Title:
Bevel Joint Modeling for Interlocking Planner Structures

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Introduction:

Design of prototypes has been increasingly emphasized by designers to achieve physical production of higher quality at a lower cost [3]. The application of digital fabrication machines, such as 3D printer, laser cutter and CNC machines etc., make it possible to fabricate models in rapid and inexpensive ways than using hand-held tools. However, methods are needed to process raw digital input/model to produce a set of components that are compatible for digital fabrication. Several approaches have been proposed by converting 3D digital model into planar physical components [1-2].

This paper describes a new modeling method that generates a planar interlocking structure with bevel joints for multi-planar models. Taking a 3D triangle mesh as input, a group of planar component with bevel joints is generated by first merging a set of planar polygon from the given triangle meshes, and then by modeling the bevel joints for each planar component based on the included angle between its corresponding planar polygon and its adjacent polygon. The application of bevel joint connection between two components leads to physical structures that are seamless at their surface, which is also referred as watertight surface.

Bevel Joint Generation:

Input to the method is a triangle mesh that needs to be reconstructed as a physical model made of planar components. The first step is to extract planar polygon surface components as shown in Fig. 1.

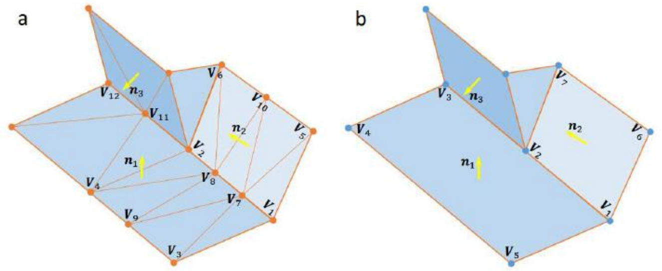

Fig. 1: Polygon surface components (b) extracted from a triangle mesh (a).

The second step is to extrude a thickness for each surface component, as shown in Fig. 2, and to calculate bevel angle between each pair of adjacent faces. The process of generating bevel joint shapes is remove overlapping volume in the vicinity of an intersection between two faces. As indicated by Fig. 2, the angle of a bevel cut is dictated by the angle of intersection, and the width of a joint is determined partly by the length of the intersecting line and partly by the number of joints. The latter can be specified by a user and is a control parameter that may vary within a range. Bevel joints between two surface components are always determined in a pair: the shape of the joint on one surface automatically determined the shape on the other, and they are complement to each other.

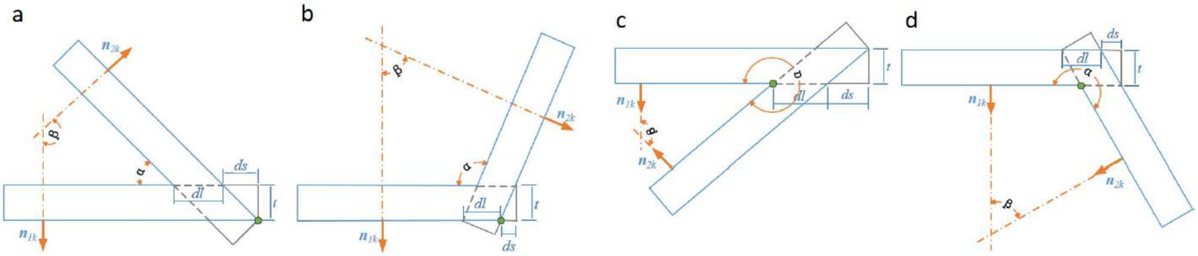

Fig. 2: Adjacent faces may take on various intersecting angles.

To make sure the interconnecting planar components can be identified correctly, the normal vector, n and n_j, of each plane indicated in Fig. 3 should be calculated from the vertices of the polygon surface. We assume that the input triangle mesh is a 2-manifold mesh object; hence, each edge belongs to two surface patches. The size (or length) of a joint is a system parameter. To generate relatively uniform size along an edge, the edge is equally divided into protruding and indenting teeth.

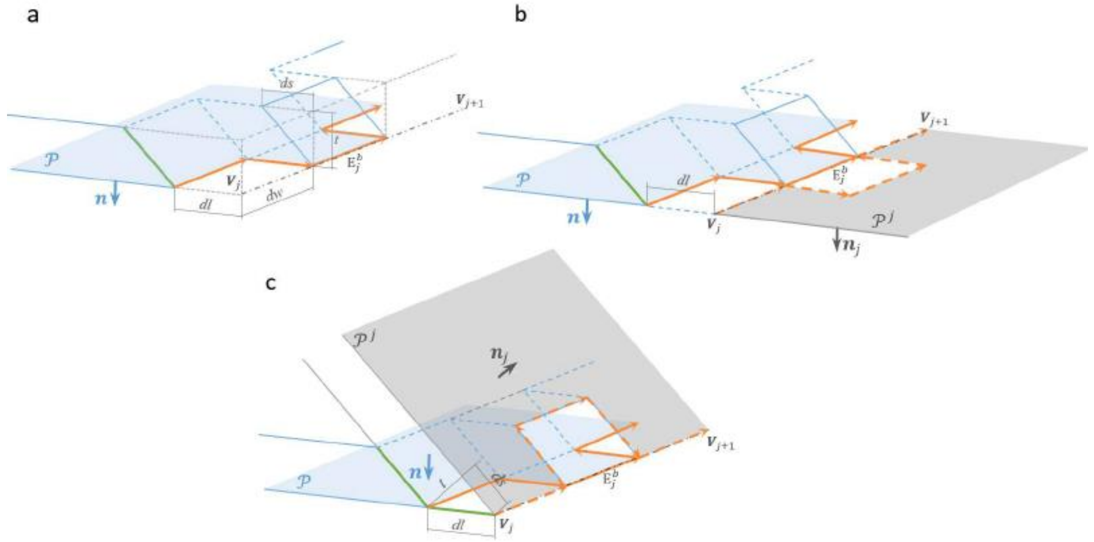

Fig. 3: Bevel joint generation.

Results:

Solid mesh models are used to test the proposed algorithm of bevel joints generation. The solid rectangular pyramid in Fig. 4 shows the process of the generation of bevel joints. As a simple example, it is only shown in the way of a digital model without fabrication. The model composed by planar polygon at the middle is extracted from the initial mesh model at left, the five planar components with bevel joints are generated from the polygon model.

Fig. 5 shows a staircase model processed and fabricated by 3D printing. The assembled physical model is shown at the bottom.

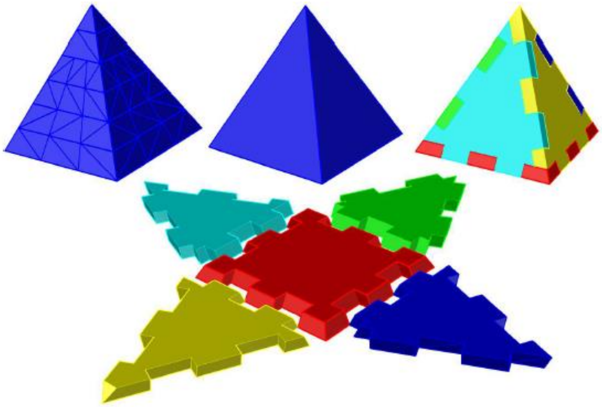

Fig. 4: Bevel joints of a pyramid structure.

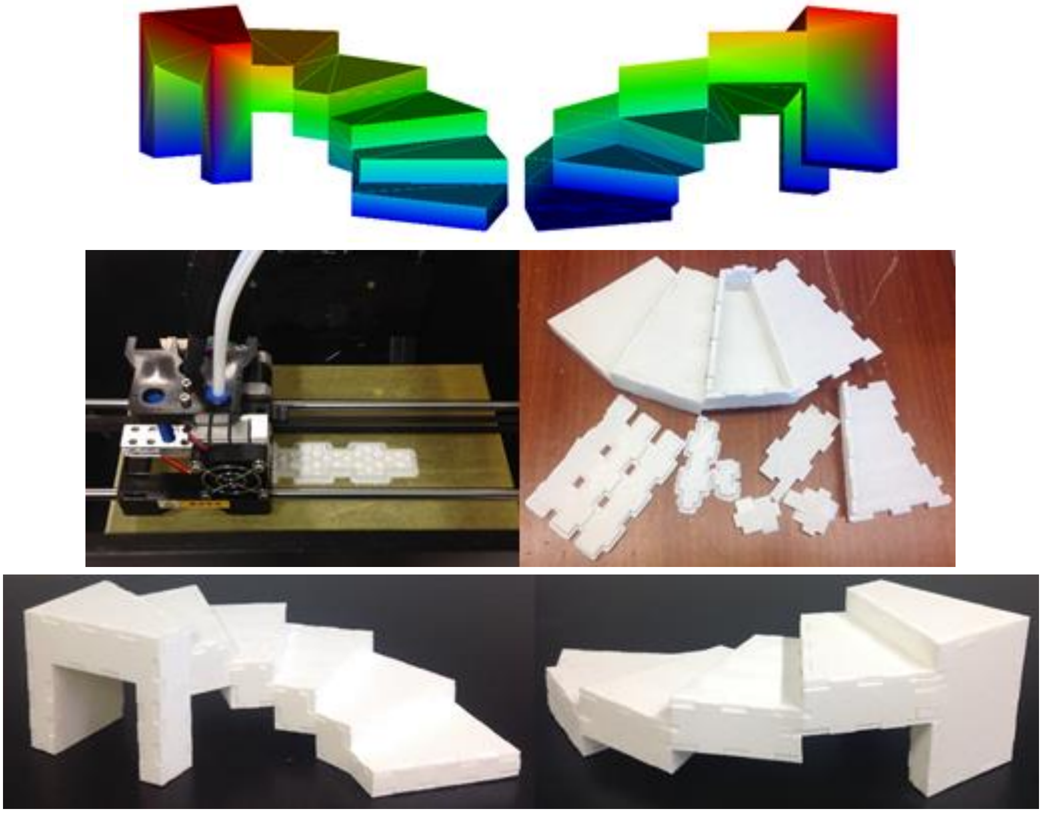

Fig. 5: Bevel joints of a staircase structure.
Top: input mesh model. Middle: 3D printed parts. Bottom: assembled physical model.

<u>Limitations:</u>

There are two limitations of the proposed method. First, as the length of a bevel joint depends on the included angle of two planar polygons, a very small tooth of a joint will be generated on polygons where the intersection angle is close to zero. To avoid small teeth being damaged during fabrication, these parts may have to be fabricated by high-precision machines. Second, bevel joint can only be fabricated by relatively special machines. Using some machine, such as a laser cutter, it is hard to cut positive and negative inclined bevel joints.

Conclusion:

The proposed algorithm automatically generates bevel joint connector for planar structures. It is suitable for making seamless physical models. Unlike previous methods, the seamless surface is maintained at surface intersections that are not perpendicular. As the bevel joint produces full contact between two surface components, the resultant structure is strong and robust. The structures are also waterproof, which enables new applications such as using the structure as mold for casting.

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