Computational MR imaging
Laboratory 6: k-space parallel imaging

Code submission is due by 12:00 before the next Thursday lab section. Please upload your code to StudOn in a described format. Late submissions will not be accepted.

Learning objectives

- Reconstruct regularly undersampled data using the GRAPPA algorithm.

1. **Prepare data**
    a. Load the file data_brain_8coils.mat used from the previous lab5.
    b. The original shape of the kdata is stored in [self.PE, self.RO, self.nCoil] variables, respectively.

2. **Implement GRAPPA algorithm**
    (hint: to understand easier, start to implement with ACS lines of 24, the kernel size of 2x3 and R=2)
    a. get_acs:
        i. Take fully-sampled auto-calibration signals from the center of the kdata
    b. get_block_h:
        i. Calculate the height of the GRAPPA block. The GRAPPA block is shown as a blue box in the Lecture slide.
        ii. Ex) For the kernel size of (2x3) and R = 2, the height of the GRAPPA box is 3.
    c. get_block_w:
        i. Calculate the width of the GRAPPA block.
        ii. Ex) For the kernel size of (2x3) and R = 2, the width of the GRAPPA box is 3.
    d. get_n_b:
        i. Calculate n_b, which is the number of blocks in the ACS region.
    e. get_n_kc:
        i. Calculate n_{kc}, which is the number of kspace coefficients to be involved in weight calculattion.
        ii. For the kernel size of (2x3) and 8 coils, n_{kc} is 24.
    f. extract:
        i. Compute a target matrix, T, and a source matrix, S, from the ACS.
    g. get_weights:
        i. Compute weight matrix, w, from T and S.
    h. get_mask:
        i. Get the undersampling mask at the acceleration factor of R
    i. undersample:
        i. Understample the fully-sampled kdata at the acceleration factor of R along the PE direction.
        ii. Preserve the original shape of the kdata and fully-sampled ACS region.

iii. Make use of the undersampling mask from get_mask().

j. Get_pad_PE_up:
   i. Calculate how many samples to be padded for the upper part of the PE direction.

k. Get_pad_PE_down:
   i. Calculate how many samples to be padded for the down part of the PE direction.

l. Get_pad_RO_left:
   i. Calculate how many samples to be padded for the left part of the RO direction.

m. Get_pad_RO_right:
   i. Calculate how many samples to be padded for the right part of the RO direction.

n. zero_padding:
   i. Pad input_k with 0s to ensure that GRAPPA blocks interpolate all missing coefficients.
   ii. Think about how many samples you should pad on each direction.

o. grappa_core:
   i. Interpolate the missing kspace coefficients in the kdata_us.
   ii. Apply the zero_pading method to *kdata_us* to ensure that the entire missing coefficients are estimated.

p. crop2original:
   i. Crop padded kdata to its original shape

q. data_consistency:
   i. Ensure the GRAPPA kdata is consistent with the original data.

3. **GRAPPA reconstruction:**
   a. Reconstruct the 8-coil data with simulated $R \in [2,3,4]$ and the kernel size of (2×3) at 24 ACS lines.
   b. Compute RMSE with respect to the matched-filter combination of the fully-sampled kspace. What do you see over different Rs?
   c. Do the same experiments with other kernel size $\in [(4 \times 5), (6 \times 7)]$.
      i. How does the kernel size affect GRAPPA reconstruction?
      ii. Why image qualities and RMSE values are different for different kernel sizes?
   d. Do the same experiment but different ACS lines, such as 36, 48, and 60.
      i. How can you interpret the results depending on different ACS lines?
      ii. What is the trade-off for the ACS lines and filter sizes?
   e. Compare GRAPPA reconstructions to your SENSE results from lab5 at different $R \in [2,3,4]$. You can load SENSE results by calling the method, load_SENSE with an acceleration rate, R.