Title:

Machining Feature Recognition from In-Process Model of NC Simulation

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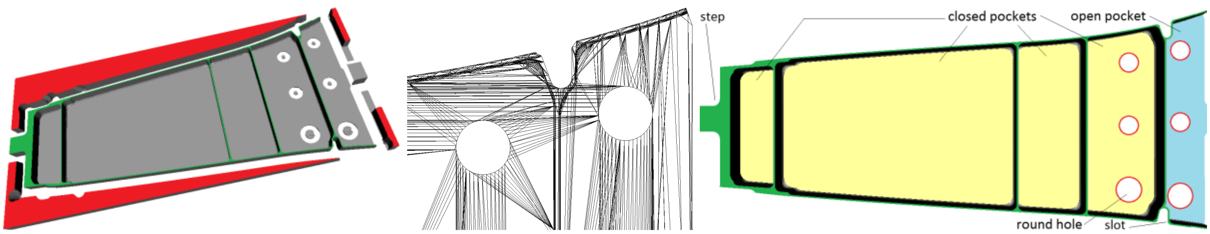
Keywords:
Machining feature recognition, NC simulation, In-process model, reverse engineering, STEP-NC

DOI: 10.14733/cadconfP.2014.90-92

Introduction:

NC simulation is one type of virtual machining, which emulates the CNC machine and the cutter move, and depicts the material removal to better visualize the machining process. It can be done on the CNC controller of a shopfloor machine, or on an offline computer. Until now, its main goals are still confined to check an unproved NC program to avoid potential collisions with fixture elements, making undercuts, or leaving excess material. In our work, by making use of the simulated output—the In-Process Model (IPM)[1], and re-establishing a model based on machining features, we extend the applications of NC simulation to build the feedback link from CAM/NC or shopfloor amendments back to CAD. This feedback link and the re-established feature model can serve for design improvements since we can compare this model with the original designed model, measure more reliable and accurate dimensions on this model, or use it for FEA, etc.

Actual research issues: The widely used NC simulation approach is the mesh-based virtual machining, whose output data of the IPM is a collection of triangles, without topological information. The IPM contains unwanted data—the offcut (Fig.1 a). Also the mesh data usually contains degenerated triangles (i.e. isolated vertices and edges) and incorrectly oriented triangles, or lacks of triangles data for building a solid. Therefore the first issue is to build a polyhedral B-rep model from the IPM. The specific tasks include elimination of the offcut data, topology construction and model healing. The second is to perform region segmentation, during which triangles are segmented into meaningful region types. The strategy is that planar faces are identified first, then ruled surfaces (like cylinders, cones), and finally other surfaces. The third is to propose a curvature-based approach for freeform surface segmentation. The fourth is machining feature recognition based on rules and face adjacency relationships.



(a) An IPM with the offcut (b) Patial view of the mesh (c) FR examples

Fig. 1: In-Process Model of NC simulation.

Approach:

Mesh based machining simulation:

In this approach, the IPMs of NC simulation systems are triangle meshes for dynamic display. One type of NC simulation systems is image-space based. This type is highly efficient, and a high rate for updating display can reached in simulation. In this approach, the workpiece and the cutter are discretized along z-axis into small rectangular bars called a dexel. The upper surface of the dexel is divided into two triangles along the diagonal line of the rectangle, and all these triangles form a mesh representing the machining surface of the workpiece. During NC simulation, the heights of the vertices of a dexel are updated along the tool path, and the rendering of the machined surface is refreshed. Another type is triangular polyhedral B-rep based, which are used in CATIA, UG, Pro/E, etc. The objects' boundaries of the simulation environment are represented by a collection of triangles. It is possible to choose the tessellation resolution to match the required speed. Therefore, in the course of simulation, the IPMs can be output as triangle meshes, usually in STL format or in VRML format.

We process the STL data to build a polyhedral B-rep model at the beginning. This model has following characteristics: It has one or more shells, of which one is the part, the others are the offcuts; In ruled surface regions and in planar regions near its curve boundary, the model has many long triangles resulting from the discretization; Triangles in flat regions are sparse and large, while dense and small in highly curved regions (Fig.1 b).

Curvature-based region segmentation:

A region is a set of connected triangles having certain geometrical attributes (curvature, surface type). Our strategy for region segmentation is: First, collect statistics about all triangles of the model, such as the maximal/average edge length, area, dihedral angle. These data can be used to set some thresholds and seed triangle selection for subsequent searching. Identify the obviously long triangles and boundary sharp edges in the model. Second, identify all planar regions using differential geometry properties for adjacent triangles. Third, identify ruled surface regions based on the connectivity of triangles. Finally, compute the principal curvatures for remaining vertices to identify the region types mainly in dense areas.

In a sparse area many vertices are on object's boundary. Since the curvature based region segmentation is limited, we propose the use of dihedral angle to obtain the boundary edge by a propagating method. If the dihedral angle between the triangle and its neighbor triangle is greater than a threshold, then their shared edge is part of the object's boundary. A boundary edge can grow as per its connectivity. In a dense area the local shape around a point on a surface is characterized by the minimum and maximum principal curvatures and by the two principal directions corresponding to the tangent vectors for which the principal curvatures are obtained. For each neighbor vertex, a discrete curvature is computed, using a discrete curvature tensor[5]. The principal curvatures are thus obtained and augmented with shape index and curvedness. The values are used to define surface types on vertices[3], which are then segmented as per the defined surface types.

Adjacency Graph and rule based feature recognition (FR):

After identifying regions and their types, some regions satisfying certain geometric criteria can be merged in order to reduce the number of logical regions. The criteria is like: If two adjacent regions are of same type and the common boundary is smooth, then merge them into one. Then we can construct a continuous B-rep model from the identified regions and the object's boundary. By computing a new curvature function of the boundary edges, the face adjacency graph can be established. A machining feature here is regarded as a set of connected regions satisfying certain geometrical and topological conditions. A rule based manufacturability analysis approach is used in our work for machining FR. Geometrical and topological rules on the identified regions are applied to FR. The rules are designed as per STEP-NC feature definitions so that the recognized feature data can be stored in conformance to STEP-NC[2]. The rule-based FR methodology based on topological combinations of regions is quite general and adaptable and can be easily extended.

Applications and case studies:

Potential applications are similar to that of reverse engineering. It can establish feedback link from NC/shopfloor to CAD/CAM for amendments,etc. It can reconstruct a feature based continuous B-rep model if the original model unavailable.

Conclusions:

An approach has been proposed for machining feature recognition from the In-Process Model of NC simulation. It involves following procedures: B-rep polyhedral model construction from the IPM; planar region extraction; ruled surface region extraction; freeform surface region extraction based on discrete curvature; rule and adjacency graph based machining FR. This approach is designed according to the IPM characteristics, and it is effective and reliable. An improvement of the approach could be to fit general parametric surfaces such as NURBS in the dense triangle region of the IPM, meanwhile performing the freeform volumetric FR based on the discrete curvatures of those vertices in this type of regions. Future works includes the recognition of freeform volumetric features especially resting on freeform regions of the IPM[4] , and testing the approach on more complex parts (five-axis and mill-turn).

Acknowledgements:

This work is a part of the ANGEL FUI project recently funded by the French Inter-ministerial Fund and endorsed by top French competiveness clusters (SYSTEMATIC PARIS REGION, VIAMECA and ASTECH) .

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