Deep-learning-based image segmentation for uncommon ischemic stroke

From infants to adults

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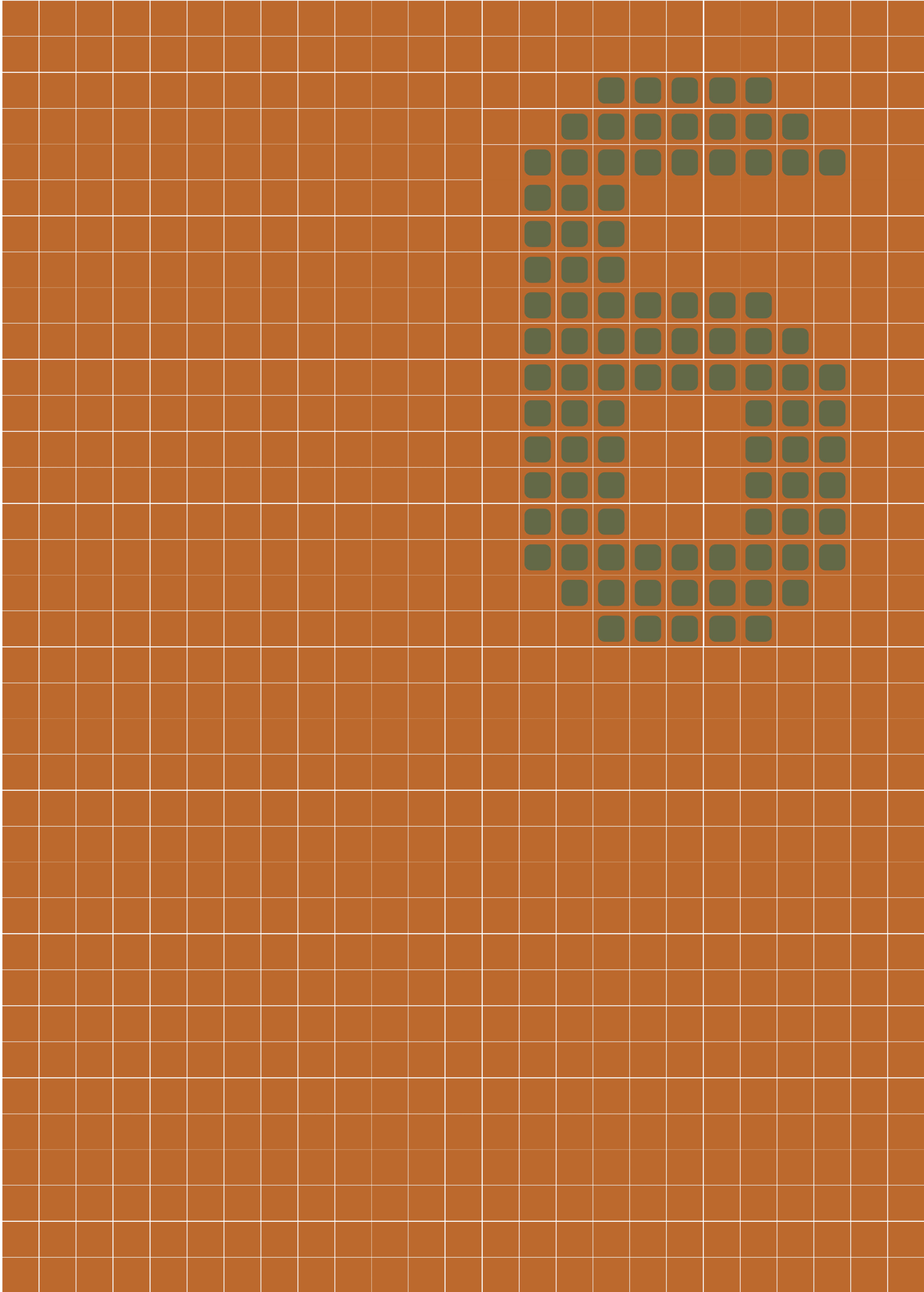

Chapter 6

Summary

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Developing deep learning-based algorithms that accurately segment structures in scans that are relevant to treatment or evaluation of the outcome of uncommon stroke is a difficult task. The difficulty is due to the presence of image artefacts, few data being available to train the networks, and the small volume of some of the target structures. Hence, the aim of this thesis was to investigate, develop, and evaluate deep learning-based algorithms for automatic segmentation of images of uncommon sub-types of stroke.

Deep transfer learning is a method by which information learned by a deep neural network on one problem can be re-used to improve performance on another problem. It is often used to ameliorate training of neural networks if few data are available. In a transfer learning scenario, a neural network is pre-trained on a source task and domain and re-used, by either fine-tuning or feature extraction, on a target task and domain. In chapter 2, we have evaluated the effect of pre-training by using various source domain and task combinations on target segmentation task performance. Convolutional neural networks were pre-trained on three types of tasks; segmentation, classification, and auto-encoding. The domain used was the same as the target task (T1-weighted MR scans) or different from the target task (natural images). The pre-trained convolutional neural networks were fine-tuned and their performance was evaluated on three target segmentation tasks: Multiple sclerosis lesion, stroke lesion and brain tissue segmentation. Our results showed that pre-training on a segmentation source task on the same domain resulted in a greater improvement in spatial agreement from transfer learning than the other source tasks and domain combinations. Pre-training on a similar task and domain resulted in a greater improvement in spatial overlap on two of the three target segmentation tasks, even when it was compared to pre-training on ImageNet [233], which is a dissimilar source domain and task and consisted of ten times more data. However, our results have also shown that the choice of source task and domain has an inconsistent effect on stroke and multiple sclerosis lesion detection accuracy. Based on this study, we can recommend that pre-training for target medical segmentation tasks should

be done on a similar source task and domain if spatial overlap is the most relevant metric.

Final lesion volume on follow-up NCCT is a common surrogate outcome measure of anterior circulation stroke. Due to the scarcity of available data in posterior circulation stroke, final lesion volume is understudied as a surrogate outcome measure for this pathology. To reduce the manual annotation burden of posterior stroke lesion segmentation, we have developed an algorithm that used deep transfer learning to automatically segment infarct lesions due to a posterior circulation stroke in chapter 3. The model that used deep transfer learning was pre-trained on segmentations of infarct lesions due to a stroke in the anterior circulation. We compared the method that used deep transfer learning to models that were trained on only anterior circulation stroke patients, only on posterior circulation stroke patients, and on patients suffering from a stroke in either one of the regions. The model that used deep transfer learning achieved a greater volumetric agreement and a higher spatial overlap between the automatic and reference lesion segmentation than the other methods. Furthermore, the deep transfer learned method also improved lesion detection relative to the other methods. This method facilitates investigation of final lesion volume as a surrogate outcome measure in posterior circulation stroke.

Segmentation-based thrombus image characteristics have been associated with stroke treatment outcome. Manual annotation of thrombi may limit the study of these associations. Hence, in chapter 4, we have developed an automatic method that localizes and segments thrombi causing a posterior circulation stroke. Segmentation methods for posterior thrombi that are not restricted to a specific region in the brain, segment a large number of false positive thrombi. We have shown that our method, which restricted itself to the area around the brainstem, improved performance relative to a standard UNet and reduced the number of false positives. Our method can be used to reduce the manual annotation burden for investigating the association between segmentation-based thrombus image characteristics and various outcome metrics.

Brain-tissue and ischemic lesion volume per hemisphere can be used to evaluate treatment efficacy in patients suffering from perinatal arterial ischemic stroke. Therefore, in chapter 5, we developed two instances of a convolutional neural network to segment the white matter, gray matter, cerebrospinal fluid, brainstem, cerebellum, basal ganglia and thalamus, ventricles, and the ischemic lesion in scans of patients suffering from perinatal arterial ischemic stroke. One network instance automatically segmented scans acquired at baseline, the other instance automatically segmented scans acquired at follow-up. Our network instances achieved comparable spatial overlap and alignment to methods that were developed in related research for brain tissue segmentation in scans of healthy brains and ischemic lesion segmentation in scans of adult patients suffering acute ischemic stroke.

Bibliography

[233] O. Russakovsky, J. Deng, H. Su, J. Krause, S. Satheesh, S. Ma, Z. Huang, A. Karpathy, A. Khosla, M. Bernstein, A. C. Berg, and L. Fei-Fei. ImageNet Large Scale Visual Recognition Challenge. *International Journal of Computer Vision*, 115(3):211–252, 9 2014.

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