Deep Predictive Coding For Super Time-Resolved MR Imaging

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Abstract

MR imaging is known to be based in an ill-posed reconstruction model more likely to introduce artifacts than other clinical imaging techniques. This study aims to model spatiotemporal correlations in MR imaging using deep recurrent neural networks for use in automated artifact identification. In particular, this study focuses on leveraging PredNet, a deep predictive coding network for video prediction developed by the Cox Lab at Harvard. PredNet was trained using time-resolved MR image slices to predict the next frame in a sequence. Our results show that PredNet correlate spatiotemporal features across time-resolved MR images. Future work will focus on the implementation of a comparison algorithm to derive a map between individual images that may contain artifacts within a time-resolved data set.

1 Introduction

Magnetic resonance imaging (MRI) is a commonly-used clinical diagnostic imaging technique known for generating high contrast images of soft tissues without requiring ionizing radiation. The acquisition process is slow, however, occurring on a time scale larger than the scale on which biological processes, such as respiration and blood flow, typically occur. As a result, MRI is very susceptible to motion artifacts.[1] To freeze motion, reconstruction data must be partially acquired, stopping at the moment motion would occur. This creates a seriously ill-posed reconstruction model which introduces artifacts. This problem is currently addressed by having radiologists perform manual checks of the scan quality, possibly several times, to determine whether a patient needs rescanning. This can be quite time and labor intensive for radiologists, and uncomfortable for the

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patients. Automation of this process would facilitate increased productivity for clinical radiologists and increased comfort for patients. In this study, we leverage a previously developed network called PredNet[2] on a large dataset of dynamic contrast enhanced (CE) images to model spatiotemporal correlations in MR images, with the end goal of developing a network that can identify changes between real-time MR image scans that are characteristic of artifact formation.

2 Materials and Methods

Abdominal MRI volumes were acquired after gadolinium-based contrast enhancement from 41 patients. Each volume contained 192 axial slices with dimensions 180x80. Images were modified with a zero-filled surrounding border to expand image dimensions to 256x128, and were used as the network input images. All scans were acquired at the Stanford Lucile Packard Children's Hospital on a 3T MRI scanner (GE MR750) with voxel resolution 1.07 x 1.12 x 2.4 mm. Networks were run on a 5TB NVIDIA GPU server remotely via TeamViewer.

Our network was adapted from the previously published PredNet network developed by the Cox Lab at Harvard University. Stack size was set to (1, 48, 96, 192), and A, $\hat{A}$, and R filter sizes were set to (3, 3, 3), (3, 3, 3, 3), and (3, 3, 3, 3) respectively. Number of time steps was set to 18 in agreement with the dataset used. All other parameters were initialized as in the original PredNet study using the KITTI dataset. Test and training sets were run for 5000 epochs, with 3500 image sets in the training set and 600 in the test set. Result images were created using the kitti_evaluate.py file available through the PredNet GitHub repository.

3 Results and Discussion

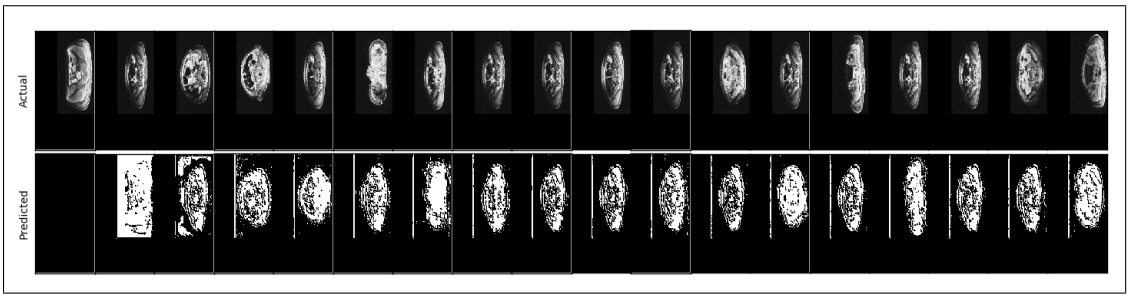

Figure 1: Preliminary PredNet Results. The top row shows the actual 18 second image sequence (one frame/second) and the bottom shows the corresponding PredNet prediction. Each true image on the top row corresponds to the predicted image below and immediately to the right of it. The initial black image on the far left of the bottom row corresponds to the initial prediction, where the network has not seen the MR images yet.

This study aimed to determine whether a previously developed deep recurrent neural network could be adapted to model spatiotemporal correlations in MR imaging for use in automated artifact identification in MR imaging. Figure 1 shows the preliminary results from PredNet. The top row shows the time-resolved image sequence shown to the network, and the bottom row shows the resulting network prediction, where said predictions are displaced one frame to the right of the corresponding true image in the top row. These observations are promising, as the network matches the shape, anatomical features, and general intensities of each image through time, progressively becoming more accurate. These results show that PredNet, when used with time-resolved MR images, can correlate spatiotemporal features across image sequences by discovering latent features present in the data. These findings can be leveraged for artifact prediction, for encoding the dynamics of motion and contrast for diagnostic purposes, and as a valuable prior for real-time MRI reconstruction. Future work will focus on the development of a deep recurrent neural network for artifact prediction and identification in clinical settings.

References

[1] Zaitsev, M. J Magn Reson Imaging (2015) 42(4), 887-901

[2] Lotter, B. ICLR 2017 (2017) arXiv:1605.08104