# Automatic Segmentation of Structures in CT Head and Neck Images using a Coupled Shape Model

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## 1 Introduction

The common approach to do a fully automatic segmentation of multiple structures is an atlas or multi-atlas based solution. These already have proven to be suitable for the segmentation of structures in the head and neck area and provide very accurate segmentation results, but can struggle with challenging cases with unnatural postures, where the registration of the reference patient(s) is extremely difficult. Therefore, we propose an coupled shape model (CoSMo) algorithm for the segmentation relevant structures in parallel. The model adaptation to a test image is done with respect to the appearance of its items and the trained articulation space. Even on very challenging data sets with unnatural postures, which occur far more often than expected, the model adaptation algorithm succeeds. The approach is based on an articulated atlas [2], that is trained from a set of manually labeled training samples. Furthermore, we have combined the initial solution with statistical shape models [1] to represent structures with high shape variation. CoSMo is not tailored to specific structures or regions. It can be trained from any set of given gold standard segmentations and makes it thereby very generic.

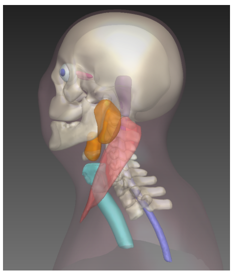

Fig. 1: Visualisation of the mean model

## 2 Coupled Shape Modell

CoSMo consists of two different kinds of model items, which are created from labeled CT image data sets, depending on the type of the structure. They are classified as rigid and deformable model items. The training is done as followed:

***Rigid Model Item Creation:*** The bones are represented as rigid model items. For each rigid model item, the segmentation for this specific item is extracted from the training samples. These segmentations are used to calculate a probability image and an average intensity image. Additionally, a relative transform with respect to the center of the training instance iss stored.

***Deformable Model Item Creation:*** The more challenging items, which are items with high shape variation or low contrast, are represented as statistical shape models. For each of these items, a statistical shape model and an appearance model is trained. Analog to rigid model items, a relative transform with respect to the center of the trainings instance is stored. Additional shape specific parameters are stored, which are needed for later shape adaptation.

For every trainings instance a parameter vector $p_j$ is determined. It contains the transformations for all model items involved in the coupled shape model. The parameter vector for the rigid items consists of 7 degrees of freedom, 3 for translation, 3 for rotation and 1 for isotropic scaling. The statistical shape models within CoSMo consist of $7+n$ degrees of freedom, where $n$ is the number of principal components of the statistical shape model (SSM). The concatenation of all parameter vectors $p_j$ leads to a parameter vector $x_j$ for a training instance $j$ and is independent from its global position and orientation. The combination of these vectors leads to a training articulation matrix $X = (\boldsymbol{x_1}, .., \boldsymbol{x_n})$, where every parameter vector $\boldsymbol{x_j}$ resides in one column. Using a principal component analysis (PCA) on this matrix returns the space of all possible poses and deformations, that is the basis for later model adaptation to an unknown data set. For more details how the articulated atlas is created, see reference: [2].

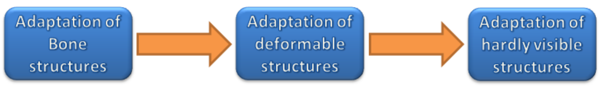


Fig. 2: Overview of the adaptation pipeline.

### 2.1 Model Adaptation

The adaptation process of CoSMo is divided into multiple levels, because the adaptation of some model items is more challenging than others (see Fig 2).

Therefore, the adaptation process starts with the items that can be adapted most reliably, namely the bone structures. Once the bone structures are adapted, the next level of the adaptation process is executed, which includes the the deformable items. This adaptation can either be done using a gradient based approach or a appearance model learned during the training phase of CoSMo. In the last level of the adaptation process, the remaining model items, which hardly have any visible image features, in this scenario the brainstem, are adapted. They obtain their shape and position from the knowledge of the trained CoSMo model and don't undergo a segmentation of their own. The complete, fully automatic adaptation process takes approximately 4 minutes.

## References

1. Kirschner, M., Becker, M., Wesarg, S.: 3d active shape model segmentation with nonlinear shape priors. In: Fichtinger, G., Martel, A., Peters, T. (eds.) Medical Image Computing and Computer-Assisted Intervention MICCAI 2011, Lecture Notes in Computer Science, vol. 6892, pp. 492–499. Springer Berlin Heidelberg (2011)
2. Steger, S., Kirschner, M., Wesarg, S.: Articulated atlas for segmentation of the skeleton from head amp; neck ct datasets. In: Biomedical Imaging (ISBI), 2012 9th IEEE International Symposium on. pp. 1256–1259 (2012)