PAPER • OPEN ACCESS

Design Intent for CAD Modeling Features Using Boolean Operations

To cite this article: Chandrakant R Sonawane and Ghadge Sujit 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **197** 012047

IOP Conf. Series: Materials Science and Engineering **197** (2017) 012047 doi:10.1088/1757-899X/197/1/012047

Design Intent for CAD Modeling Features Using Boolean Operations

[1]Sonawane Chandrakant R, [2]Ghadge Sujit

[1]Mechanical Engineering Department, Symbiosis Institute of Technology, Symbiosis International University, Pune, Maharashtra, India.
[2] PG Student, Pune, Maharashtra, India.

Corresponding author's e-mail address : chandrakant.sonawane@sitpune.edu.in

Abstract*:* The objective of this paper is to add one more enhancement to design intent by adding a rule to find the intersection edges created between Boolean features. Design Intent is a core module in CAD software which is used for smart design of referencing elements to create required features. In general, the particular design intent will form a particular rule which can be utilized for specified purpose. In this paper, a design intent rule for Edge Blend feature is designed. The rule is also implemented and integrated with CAD software. The major contributions of this paper is to create a new intent design rule which picks the edges of the feature Present design intent rule is intended to pick the intersection edges of the feature, in doing so; the intent will avoid referencing to topology over referencing to hierarchy objects for greater reliability

1. Introduction

Today's Computer Aided Design (CAD) software's are designed to improve the productivity of the user. In the interest of robust update, body in white workflow avoids topology referencing. Update feature replaces work flow in CAD software and are very robust. This success of replace workflow relies on referencing hierarchy objects. Input of topology (an edge or a face) is less reliable as compared to the input of a hierarchy object (a body or a feature). While modelling, the user generally has the intent to select bodies, faces, curves and points. Many of the commercially available software like PTC PRO-E, Siemens-NX, and Dassault Systems-CATIA have their own mechanism to select the object in graphics window. CAD has been evolving by incorporating various ways of collecting the entities by finding new ways of smart selections. Many researchers' were working on smart selection of an entity resulting various rules have been added to empower the selections from graphic window and part navigator.
P. Hachenberger et al [1] developed algorithm for the geometric operations on "Selective Nef Complexes"(SNC). Their algorithm is based on Boolean operations where partitions of three dimensional entities are carried out by planes and whole domain is divided into the cells. In order to optimize the performance they implemented the two methods of finding topological intersections viz. kd-Tree method and fast box-intersection algorithm method. J. M. Smith et al [2] worked on B-rep models which contains polyhedral boundaries and presented an algorithm which typically utilizes Boolean operations. Their algorithm is so robust that for given Boolean with valid connectivity the

algorithm always generates a result. The algorithm is also finds and produce results with fewer numerical errors associated with geometries or arithmetic or even with input data.

Gang Mei et al [3] developed approach for triangulated faces. Both open and closed surfaces had been considered. Their Boolean operation based algorithm identifies the surfaces/edges formed due to intersection, union and subtraction features. Yu Peng et al [4] developed an algorithm for planar polygon constructed with Boolean operations. The simplex theory based mathematical model is developed and applied in the algorithm to indentify the required intersecting surfaces. Cha-Soo Jun et al [5] utilized the topological transition points over the interaction of curve. They pre-processes the curve and surfaces to locate these topological transition point. Hence their algorithm can compute the interactions points created due to the parametric regular surface with a set of available parallel planes.

Ouyang Ying-xiu et al [6] developed an algorithm which also based on finding the topological transition points. Their algorithm utilizes the available topological relations to find first topological transition point/loop. Then these previously computed loop/points utilized to compute new subsequent loop occurring on the intersecting geometries. Kyu-Yeul Lee et al [7] presented an algorithm based on tracing principle. For surface boundaries identification, they utilized trace-terminating condition along the surface-surface intersection curves. A. Borkowski et al [8] presented mathematical approach for finding intersection curves. Their work mainly focuses on locating terrain edges for an available three-dimensional entity. Pinghai Yang et al [9] developed algorithm based on the moving least-squares (MLS) surface. They utilized MLS to obtain point-sampled geometry from the underlying surface representation. They also derived a closed form formula which helps to evaluate the curvature of planar surface/curves.

Laurent Buse et al [10] developed the generalized matrix based representations of the parameterized surfaces where the intersection curve of two topological surfaces as the zero set of a matrix determinant is obtained. In this way, a compact and efficient representation of intersection curves is obtained by allowing reduction of a few geometric operations on curves to matrix operations using linear algebra. Manuel Ventura et al [11] developed methodology to compute the intersection formed due to the complex curves. They consider the application of modeling the ship-Hull which involves interaction of many complex curves and surfaces. The major focus is to study the surfaces form due to the combinations of non uniform rational B-Splines (NURBS). Other algorithms, methodology and/or mathematical analysis work for computing intersection curves and computing the two rational parametric surfaces can also be found in [12, 13, 14].

From above discussion it is clear that researchers' are continuously trying to modify the Boolean operations to make the task of finding or locating the intersection edges more generic, scalable, robust, and of reduced computational efforts. Many algorithms for Boolean operations on polygons were based on the use of bitmaps and have many drawbacks like large memory usage. Researchers described various methods for Boolean operations on solids/planes/surfaces with specified boundary representation. Their main interest is to reduce an available three dimensional (3D) geometrical problem to two dimensional (2D) one using reconstruction or other suitable ways which ultimately makes the algorithm more robust. But such algorithm could process objects with planar surfaces.

This paper aims to add a rule to find the intersection edges created between Boolean features resulting in enhancement to CAD design. The key task in implementing this new rule is to evaluate the intersection edges, which should ultimately correspond to the optimized solution. The proposed new rule is capable to evaluate intersection surface/edge of the Boolean bodies even if it has one or more intersecting bodies. The scope is limited to the evaluation of intersection of the Boolean like features

2. Basics of Selection Intent

In CAD software, there are various features to carry out modelling operations. Every feature takes some input and returns desired output. When user launches a particular feature command, a user Interface (UI) dialog pops up asking for various inputs. As far as topological inputs are concerned,

user may have intent to specify point, curve, face, or body. There are number of ways to specifying the inputs. The term referencing points to the way in which input is specified.
Topological referencing as shown in figure 1 is the method of input specification, in which user directly specifies the basic topology required for that feature. For example, “Measure Face” command needs a face. If user specifies it with a single click on individual face, this becomes a case of topological referencing. Every feature asking for topological input is enabled with this type of referencing. In Hierarchical referencing, it is not required that user specifies input of the same level of Topology as required by the command. The user actually specifies a topologically higher entity, and the required entity is evaluated from the input.

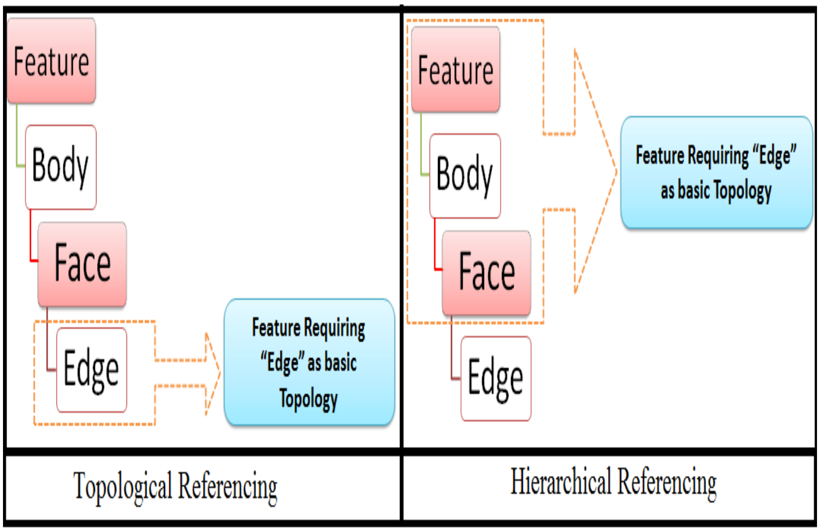


Figure 1. Topological referencing and Hierarchical referencing.

For example, let’s assume user wants to evaluate of perimeter of a face using “Measure Length” command. Measure Length command actually works on curves. So, basic topology here is a curve. Individually specifying every edge of the face is example of topological referencing, while if user sets “Face Edges” as a rule and specifies the edges by selecting the face directly, it is the example of hierarchical referencing.

3. Computational Algorithm

Figure 2 shows the algorithm for select Feature/Edge. The flow chart is self explanatory. The filter selection does validation before collection of edges and then create rule for selection. Figure 3 shows the workflow diagram for computer code generated.

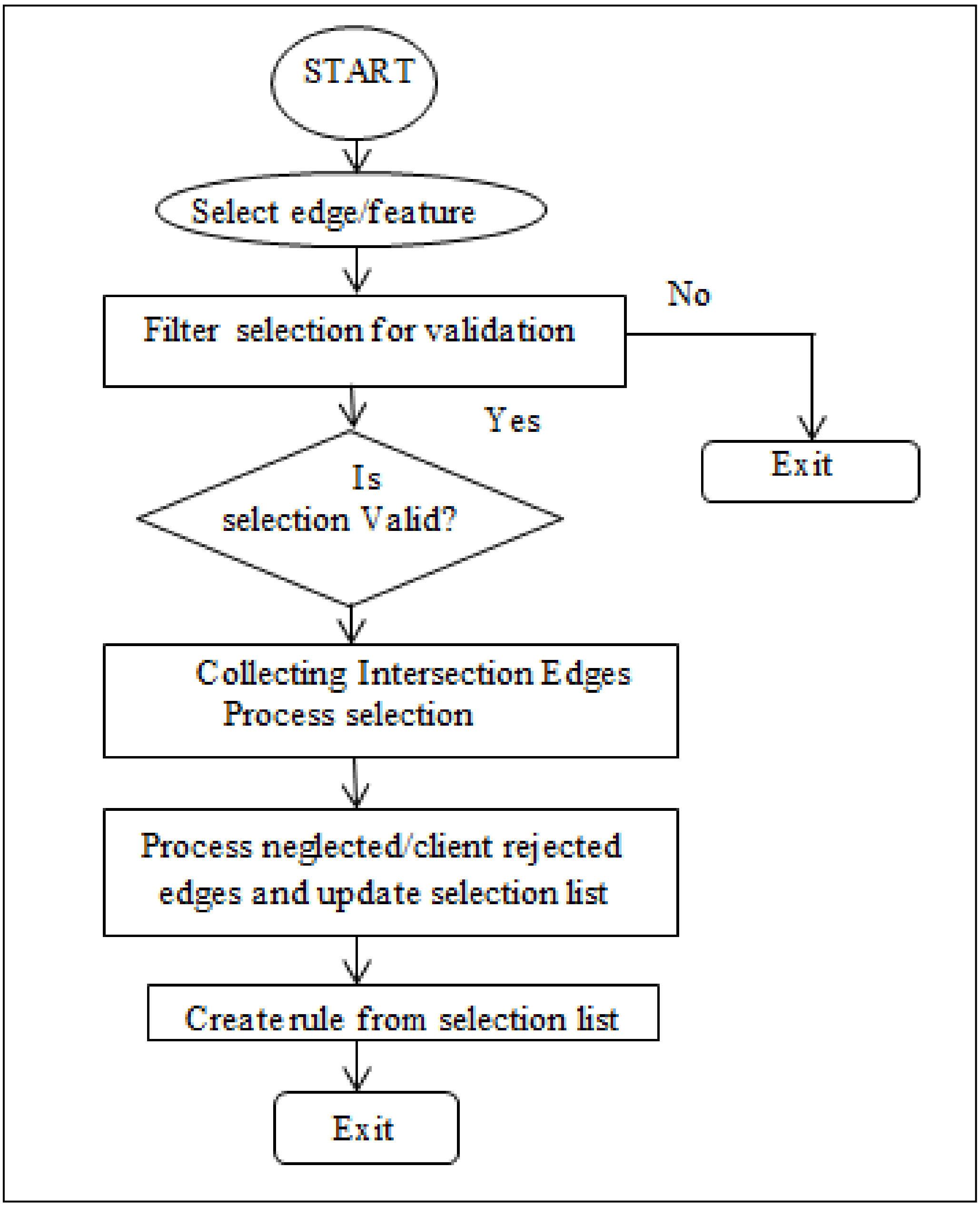


Figure 2. Activity Flowchart.

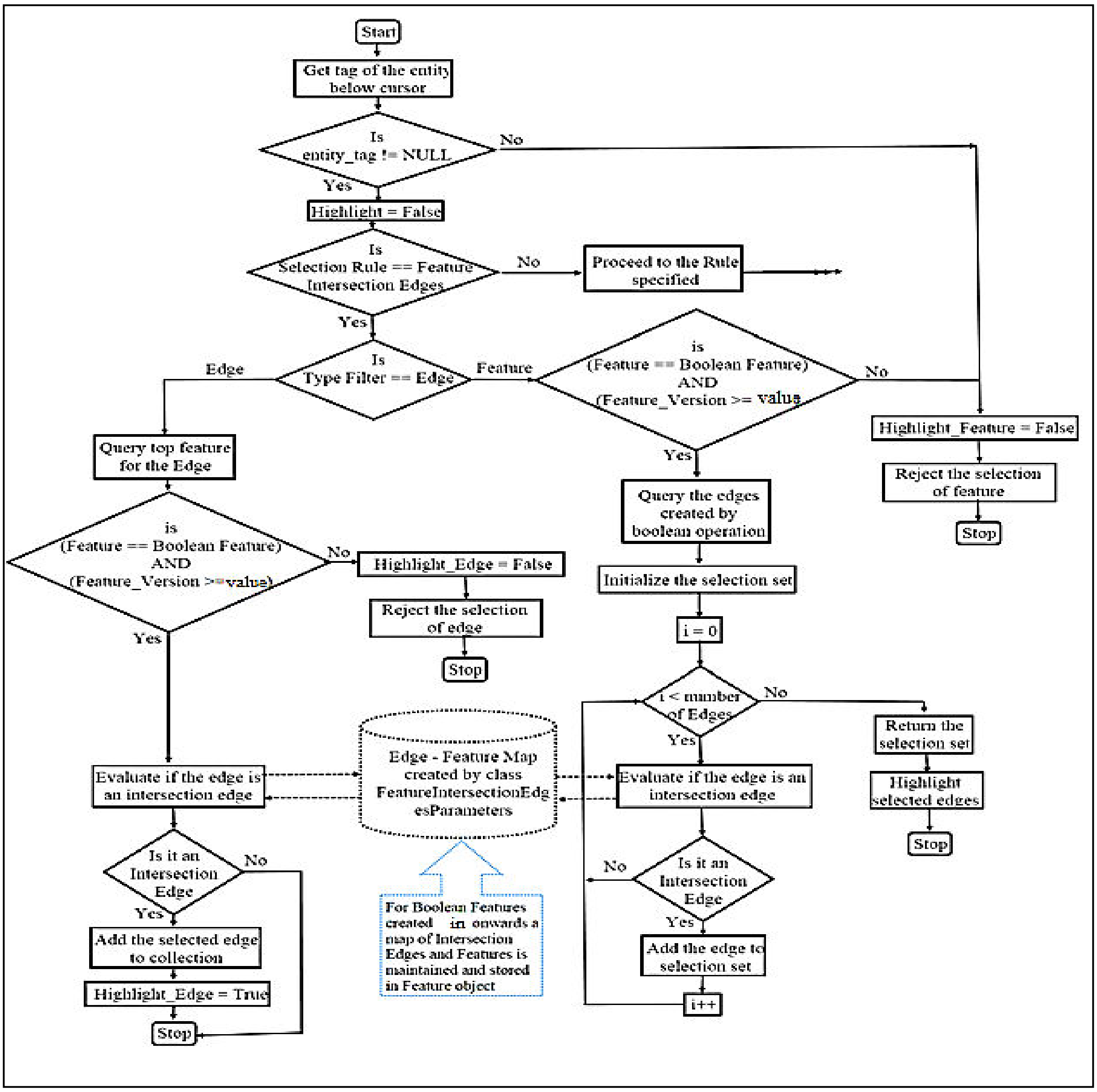


Figure 3. Workflow diagram.

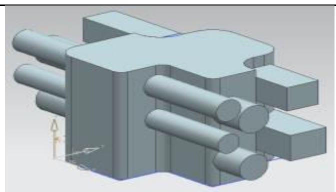
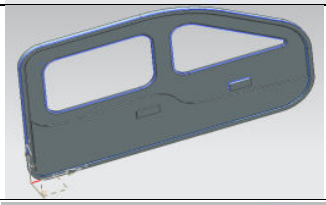
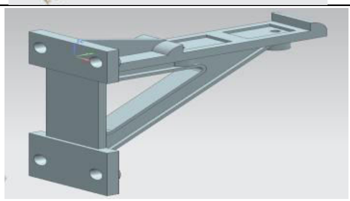
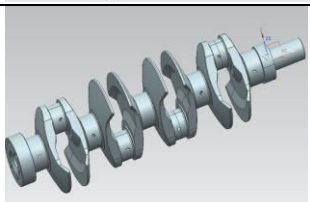
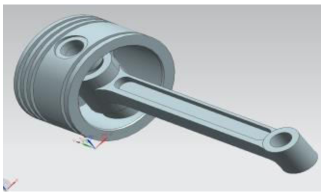
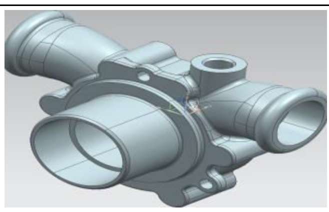
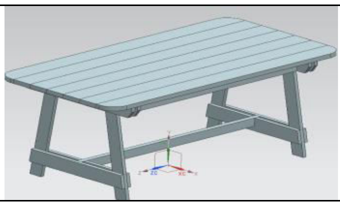
4. Time Saving Analysis

As the new rule assists to grab the intersection edges at very ease it is good to realize how much time saving is achieved with the new enhancement. Here, we tried to apply edge blend to various complex parts using conversional single selection rule and “Feature Intersection Edges” rule.
Table 1 shows that how Feature Intersection Edges are saving the time to apply blend at intersection of Boolean features like Unit, Subtract and Intersect. From Table 1 it can be observed that about 80% - 95% time saving is achieved using new selection intent rule.

IOP Conf. Series: Materials Science and Engineering **197** (2017) 012047 doi:10.1088/1757-899X/197/1/012047

Table 1: Time saving analysis

(*I - Total Blend Length (mm); II - No. of clicks Required with single selection; III - Time required with single Selection (sec); IV - No. of clicks Required with Feature Intersection Edge Rule; V - Time required with Feature Intersection Edge Rule; VI - Percentage Time Saving)*

Sr No	Image of the Part	I	II	III	IV	V	VI
1.		562	24	30	1	2	93.33
2.		1745	34	270	1	30	88.89
3.		550	89	240	1	45	81.25
4.		845	157	789	1	94	88.09
5.		200	78	450	1	40	91.11
6.		2457	540	2480	1	120	95.16
7.		5480	480	1170	1	185	84.19

5. Conclusion

The New rule for selection intent is developed and applied successfully. It is evident from the testing results that new rule has enhanced CAD's Design Intent capability to incorporate the idea of hierarchical referencing. The new Design Intent rule leaves behind the caveat of not implementing for interpart edges.
There is scope to give thought for implementing the rule for interpart collections too. Also, new rule can be used for picking the edges for other modelling features. The scope was limited to Boolean like features and future enhancement is possible so that intersection edges can be picked for non-Boolean like features.
The current rule enhanced the usability of edge blend tool of CAD software. Design time of the designer is reduced and the accuracy of work will be increased.

Acknowledgment

Thanks to Siemen, Pune for their valuable interaction and suggestions contributed in the research work of the new rule of Selection Intent.

References

[1] Peter Hachenberger, Lutz Kettner, Kurt Mehlhorn, Boolean operations on 3D selective Nef complexes: Data structure, algorithms, optimized implementation and experiments, Computational Geometry, 2007, Vol. 38, issue1-2, 64–99.
[2] J. M. Smith and N.A. Dodgson, A topologically robust algorithm for Boolean operations on polyhedral shapes using approximate arithmetic, Computer Aided Design, 2007, Vol. 39, issue 2, 149-163.
[3] Gang Mei and John C. Tipper, Simple and Robust Boolean operations for Triangulated Surfaces, arXiv preprint arXiv:1308.4434.
[4] Yu Peng, Jun-Hai Yong, Wei-Ming Dong, Hui Zhang, Jia-Guang Sun, A new algorithm for Boolean operations on general polygons, Computers and Graphics, 2005, Vol. 29, issue 1, 57-70.
[5] Cha-Soo Jun, Dong-Soo Kim, Deok-Soo Kim, Hyun-Chan Lee, Tien-Chein Chang, Surface slicing algorithm based on topology transion, Computer Aided Design, 2001, Vol. 33, issue 11, 825-838.
[6] Ouyang Ying-xiu, Tang Min, Lin Jun-cheng, Dong Jin-xiang, Intersections of two offset parametric surfaces based on topological analysis, Journal of Zhejiang University Science, 2004, Vol. 5(03), 259-268.
[7] Kyu-Yeul Lee, Doo-Yeoun Cho, Tar-Wan Kim, A Tracing Algorithm for Surface-Surface Intersections on Surface Boundaries, Journal of Computer Science and Technology, 2002, Vol. 17, No 6, 843-850.
[8] A. Borkowski, W. Keller, Global and local methods for tracking the intersection curve between two surfaces, Journal of Geodesy, 2005, Vol. 79, issue 1, 1-10.
[9] Pinghai Yang, Xiaoping Qian, Direct Boolean intersection between acquired and designed geometry, Computer Aided Design, 2009, Vol. 41, issue 2, 81-94.
[10] Laurent Busé, ThangLuu Ba, The surface/surface intersection problem by means of matrix based representations, Computer Aided Geometric Design, 2012, Vol. 29, issue 8, 579-598.
[11] Manuel Ventura and C. Guedes Soares, Surface intersection in geometric modeling of ship hulls, Journal of Marin Science and Technology, 2012, Vol. 17, issue 1, 114-124.
[12] V. B. Sunil, Rupal Agarwal, S. S. Pande, An approach to recognize interacting features from B-rep CAD models of prismatic machined parts using a hybrid (graph and rule based)

technique, Computers in Industry, 2010, Vol. 61, issue 7, 686-701.
[13] Tobias Dipper, Xun Xu, Peter Klemm, Defining, recognizing and representing feature interactions in a feature-based data model, Robotics and Computer-Integrated Manufacturing, 2011, Vol. 27, issue 1, 101-114.
[14] Li-Yong Shen, Jin-San Cheng, XiaohongJia, Homeomorphic approximation of the intersection curve of two rational surfaces, Computer Aided Geometric Design, 2012, Vol. 29, issue 8, 613-625.