Learning image transformations via convolutional neural networks: a review

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Abstract

Recent methodological innovations in deep learning and associated advancements in computational hardware have significantly impacted the various core subfields of quantitative medical image analysis. The generalizability, computational efficiency, and open-source availability of deep learning algorithms, particularly those utlizing convolutional neural networks, have produced paradigm shifts within the field. This impact is evident from topical prevalance in the literature, conference and workshop themes, and winning methodologies in relevant competitions. In this work, we review the various state-of-the-art, fully convolutional network approaches to learning and predicting image transformations. Although of primary importance within the quantitative imaging domain, image registration algorithmic development, in the context of these deep learning strategies, has received comparatively less attention than its counterparts (e.g., image segmentation). Nevertheless, significant inroads have been made and presented in various research venues. We contextualize these contributions within the broader scope of deep learning advancements and, in so doing, attempt to facilitate the leveraging and further development of such techniques within the medical imaging research community.

Key words: deep learning, diffeomorphisms, image registration, spatial normalization

Introduction

Determining the spatial correspondence between imaging domains is frequently a critical component in quantitative image analysis workflows. The evolution of image registration theoretical and technological development has led to increasingly high quality transformational mappings that have significantly improved performance in related processing tasks (e.g., image segmentation via joint label fusion [1]) and imaging-based statistical analysis strategies (e.g., sparse canonical correlation analysis [2]). Several reviews [3–8] have charted this chronology and provided insight into related issues such as algorithmic classification, available implementations, relevant evaluation strategies, and speculation concerning future directions of the field. Although prescient in many respects, even in later reviews, speculation vis-à-vis deep learning was somewhat limited almost certainly due to its relatively recent and sudden overwhelming of the field in terms of popularity and research focus.

Although the foundational concepts that form the basis for modern deep learning architectures are historically well-established, it is only recently that hardware availability has made sufficient advancements to meet the computational requirements of deep learning applications.

back-propagation

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