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Topological Interlocking Cylinder Configurations: A Geometric Approach

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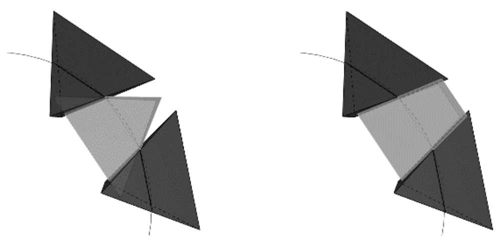
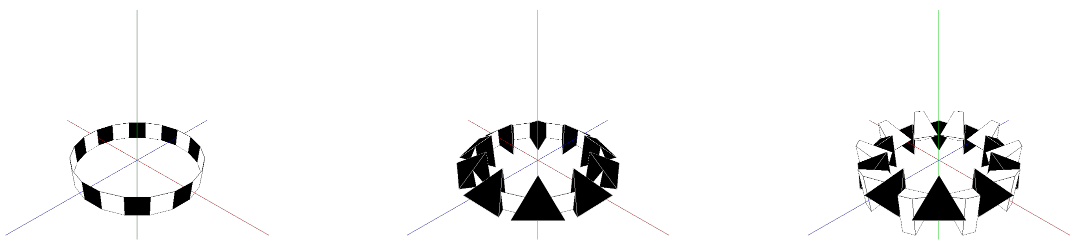
A Topological Interlocking Configuration (TIC), from a geometric point of view, is an assembly of building blocks that is stable without fasteners or adhesives of any kind. Stability is achieved by the geometry of the contact interfaces of the building blocks. The fundamental concepts regarding the construction of such configurations as well as their geometric interlocking attributes have been formulated in [1]. Different TICs based on semi-regular tessellations of the plane and of curvilinear surfaces using polyhedra other than the Platonic solids are described in [2], [3] and [4].

The basic generation method sets up first a direction vector and a rotation angle on each side of the tiles in the tessellation. A plane in which adjacent tiles touch is tilted as function of the respective direction and angle values. The planes belonging to a specific tile intersect in the vertices of the interlocking block. This generation method fails if two pieces intersect in a volume, in that case the angle values are adjusted until a valid configuration is obtained or a limit of iterations is reached.

We are interested in the generation and analysis of TICs composed of convex polyhedra from meshes of different geometry. On this work we present a generation method for the approximation of a polygonal cylinder, our method generates two types of pieces: regular and quasi tetrahedra. The cylinder is composed of identical rings, each ring is an $2n$ sided polygon of radius r. Accordingly, the mesh of 1 ring is a strip of $2n$ squares. mesh with an even number of squares, the height of the ring is $l = 2r\sin(\pi/2n)$. When the entire mesh is rolled up with a black and white checkerboard of size $2nm$, where m is the number of rings.



(a) (b)



(c) (d) (e)

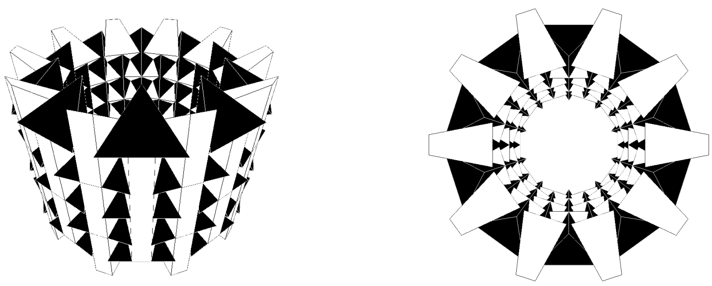
Figure 1: TIC generation on a cylinder: (a) Generated pieces using the original method, (b) Quasi tetrahedron between two regular tetrahedra, (c) Ring of squares following the polygonal approximation of the cylinder, (d) Regular tetrahedra generated from black squares, (e) Quasi tetrahedra pieces generated from white squares. A single ring is shown for visualization purposes.

The black squares in the checkerboard expand to regular tetrahedra, the white squares to quasi regular tetrahedra. The generation of the regular tetrahedra from the black squares is routine. The quasi regular tetrahedra are obtained by first generating regular tetrahedra – which overlap the black tetrahedra on the inside of the mesh and leave a gap on the outside of the mesh. To correct, we rotate the faces that should touch the black tetrahedra. This can be done in such a way that the overlap on the mesh inside is eliminated, and that the gaps on the mesh outside are closed. So modified, the polyhedra over the white squares are the quasi regular tetrahedra from above.

Given the number of sides n of each polygonal ring, the plane rotation that defines the quasi regular tetrahedra is obtained as shown in Figure 1b. The computation fully determines the rotation angle and so the shape of the quasi-regular tetrahedra.

Thus, given n, the cylinder radius r and the height of each ring, the two types of blocks are fully determined and no iteration is needed.

In contrast to the classical generation method, our method avoids having to set up both direction and angle values on the sides of the tiles in the tessellation. Therefore, we determine the particulars of the building blocks in constant time. The entire assembly can be drawn in linear time.



(a) (b)

Figure 2: TIC based on a cylinder with radius 10, 20 pieces per ring and 5 rings: (a) Perspective view, (b) Top view.

Figure 2 shows a cylindrical TIC generated using our proposed method. The generation method and some additional features have been implemented in TICYL (Topological Interlocking CYLinder), as a web app in Javascript that let users generate such configurations and visualize them in 3D in any browser. The generated pieces can be written to a file in OBJ format, a standard used for storing 3D models and geometries for computational purposes. The pieces are readily converted to STL and printed.

A cylindrical TIC can be split in two ways: The cylinder can be split into two by separating along a plane containing the axis, and by a plane perpendicular to the axis. Absent a suitable interior structure, we would advocate the use of end caps, tied together with an interior rod to avoid longitudinal and latitudinal splits.

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