05.ISBI19_notebook

January 6, 2021

1 Fifth exercice: Non-Cartesian radial under-sampling

In this notebook, you can play with the design parameters to regenerate different radial in-out patterns (so, we draw radial spokes over a rotating angle of π). You can play with the number of shots by changing the under-sampling factor.

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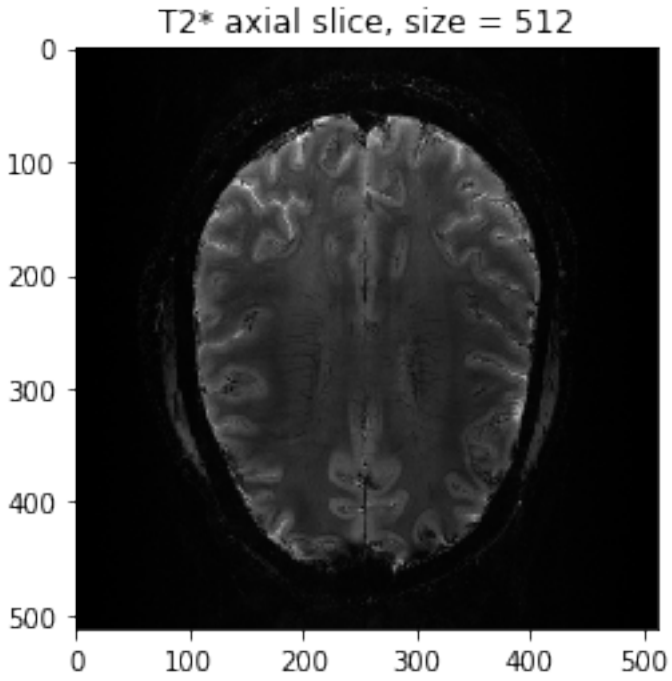
- Target: ISBI'19 tutorial on **Recent advances in acquisition and reconstruction for Compressed Sensing MRI**
- **Revision**: 01/06/2021 for ATSI MSc hands-on session at Paris-Saclay University.

[1]:
```
#DISPLAY BRAIN PHANTOM
%matplotlib inline

import numpy as np
import os.path as op
import os
import math ; import cmath
import matplotlib.pyplot as plt
import sys
from mri.operators import NonCartesianFFT
from mri.operators.utils import convert_locations_to_mask, \
    gridded_inverse_fourier_transform_nd
from pysap.data import get_sample_data


from skimage import data, img_as_float, io, filters
from modopt.math.metrics import ssim

#get current working dir

#cwd = os.getcwd()
#dirimg_2d = op.join(cwd,"..","data")
#FOV = 0.2 #field of view parameter in m (ie real FOV = 20 x20 cm^2)
#pixelSize = FOV/img_size
#load data file corresponding to the target resolution
#filename = "BrainPhantom" + str(img_size) + ".png"
```

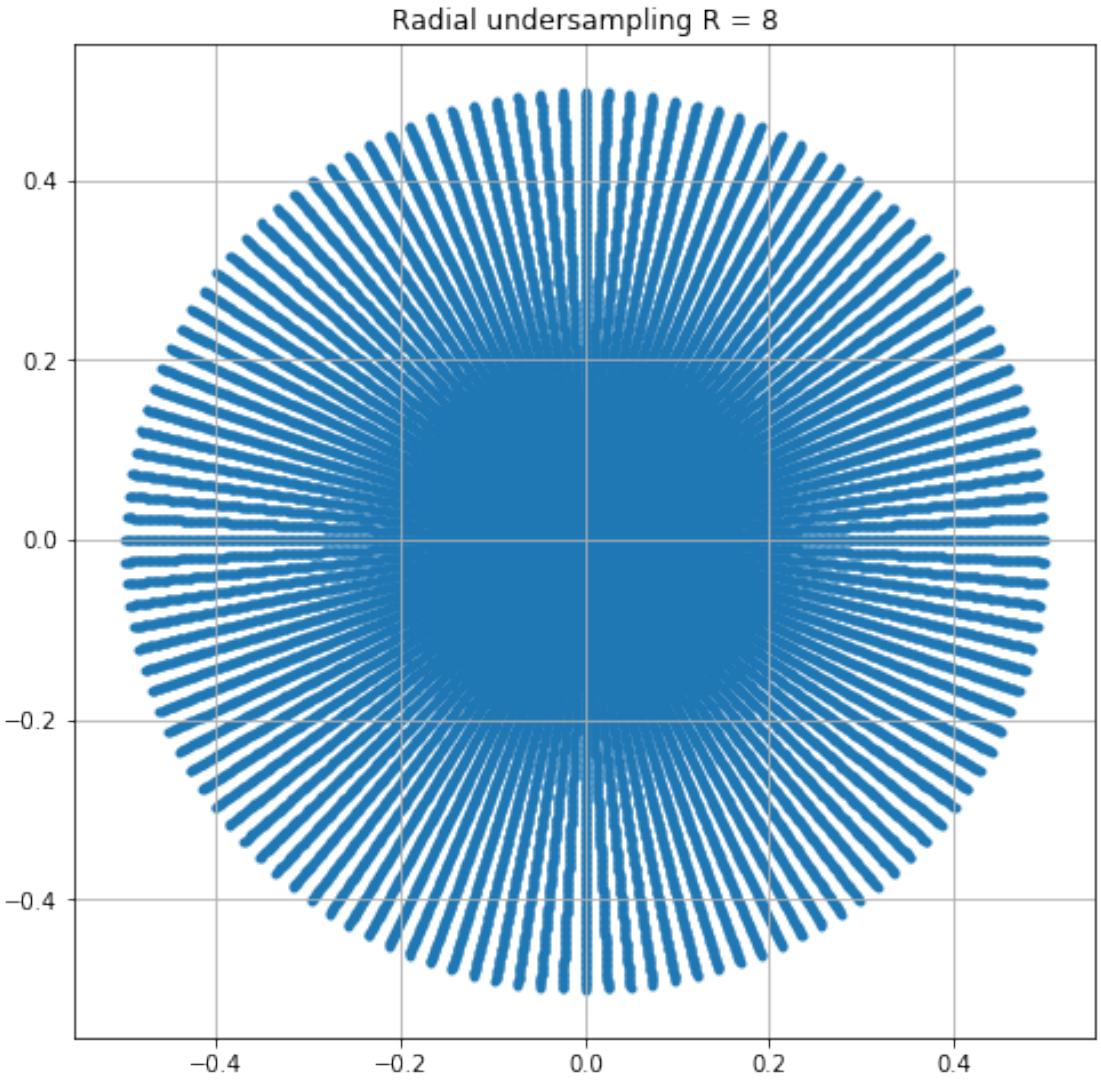
```
#mri_filename = op.join(dirimg_2d, filename)
#mri_img = io.imread(mri_filename, as_gray=True)

mri_img = get_sample_data('2d-mri')
img_size = mri_img.shape[0]

plt.figure()
plt.title("T2* axial slice, size = {}".format(img_size))
if mri_img.ndim == 2:
    plt.imshow(mri_img, cmap=plt.cm.gray)
else:
    plt.imshow(mri_img)
plt.show()
```

```
/home/ciuciu/anaconda3/lib/python3.7/site-
packages/mri/operators/fourier/cartesian.py:33: UserWarning: pynufft python
package has not been found. If needed use the master release. Till then you
cannot use NUFFT on GPU
  warnings.warn("pynufft python package has not been found. If needed use "
/home/ciuciu/anaconda3/lib/python3.7/site-
packages/mri/operators/fourier/non_cartesian.py:42: UserWarning: gpuNUFFT python
package has not been found. If needed please check on how to install in README
  warnings.warn("gpuNUFFT python package has not been found. If needed "
```



[2]:
```
# set up the first shot
rfactor = 8
nb_shots = math.ceil(img_size/rfactor)
print("number of shots: {}".format(nb_shots))

# vectorize the nb of shots
vec_shots = np.arange(0,nb_shots)

# define the regularly spaced samples on a single shot
nsamples = (np.arange(0,img_size) - img_size//2)/(img_size)
print("number of samples per shot: {}".format(np.size(nsamples)))

shot_c = np.array(nsamples, dtype = np.complex_)
shots = np.array([], dtype = np.complex_)
# acculumate shots after rotating the initial one by the right angular␣
 ↪increment
for k in vec_shots:
    shots = np.append(shots, shot_c * np.exp(2 * np.pi * 1j * k/(2*nb_shots)))

kspace_loc = np.zeros((len(shots),2))
#assign real and imaginary parts of complex-valued k-space trajectories to␣
 ↪k-space locations
kspace_loc[:,0] = shots.real
kspace_loc[:,1] = shots.imag
#Plot full initialization
kspace = plt.figure(figsize = (8,8))
#plot shots
plt.scatter(kspace_loc[:,0],kspace_loc[:,1], marker = '.')
plt.title("Radial undersampling R = %d" %rfactor)

axes = plt.gca()
plt.grid()
```

```
number of shots: 64
number of samples per shot: 512
```



[3]:
```
data=convert_locations_to_mask(kspace_loc, mri_img.shape)
fourier_op = NonCartesianFFT(samples=kspace_loc, shape=mri_img.shape,
                             implementation='cpu')
kspace_obs = fourier_op.op(mri_img.data)
```

```
/home/ciuciu/anaconda3/lib/python3.7/site-
packages/mri/operators/fourier/utils.py:76: FutureWarning: Using a non-tuple
sequence for multidimensional indexing is deprecated; use `arr[tuple(seq)]`
instead of `arr[seq]`. In the future this will be interpreted as an array index,
`arr[np.array(seq)]`, which will result either in an error or a different
result.
  mask[test] = 1
```

[4]:
```
grid_space = np.linspace(-0.5, 0.5, num=mri_img.shape[0])
grid2D = np.meshgrid(grid_space, grid_space)
grid_soln = gridded_inverse_fourier_transform_nd(kspace_loc, kspace_obs,
                                                 tuple(grid2D), 'linear')
plt.imshow(np.abs(grid_soln), cmap='gray')
# Calculate SSIM
base_ssim = ssim(grid_soln, mri_img)
plt.title('Gridded Solution\nSSIM = ' + str(base_ssim))
plt.show()
```