A streamlined NURBS-based workflow for precise Additive Manufacturing

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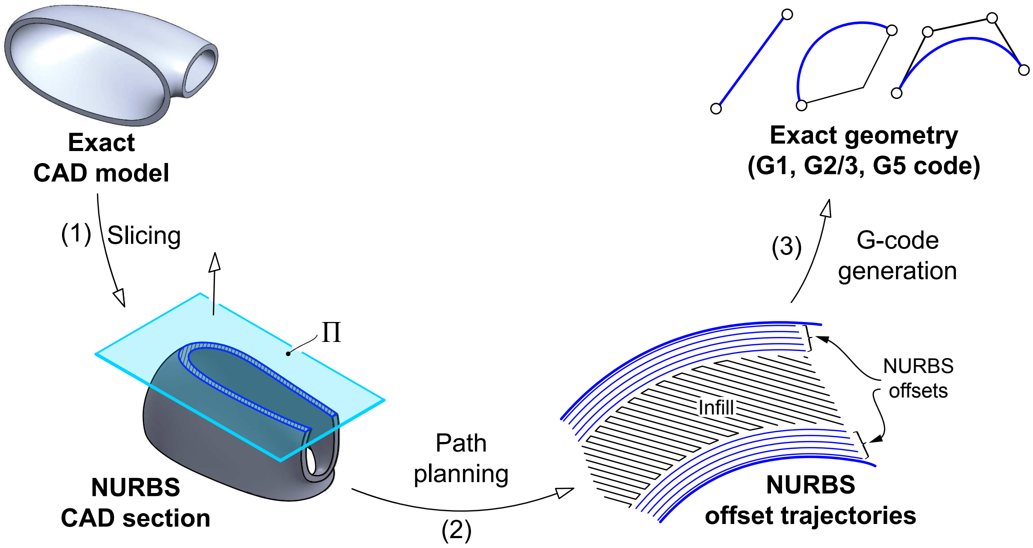

Figure 1: Our approach for generating accurate G-code for AM

We put forward a streamlined AM workflow, with a seamless transfer from the initial CAD description to the final G-code. Polygonal approximations and associated errors are avoided by adhering to the NURBS standard at all steps. Experimental results confirm a considerable improvement in quality over the traditional AM workflow, consisting of an initial polygonization of the object (e.g., via STL), slicing this approximation, offsetting the polygonal sections, and finally generating G-code made up of polyline trajectories (G1 commands). This traditional AM workflow does not meet the requirements for truly functional parts regarding quality and precision, especially in large-scale 3D printing, hence wasting the possibilities of existing AM hardware.

Our proposal (Fig. 1) bypasses the polygonal approximation and then proceeds as follows:

(1) Direct slicing of the CAD model in the NURBS environment provided by a NURBS-based CAD system.
(2) Path planning, including offset trajectories, in this NURBS environment.
(3) Accurate G-code generation of NURBS: circular arcs (G2/3 code), Bézier cubics (G5), and polylines (G1).

Slicing (1) and offsetting, the most complex geometry operation in path planning (2), are already available in any CAD system in a reliable way. Therefore, there is no need to develop ad-hoc procedures, as we can access these capabilities through a suitable programming environment. In particular, we employ a NURBS-based commercial CAD system (Rhino3D along with its programming environment Grasshopper) for direct slicing of the model, offset generation, and trimming.

Our main contribution is sticking to the NURBS standard at the last step (3) of AM, namely G-code generation, a possibility overlooked in both the literature and commercial applications. To this aim, we exploit the possibilities of exiting firmware controlling 3D printers, such as Marlin, incorporating G2/3 (circular arcs) and G5 (cubic Bézier curves) commands. Since trajectories resulting from offsetting in Rhino3D usually restrict to circles and polynomial (cubic or quadratic) splines, the exact conversion into G2/3 and G5 code is readily performed via standard NURBS geometry processing, such as knot-insertion and degree-elevation.

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