RECONSTRUCTION OF PARTIAL LIVER SHAPES BASED ON A STATISTICAL 3D SHAPE MODEL

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Background: Statistical shape models (SSM) describe complex shape variations derived from a training population in a compact way. Thus, they are well suited for robust reconstruction of unknown shapes, especially in situations where data is affected by noise, artefacts, or only partially contains the unknown shape. Important applications are, e.g., image segmentation as well as reconstructive surgery [1].

Aims: To provide an automatic method to reconstruct and complete partial liver surfaces.

Methods: The main idea of our method is to formulate the reconstruction process as a segmentation problem and adopt the methodology presented in [2]. This is accomplished with three main modifications: (1) from the open input surface, we create a 3D image to be segmented. (2) We provide a new cost function that drives the SSM deformation towards the target image. (3) We merge the unknown part of the liver reconstructed by the SSM with the remaining liver, given as input. Otherwise the same multilevel optimization framework as in [2] is used: (a) initialization of pose, (b) several phases of SSM deformations with different parametrizations, (c) free-form deformation.

Image to be segmented

The input mesh is closed by a surface hole filling method [3]. The closed surface is scan-converted into a binary image. This image is further decomposed by morphological operations into four volumetric regions: rim (R), hole (H), liver (L), exterior (E) (see Fig. 1-a). This image will be used as input to the segmentation.

Cost function

We distinguish between profiles that cut through rim, hole, liver or exterior volume (see Fig. 1-b) to determine the costs that drive the SSM deformation. This allows to emphasize the rim region in particular in order to achieve a tangential continuity of the reconstructed SSM with the remaining liver shape.

Surface merge

The final reconstructed surface is merged from two volumes. The SSM reconstruction is used within the cutting volume (see Fig. 1-c), which is computed from the cutting contours. We assume that cuts are either planar or spherical. This volume is merged with the original liver volume outside the cutting volume into a single binary mask, from which the final reconstructed liver surface is generated. (Fig. 1-c shows the spherical cutting volume and the smooth transition between both volumes in the final surface contour, shown in orange).

Results: The deformation phases have been trained on 20 of the liver segmentations provided by [4]. 20 different liver segmentations from this collection were modified, removing sections of different sizes and locations of the liver, in order to validate the full algorithm and select the best performing parameters (i.e. weight of the rim region, search lengths and PCA modes in all deformation phases). We finally tested the algorithm on the 10 incomplete liver meshes from the Shape 2015 Challenge.

The validation phase on 20 sets not included in the training data of the model yielded results with an average error of 1.197 $\pm$2.917 mm.

Conclusions: Livers are particularly challenging due to their shape variability caused by external factors (e.g. breathing), which makes bone reconstruction a more suitable application.

Regardless, this method yields precise reconstructions for livers. It could be further improved by studying the relationship between deformation parameters and hole shape and location. This approach would improve the performance and reduce the risk of overfitting to a particular set of training cases.

References:

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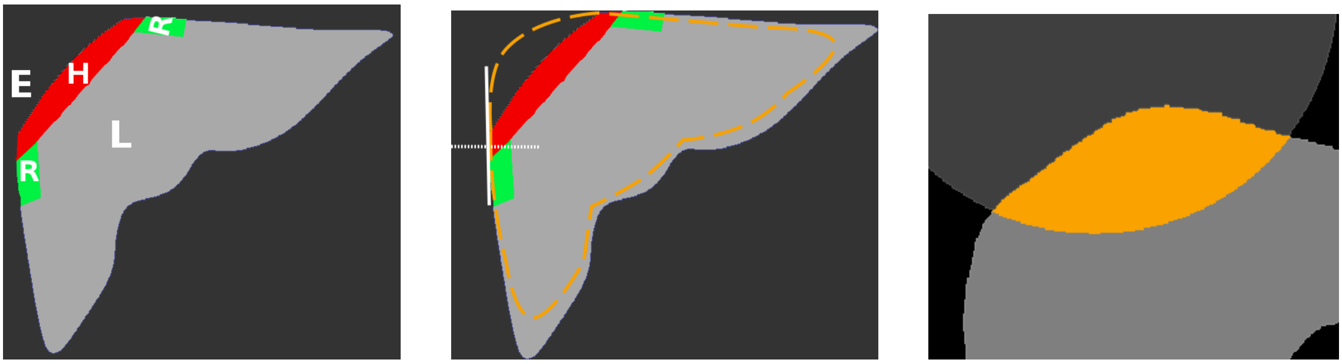

Figure 1: *(a) Sketch of the different areas in the new 3D image to be segmented. (b) Sketch of a search profile (white dashed line) crossing both the rim and hole areas and model being deformed (orange dashed line). (c) Slice: zoom on the merge of the known shape and deformed SSM (orange) selected with the spherical cutting volume.*