Convolutional neural networks, despite their profound impact in countless domains, suffer from significant shortcomings. Linearly-combined scalar feature representations and max pooling operations lead to spatial ambiguities and a lack of robustness to pose variations. Capsule networks can potentially alleviate these issues by storing and routing the pose information of extracted features through their architectures, seeking agreement between the lower-level predictions of higher-level poses at each layer.

In this dissertation, we make several key contributions to advance the algorithms of capsule networks in segmentation and classification applications. We create the first ever capsule-based segmentation network in the literature, SegCaps, by introducing a novel locally-constrained dynamic routing algorithm, transformation matrix sharing, the concept of a "deconvolutional" capsule, extension of the reconstruction regularization to segmentation, and a new encoder-decoder capsule architecture. Following this, we design a capsule-based diagnosis network, D-Caps, which builds off SegCaps and introduces a novel capsule-average pooling technique to handle larger medical imaging data. Finally, we design an explainable capsule network, X-Caps, which encodes high-level visual object attributes within its capsules by utilizing a multi-task framework and a novel routing sigmoid function which independently routes information from child capsules to parents. Predictions come with human-level explanations, via object attributes, and a confidence score, by training our network directly on the distribution of expert labels, modeling inter-observer agreement and punishing over/under confidence during training. This body of work constitutes significant algorithmic advances to the application of capsule networks, especially in real-world biomedical imaging data.

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The public is welcome to attend.