Skeletonization and segmentation of binary voxel shapes (PhD thesis)
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English summary
Skeletons are shape descriptors that are of a lower dimensionality than the shape they describe. They are centered within the shape, capture the shape’s symmetry, and describe the topology and articulation of the shape in a compact manner. These qualities make skeletonization a desirable pre-processing step in a variety of applications ranging from shape segmentation and retrieval, to pose estimation and motion planning. The skeleton was formally defined by Blum in 1967. For 2D shapes, the skeleton consists of curves. Extending the definition to 3D shapes, the skeleton is a 2D structure consisting of manifolds and curves, and is called surface skeleton. Because a 1D structure is more compact and more suitable for some applications such as motion planning, alternative skeleton definitions have been proposed that yield 1D structures, known as curve skeletons.

There are still a number of unsolved problems for the computation of both curve and surface skeletons, as follows. First, skeletons are expensive to compute accurately, especially in three and higher dimensions. Second, skeletons are sensitive to discretization artifacts and noise on the shape boundary, resulting in many spurious skeleton parts. Skeletonization methods need to ensure that the produced skeletons are robust to noise, so that they can be used in subsequent applications.

In the first part of this thesis, we focus on efficiently computing skeletons that are robust to noise. We introduce the notion of Tolerance-based Feature Transforms, which enables the robust computation of skeletons of 2D shapes. We present a new method for computing simplified curve-skeletons and surface-skeletons for 3D shapes. We define a global importance-measure, which yields simplified skeletons when thresholding this measure using a single, intuitive user-parameter. Finally, we extract the simplified-skeleton structure by identifying its constituent manifolds. Although the methods presented in this thesis work on binary voxel-shapes, many of the ideas and heuristics apply to other shape representations as well.

In the second part of the thesis, we use our simplified skeletons to develop two new 3D shape segmentation methods. First, we present a method for segmenting articulated shapes using the curve skeleton. The segments produced capture logical parts of the shape such as the fingers of a hand. The segmentations are robust to boundary noise, have smooth segment borders, and are pose-invariant. Second, we present a method for producing patch-type segmentations, which are more suitable for geometric, faceted shapes.