Investigation on Compressed Sensing Regularization Parameter using Case-PDM

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INTRODUCTION

Compressed Sensing (CS) can be used to speed up MR acquisition by highly undersampling k-space. In CS, a set of regularization parameters are used to balance artifact removing and spatial resolution preservation [1]. Amongst these regularization parameters, Total Variation (TV) weight is the most affective parameter to image quality. To date, the choice of TV regularization weight has not been justified in any literature. In this paper, we systematically study the influence of TV weight on image quality. A perceptual difference model (Case-PDM), which has been successfully applied to optimize keyhole, spiral, SENSE, and GRAPPA algorithms [2-4], was used for optimizing the TV weight. Experimental results show that there is a variation of the optimal TV weights across different image data sets, and a small difference between high and low sampling ratios for the same data set.

METHODS

An exhaustive search strategy was used to search for the optimal TV weight corresponding to the best image quality (or the lowest PDM score) in each data set. 6 different raw MR brain data sets were used in the experiments. Two whole brain volume data sets (Dataset 1 and Dataset 2), one transverse and one saggital, were acquired on a GE 3T system (Waukesha, USA) using T1 FLAIR sequence. Two data sets (Dataset 3 and Dataset 4) were acquired on a Philips 3T system (Best, Netherlands) with IR pulse sequence but with different inversion time. The above 4 data sets were acquired with 8-channel head coils (Invivo Corp, Gainesville, USA) designed for GE and Philips respectively. Another data set (Dataset 5) was acquired on a SIEMENS 1.5 T system (Erlangen, Germany) with a 4-channel head coil (Invivo Corp, Gainesville, USA) using unknown acquisition parameters. The 3D volume of Dataset 1 was used to study 2 dimensional undersampling. Variable density (VD) undersampling in phase encodes (and z direction in 3D data set) with different sampling ratios was used. The randomized VD sampling scheme, proposed in CS, is controlled by a probability density function (PDF) so that central k-space has higher probability to be sampled than the outer k-space locations. The implementation of CS was based on Ref [1]. Totally, more than 7400 test images covering a wide range of image quality were evaluated.

RESULTS

Optimal TV weights are inconsistent across different data sets, and may change slightly for the same data set with different sampling ratio. For the 5 data sets with 1 dimensional acceleration, the optimized TV weights at [high sampling ratio (>50%), low sampling ratio (<50%)] are [0.0005, 0.002], [0.0005, 0.002], [0.0001, 0.0001], [0.0001, 0.0001], and [0.0001, 0.002]. respectively. For the 3D data sets with 2 dimensional acceleration, the optimized TV weights at [high sampling ratio, low sampling ratio] is [0.002, 0.002], Figs. a and b show two examples of the influence of TV weights. It was also observed that the fluctuation of image qualities amongst different TV weights decreases from low reduction factor (i.e. high sampling ratio) to high reduction factor (i.e. low sampling ratio) except for the 3D data set, as also demonstrated in Figs. a and b. From the comparison of CS and zero padding technique (i.e. all regularization parameters are 0), it can be seen that CS reconstruction can be worse than zero padding if the TV weight is not appropriate.

CONCLUSIONS

In conclusion, the optimal TV weight varies across different subject/ pulse sequence/ scanner. For brain imaging, the range of optimal parameter is 0.0001 to 0.002. To achieve a high image quality CS reconstruction, a pre-calibration is necessary to find the optimal TV weight. Improved CS model, which is insensitive to the regularization parameter, is expected to apply CS on routine clinical application.

ACKNOELEDGEMENT

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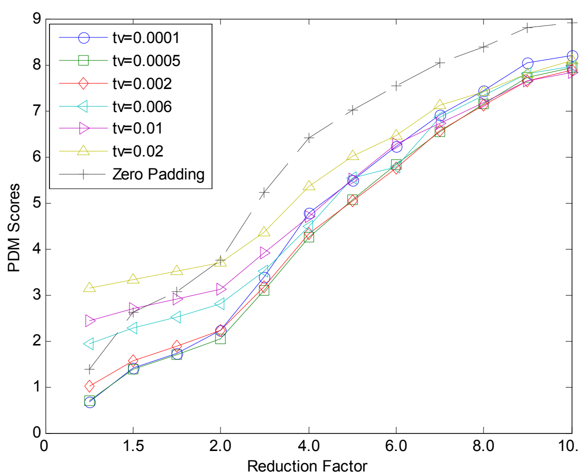
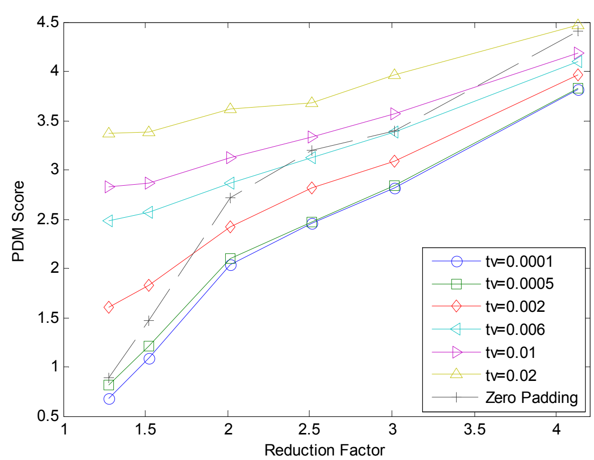


(a)



(b)

Figure Experimental results for Dataset 1 and Dataset 3 are demonstrated in (a) and (b), respectively. In these results, the optimal TV weight varies across different data sets, and is subtly different between low reduction factor (<2) and high reduction factor (>2). CS reconstruction with optimal TV weight has better image quality (or lower PDM score) than zero padding technique, as shown in (a) and (b). However, CS reconstruction can be worse than zero padding if the TV weight is not appropriate.