inherent wobble as each of its faces are free to move sixty degrees between a rhombus and equilateral triangle.*

Flux

The flux is a very interesting construction. Here we are making a triangular flux, but you could make flux with four to eight sided prisms. Flux are elaborate sarrus linkages and are very interesting because they demonstrate how the circular arc motion of a hinge can produce a linear vertical movement. The upper plate moves vertically up and down, towards and away from the lower one. See Figure 11.

Figure 11: *The triangular flux.*

The Flex Cube

The flex cube is a Lux cube made with an edge length 3 Lux that has been destabilized by removing its corners, which normally would lock its motion into place. Note that the corners of cubes are tetrahedral. Tetrahedrons are inherently stable. Eliminating the tetrahedral corners of the cube gives the flex cube an interesting range of motion. The flex cube is permitted to inflate into a spherical shape Figure 15, and to collapse into any number of ways. It can be squeezed into a relatively stable inverted cube as long as equal pressure is applied to the center of all six of its faces (the plus signs). See Figure 13. It can also form a toroidal polyhedron, Figure 12, and elongate behaving like a sarrus linkage, Figure 14.

Figure 12: *Toroidal polyhedron.*

Figure 13: *Cube with faces inverted.*

Figure 14: *Fully stretched flex cube.*

Figure 15: *Fully exploded flex cube.*

Conclusion

Lux offers a constructive way of exploring structural and dynamic systems expressed as linkages. Lux helps to build understandings and increase sensitivities of the way in which the structural world is connected to mathematics and nature.

References

[1] Brosterman, N., *Inventing Kindergarten*, Harry N. Abrams, 1997.
[2] Pearce, P.J., *Structure in Nature is a Strategy for Design*, MIT, 1980.