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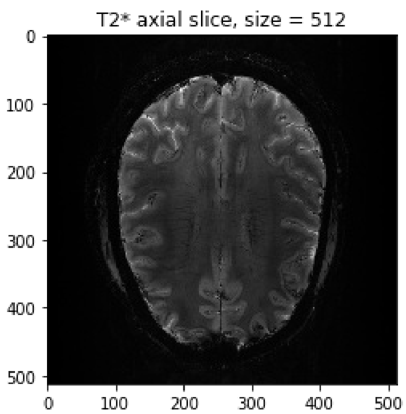
- Target: ISBI'19 tutorial on **Recent advances in acquisition and reconstruction for Compressed Sensing MRI**
- **Revision**: 01/06/2021 for ATSI MSc hands-on session at Paris-Saclay University.

In [23]:

```
#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()
```



In [30]:

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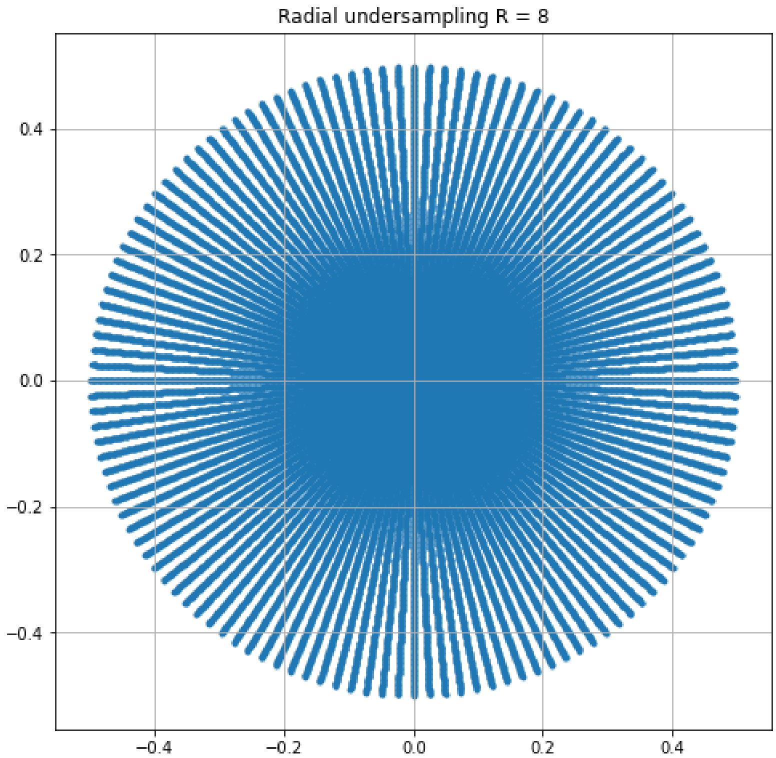
```python
# set up the first shot
rfactor = 8
nb_shots = math.ceil(img_size/rfactor)
print("number of shots: {}".format(nb_shots))

# 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
```



In [29]:

```python
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)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-29-b3cf02563ff2> in <module>
```

```
      1 data=convert_locations_to_mask(kspace_loc, mri_img.shape)
      2 fourier_op = NonCartesianFFT(samples=kspace_loc, shape=mri_img.shape,
----> 3                              implementation='cpu')
      4 kspace_obs = fourier_op.op(mri_img.data)

~/work/code/git/pysap-mri/mri/operators/fourier/non_cartesian.py in __init__(self, samples, shape,
implementation, n_coils, **kwargs)
    550         if implementation == 'cpu':
    551             self.implementation = NFFT(samples=samples, shape=shape,
--> 552                                        n_coils=self.n_coils)
    553         elif implementation == 'cuda' or implementation == 'opencl':
    554             self.implementation = NUFFT(samples=samples, shape=shape,

~/work/code/git/pysap-mri/mri/operators/fourier/non_cartesian.py in __init__(self, samples, shape,
n_coils)
    105         # TODO Parallelize this if possible
    106         self.nb_coils = n_coils
--> 107         self.plan = pynfft.NFFT(N=shape, M=len(samples))
    108         self.plan.x = self.samples
    109         self.plan.precompute()

NameError: name 'pynfft' is not defined
```

In [17]:

```
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()
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-17-e6c474cb4bbd> in <module>
      1 grid_space = np.linspace(-0.5, 0.5, num=mri_img.shape[0])
      2 grid2D = np.meshgrid(grid_space, grid_space)
----> 3 grid_soln = gridded_inverse_fourier_transform_nd(kspace_loc, kspace_obs,
      4                                                  tuple(grid2D), 'linear')
      5 plt.imshow(np.abs(grid_soln), cmap='gray')

NameError: name 'kspace_obs' is not defined
```