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# Loss function analysis and optimization for spinal segmentation in Magnetic Resonance Imaging

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**Abstract**   Loss functions describe how accurate the prediction of the model is compared to the ground truth, and therefore play an essential role in the training process. In the field of medical image segmentation, many different loss functions have been developed that achieve superior results for specific subdomains compared to standard loss functions, but this success cannot be transferred to other subdomains due to the lack of generalisation. Therefore, this thesis deals with the primary research question, which loss function achieves the best segmentation results for the magnetic resonance imaging data of cervical and lumbar vertebrae with the given model architecture of 3D U-Net. For this purpose, the differences and advantages of selected loss functions are shown through categorisation and analysis. Additionally, as secondary research questions to address automation possibilities of the training process, methods are presented that attempt to learn loss functions directly from the data and to optimise existing loss functions. In a comprehensive study, all results of the loss functions and the applied methods are then summarised, presented and compared.

**Relevant literature**   To address the primary research question, loss functions from the areas of distribution-based [LGG$^+$18] , region-based [SEG17] [HMSE$^+$19] , distance-based [KS19] [KBD$^+$21] and compound-based [AK18] [IVH21] are considered and analysed. The basis of the first secondary research question, how to learn a loss function, is formed by two publications that respectively use genetic algorithms [GM20] and meta-learning [BMC$^+$21]. To address the second secondary research question, methods [SBX20] that adaptively change the learnable parameters of existing loss functions and methods [HTM19] [GKGM20] that adaptively change the weights of multi-loss functions are investigated.

**Datasets and Evaluation**   All loss functions and the applied methods are tested on two different datasets and evaluated based on a k-fold cross validation strategy. The first dataset contains Magnetic Resonance Imaging data of the cervical vertebrae and was provided by the VisSim research group of the University of Koblenz-Landau. The second dataset contains Magnetic Resonance Imaging data of the lumbar vertebrae and was made available by the MyoSegmenTum database [BRS$^+$19].

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