博士論文（要約）

Feature-aware Partitioning of Quadrilateral Meshes for Reverse Engineering
(リバースエンジニアリングのための特徴を考慮した四辺形メッシュ分割)

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Reverse engineering is a tool that transforms a real-world object into digital world to perform assessments and improvements on the object particularly using CAD/CAE/CAM applications. B-spline surfaces are the most common representation that is used for representing free-form shapes mainly in ship building, automotive and airplane industry. Conversion of scanned data (obtained using 3D scanning machines) to B-spline surfaces is nontrivial and a little work has been done on this conversion. The research in this dissertation aims to generate B-spline surfaces from a given quadrilateral mesh which is preferable than triangular mesh because of its good fit with surface parameterization, its oriented elements according to the principal curvature directions, etc. Highly-curved regions (feature curves) inside partitions cannot be represented well with smooth B-spline surfaces, therefore feature curves in the model is appropriate to be located on the surface boundaries which is the basic approach in this dissertation. Three different algorithms which uses the concept of placement of feature curves on the surface boundaries are proposed in order to generate high-quality B-spline surfaces.

The bi-monotone approach generates bi-monotone partitions that have ability to capture the surface details of an object easier than the quad-like partitions. Therefore, they are appropriate for use in reverse engineering applications since an appropriate number of partitions can determine feature curves within the boundaries which is not always possible when quad partitions are used. The proposed algorithm also includes sequence of methods that generates bi-monotone partitions which are at the end fitted with B-spline surfaces.

The Path Flipping approach generates quadrilateral partitions from a given quadrilateral mesh which is based on the motorcycle graph (MCG) algorithm of Eppstein et al. As the MCG algorithm does not take surface geometry into account during partitioning, the partitions produced are not appropriate to fit by B-spline surfaces. Initial partitioning is first performed using a speed control algorithm identical to the original algorithm except that it assigns variable rather than constant speed to particles. Partition boundaries are then improved via local path flipping operations. However there are still highly-curved regions existing inside the partitions after these two steps. For this reason, feature curves are extracted and integrated into the proposed framework by using some

methodology. Some of flat partition boundaries are then removed. The generated partitions of this algorithm are in quad-shape and fitted with B-spline surfaces without surface trimming.

The MCG enumeration approach, the third approach, also intends to generate quadrilateral partitioning from motorcycle graph and it is motivated by the weak point of local path flipping operation (of the second algorithm). This algorithm is locally performed and therefore the results produced converge to the local optimum. In order to reach global optimum, all possible motorcycle graphs of a given quadrilateral mesh are intended to be listed to find the global optimum one. Even though this is possible, it has high computational cost. In order to reduce the computation cost, mesh is divided into several sub-meshes and optimum motorcycle graph is found separately by enumerating all motorcycle graph combinations of these sub-meshes. Finally a quasi-optimum motorcycle graph of the whole mesh is obtained by combining the separate solution in each sub-meshes. The motorcycle graph obtained using this method is appropriate to fit by B-spline surfaces.

The results of each algorithm are demonstrated and comparison is made by checking visually as well as using surface fitting quality of the generated surfaces. In terms of capturing feature curves not aligned with parameter uv directions, the bi-monotone approach is much more advantageous than other two approaches. The Path Flipping approach can generate better results (more highly-curved regions can be placed on partition boundaries) than the bi-monotone approach and it can generate similar results in a shorter time compared to the MCG enumeration approach for the models having smooth features. The MCG enumeration enumerates many motorcycle graphs in order to find the optimum one, and therefore the partitions generated using this method are possibly more appropriate to fit by B-spline surfaces than that of the bi-monotone and Path Flipping approaches. All tests in this dissertation has been made with semi-regular quadrilateral mesh models generated using the mixed integer quadrangulation technique of Bommes et al.