Abstract #551

G-CASPR and VDRad: extreme cases of a continuum. Intermediate may be better.

A. Godino-Moya, J. Royuela-del-Val, R.M. Menchón-Lara, M. Martín-Fernández, C. Alberola-López
Valladolid, ES, University of Valladolid, Image Processing Lab

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Purpose / Introduction

Different approaches that use Cartesian trajectories with spiral profiles and golden angle step have been proposed to accelerate MRI acquisition. G-CASPR[1] is characterized by a scheme with uniform k-space sampling and it is usually applied to static MRI, but in [2] it is used in cardiac cine. Nevertheless, compressed sensing shows better results if the center of k-space is sampled more densely[3,4]. VDRad[5] is a variable density sampling scheme that has been reported for abdominal imaging. VDRad, however, has the drawback that some positions in the k-space are repeatedly acquired, decreasing efficiency. We define a versatile sampling scheme that varies continuously from the G-CASPR to VDRad. Our goal is to determine whether intermediate configurations can provide better sampling schemes for cine cardiac MRI applications.

Subjects and Methods

The proposed sampling scheme is described as follows: given a spiral length L, the (Kx,Ky)-plane is divided into L elliptical rings and each ring in turn is divided in L sectors. Rings can have constant area, constant radial width or something in between, which is controlled by the parameter alpha (Figure1). α=0 produces rings with the same number of samples (equivalent to G-CASPR), whereas α=1 produces rings with different number of samples (equivalent to VDRad). Samples within each ring are ordered by radius and by angle in the k-space. Trajectories are formed by choosing each time one sample of one ring and sector forming a spiral twist. Resulting spirals are ordered according to the golden angle 137.5º. The number of the total acquired samples is adjusted by the desired acceleration factor. Images were reconstructed using kt-SPARSE-SENSE with temporal total variation[6]. One slice of real data from a regular fully sampled, Cartesian breath hold acquisition with 32 coils was used to test our method. SER and HF-SER[7] were calculated to measure image reconstruction quality.

Results

Figure2 shows the SER and HF-SER for a 2D image reconstruction with different AF and α-values. The plot seems coherent with the reconstructions included in Figure3. Differences, albeit subtle, can be appreciated (highlighted with arrows).

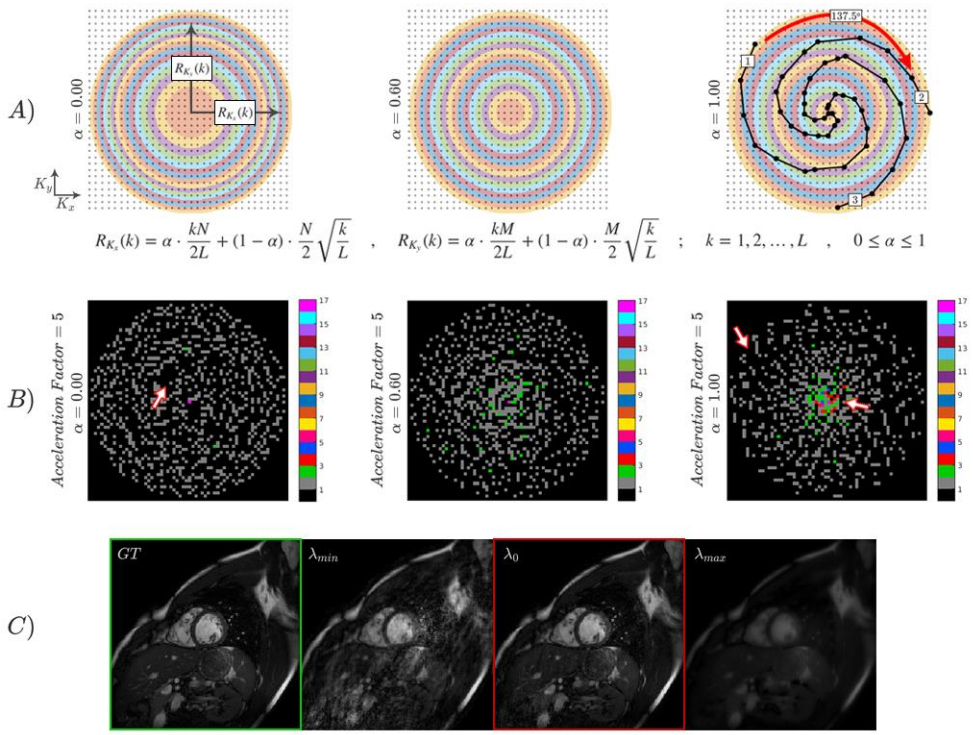

Figure 1: proposed method overview: A) (Kx,Ky)-plane is divided into rings. Each ring radius is calculated according to the equations indicated. R_Kx(k) and R_Ky(k) are the radii of the k-th ring in the Kx and Ky directions, respectively. L is the number of samples per spiral and N×M is the size of the image. In the figure, N=M and, therefore, circles are represented. Consecutive spirals are separated an angle given by the golden ratio. On the left, each ring has the same area (α=0.00), on the right each ring has the same radial width (α=1.00). In the center an intermediate case is shown (α=0.60) where each ring has variable radial width and area. B) Resulting sampling patterns for different values of α after the cardiac binning. Sampling patterns show uniformity for α=0, although there are some zones with a few samples in the center of k-space. The density in the center of k-space increases progressively with the value of α and so do the repetitions of samples. The number of times that a sample has been visited is represented by colors. C) Reconstructions for different values of the regularization parameter λ. Green frame: ground truth image. Red frame: reconstructed image with empirically selected value of λ.

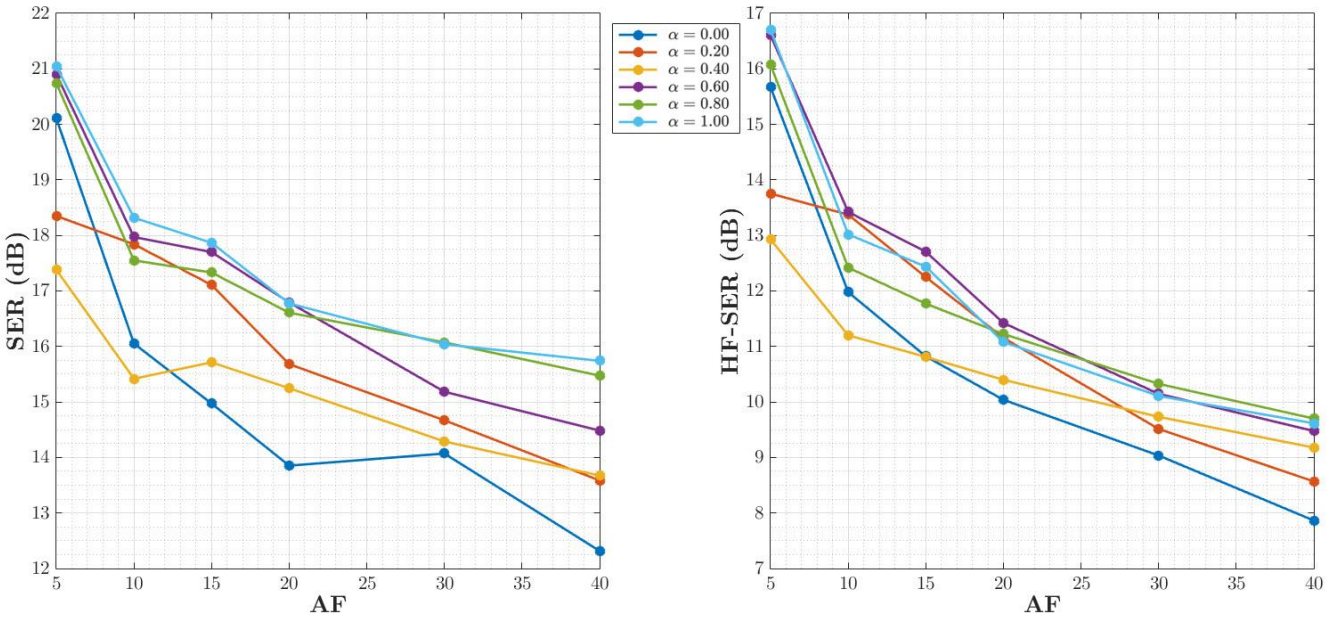

Figure 2: results for 2D image reconstruction with different AFs; each curve is parameterized by the value of α employed. The figure on the left hand side shows the values of SER. The figure on the right hand side shows the values of HF-SER for the same AFs and values of α. HF-SER is a specialized quality measure in which the sharpness of boundaries plays a higher role.

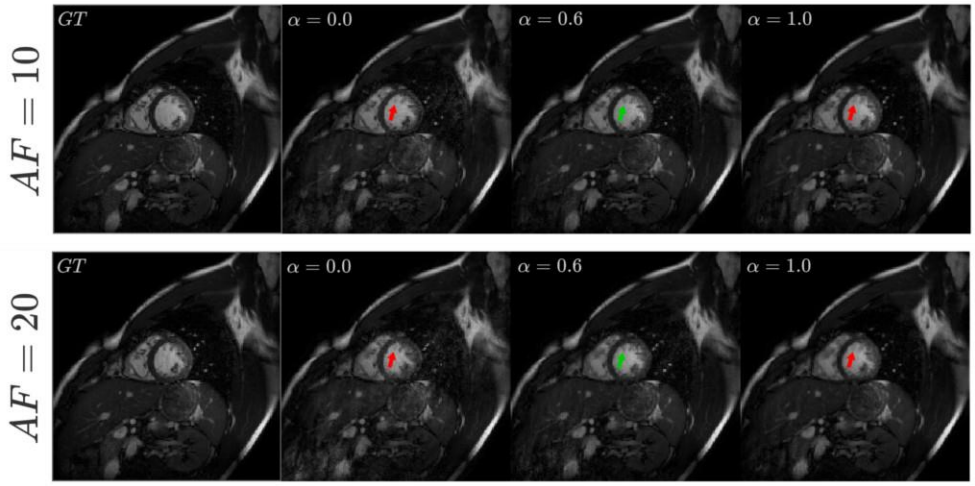

Figure 3: reconstructed images for different values of AF and α. Two AFs have been used and we show three values of α (the two extremes and the best intermediate α for those AFs, i.e., α=0.6). Green arrows point significant locations with better quality than red ones. Ground truth is included for easier reference. Images for α=1.0 show more blurring than with intermediate α-values and some structures are more clearly revealed with these values, which agrees with HF-SER graphic in Figure 2.

Discussion / Conclusion

We have developed a variable sampling scheme that allows, by means of a continuous parameter, to select from uniform sampling of k-space to denser sampling in its center. The extremes cases (α=0, α=1) are not necessarily the best choice, as we have shown in Figure3 and quantified in Figure2.

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