Title

Application of sparse shape modeling to automated planning of mandibular reconstruction

Authors

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Abstract

1. Purpose

Preoperative planning using computer-aided design with three-dimensional computed tomography (3D CT) data is an active area of research. The application to mandibular reconstruction with vascularized fibular flaps gains attention because there are various reconstruction patterns of mandibular defects, and the shape of the mandible varies from person to person. Interactive planning software enables intuitive design of reconstruction plans [1]; however, it causes a lack of objectivity and is time-consuming because various parameter settings are required. A recent study presented an automated planning model that formulates fibular transfer procedures in mandibular reconstruction [2]. As optimization of high dimensional parameters requires computational cost, we focus on a machine learning approach using past planning data, and explore essential features of surgical procedures.

We propose an automated preoperative planning method with sparse shape modeling [3] to handle the complexities of mandibular shape variations and defects. This framework does not use all datasets but rather a subset of the past datasets whose features are similar to those of the target mandible. In this presentation, we present its application to mandibular reconstruction and discuss if this approach can estimate the appropriate fibular placement for each case within a unified mathematical framework.

2. Methods

The proposed methods use the manual planning results as the training data, select a subset of the training data that is similar to the target mandible based on the geometrical features, and generate a reconstruction plan by a sparse combination of the data. We introduce a feature matrix D_f to represent the information of mandibular features and defects of past plans, and a plan matrix D_p to represent the virtual cutting planes S_i and the connection points $\mathbf{p}_i$ between fibular segments (Fig. 1). To quantify individual mandibular shape, we define a mandibular contour: the maximum curved line that is perpendicular to the mandibular tangent plane [2]. The mandibular contour is uniquely obtained from CT data, and stored in D_f. The target plan is computed by a weighted linear combination of the past plans, and the weight parameter $\boldsymbol{x}$ is solved by a L1 minimization problem. To manage the complexities of mandibular shape variations and differences of

defects, we hypothesized that a combination of similar training data is better for the approximation than a combination of all datasets, *i.e.*, the weight parameter $\boldsymbol{x}$ is computed as a sparse vector.

3. Results

Experiments were performed to evaluate the proposed methods with oral surgeons. One hundred and twenty reconstruction plans were retrospectively reproduced from 10 CT images using virtual planning software [4]. The proposed automated planning model was quantitatively compared with the surgeons' plans by using a positional error of the connection points between fibular segments. Typical planning results of manual plans and automated plans are shown in Fig 2. We performed 10-fold cross-validation, i.e., six instances were used for the test data (new cases) and the other 54 instances for the training data. In this experiment, 5, 25, 51 and 101 points were extracted from each 3D CT image of the mandible for comparison, and used in the feature matrix. The results showed that the positional error of the connection points varied from 1.0 to 6.0 mm, and the mean error was 2.6–3.0 mm, regardless of the number of feature points. The results suggested that the cutting area could be an important factor for this type of surgical procedure.

4. Conclusion

This study proposed sparse shape modeling for automated fibular transfer planning in mandibular reconstruction. Sparse linear combination of the past planning results provided stable fibular placements for the new data, and could generate valid planning results similar to the surgeons' plans. Future work will include further improvement and evaluation of the planning framework.

Reference

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Figures

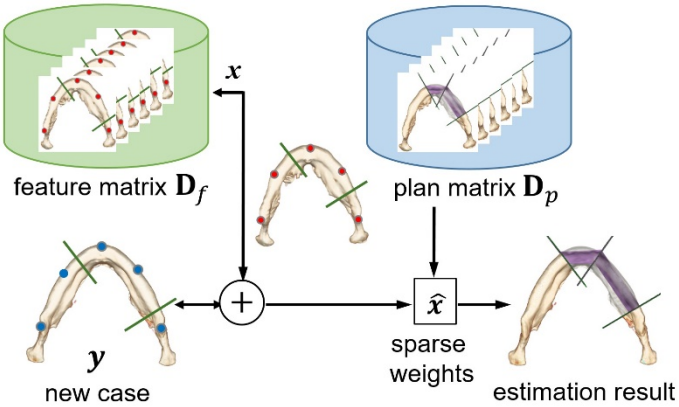

Fig. 1. Sparse shape reconstruction of fibular transfer surgery procedures

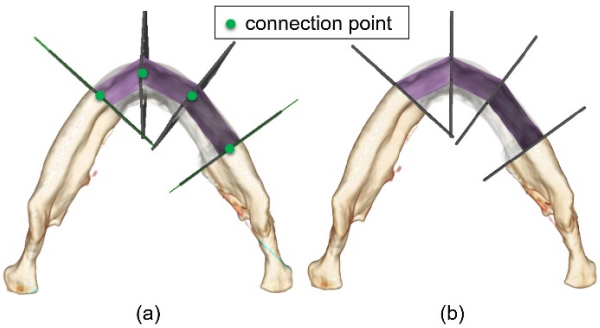

Fig. 2 Typical example of automated planning results and manual plans; (a) surgeon's plan and (b) computation result