

EE 610 Image Processing Project 2

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Implementing the 'A' matrix

The plots the initial image estimates (the data) and the final image estimates (the output after carrying out the TV constraint and so on) are as follows:

Initial image estimate using 8 spokes

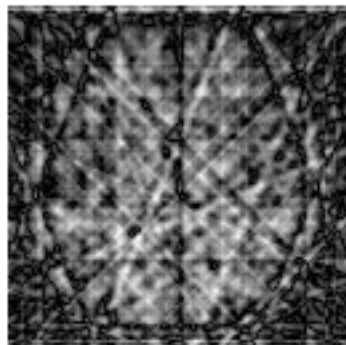
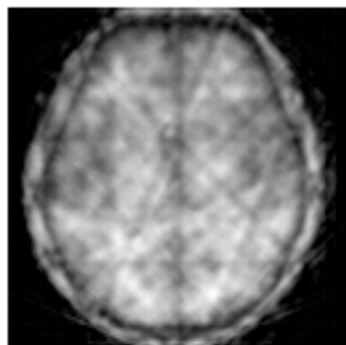


Image estimate using 8 spokes



Initial image estimate using 16 spokes

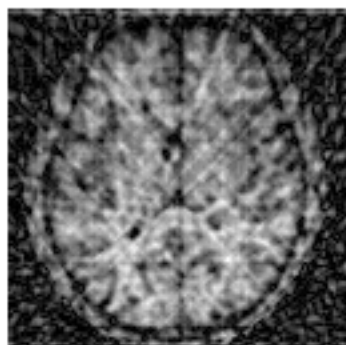
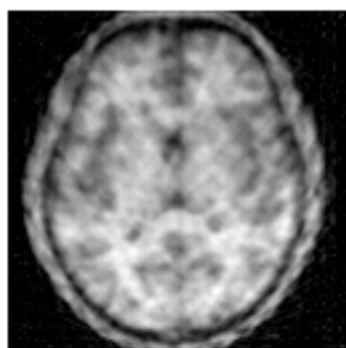


Image estimate using 16 spokes



Initial image estimate using 32 spokes

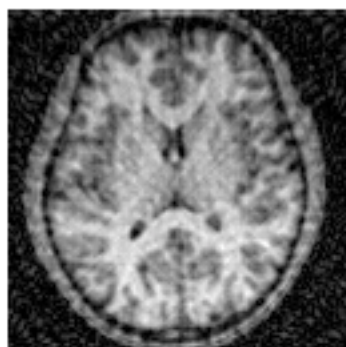
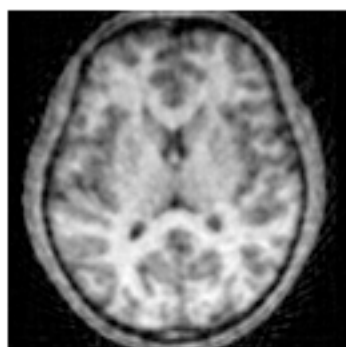


Image estimate using 32 spokes



Initial image estimate using 64 spokes

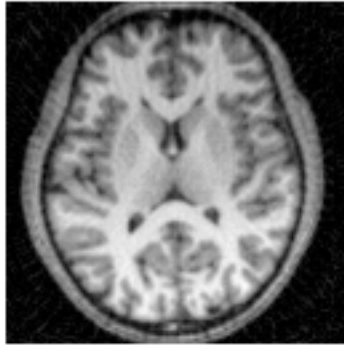
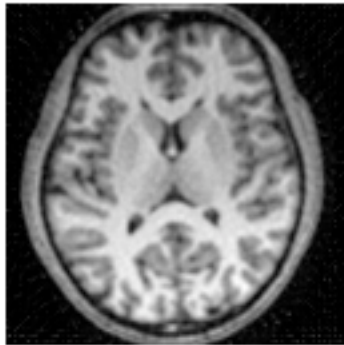


Image estimate using 64 spokes



The functions:

```
function [x, repetitionCounter] = fnlCg(x0,numberOfSpokes,data,  
param)  
%-----  
-----  
%-----  
-----  
% the nonlinear conjugate gradient method  
disp('running fnlcg');  
  
x = x0;
```

```

% line search parameters - Dont touch..leave alone
maxlsiter = 150;
gradToll = 1.0000e-030;
alpha = 0.0100;
beta = 0.6000;
t0 = 1;
Itlim = 16;

%%%%%%%%%%
repetitionCounter = 0;
previousObjective = 0;
%%%%%%%%%%

k = 0;

% compute g0 = grad(Phi(x))
g0 = wGradient(x,numberOfSpokes,data, param);

dx = -g0;

% iterations
while(1)

% backtracking line-search

    % pre-calculate values, such that it would be cheap to
    compute the objective
    % many times for efficient line-search
    f0 = objective(x,dx, 0, numberOfSpokes,data, param);
    t = t0;

    [f1] = objective(x,dx, t,numberOfSpokes,data, param);

    lsiter = 0;

    while (f1 > f0 - alpha*t*abs(g0(:)'*dx(:)))^2 &
(lsiter<maxlsiter)
        lsiter = lsiter + 1;
        t = t * beta;
        [f1] = objective(x,dx, t,numberOfSpokes,data, param);
    end

    if lsiter == maxlsiter
        disp('Reached max line search,.... not so good... might
have a bug in operators. exiting... ');

```

```

        return;
    end

    % control the number of line searches by adapting the
    initial step search
    if lsiter > 2
        t0 = t0 * beta;
    end

    if lsiter < 1
        t0 = t0 / beta;
    end

    x = (x + t*dx);

    %----- uncomment for debug purposes
    -----
    disp(sprintf('%d    , obj: %f ', k, f1));

    %-----

    %conjugate gradient calculation- Dont touch

    g1 = wGradient(x, numberOfSpokes, data, param);
    bk = g1(:)'*g1(:)/(g0(:)'*g0(:)+eps);
    g0 = g1;
    dx = - g1 + bk* dx;
    k = k + 1;

    %TODO: need to "think" of a "better" stopping criteria ;- )

    if f1 == previousObjective
        repetitionCounter = repetitionCounter + 1;
    else
        repetitionCounter = 0;
    end
    previousObjective = f1;

    if (k > Itnlim) | (norm(dx(:)) < gradToll)
        break;
    end
    if repetitionCounter > 7
        break;
    end
end
end

```

```
repetitionCounter  
return;
```

```
end
```

```
%% the objective function
```

```
function [res] = objective(x,dx,t,numberOfSpokes,data, param)  
%DEFINE obj  
x = x + (t * dx);  
b = data;  
Ax = getDataMatrix(x, numberOfSpokes);  
obj = (Ax - b);  
res= (obj(:)'*obj(:)) + (param.TVWeight * getTotalVariation(x))  
+ ...  
    (param.FOVWeight * fov(x)) + (param.POSWeight *  
getPosResidual(x)) + ...  
    (param.LaplacianWeight * getLaplacianResidual(x));
```

```
end
```

```
%% the grad function
```

```
function grad = wGradient(x,numberOfSpokes,data, param)  
  
%Define this function  
gradObj=gOBJ(x,numberOfSpokes,data);  
grad = (gradObj) + (param.TVWeight * gradTotalVariation(x))  
+ ...  
    (param.FOVWeight * gradFOV(x)) + (param.POSWeight *  
getPosGradient(x)) ...  
    + (param.LaplacianWeight * getLaplacianGradient(x));
```

```
end
```

```
%% calculating the gradient of the Objective
```

```
function gradObj = gOBJ(x,numberOfSpokes,data)  
  
% computes the gradient of the data consistency  
b = data;  
inputSize = size(x, 1);
```

```

Ax = getDataMatrix(x, numberOfSpokes);
AhAx = getImageMatrix(Ax, numberOfSpokes, inputSize);
Ahb = getImageMatrix(b, numberOfSpokes, inputSize);
gradObj = 2 * (AhAx - Ahb);

end

%% the function implementing system matrix A

function dataMatrix = getDataMatrix(imageMatrix, numberOfSpokes)

theta = 0:numberOfSpokes-1;
theta = theta .* (180/numberOfSpokes);
dataMatrix = radon(imageMatrix, theta);
dataMatrix = fft(dataMatrix, [], 1); % column fft of the matrix

end

%% function implementing the adjoint system matrix A*

function imageMatrix = getImageMatrix(dataMatrix,
numberOfSpokes, inputSize)

theta = 0:numberOfSpokes-1;
theta = theta .* (180/numberOfSpokes);
imageMatrix = ifft(dataMatrix, [], 1);
imageMatrix = iradon(imageMatrix, theta, 'linear', 'Ram-Lak', 1,
inputSize);

end

%% the total variation penalty function

function totalVariation = getTotalVariation(imageMatrix)

variationX = filter2([1 -1 0], imageMatrix);
variationY = filter2([1; -1; 0], imageMatrix);
mag = sqrt( (abs(variationX) .^ 2) + abs((variationY) .^ 2));
totalVariation = sum(mag(:));

end

%% gradient of the total variation

```



```

function gradTV = gradTotalVariation(imageMatrix)

gradTV=filter2([0 -1 1],filter2([1 -1 0], imageMatrix))
+filter2([0;-1;1],filter2([1; -1; 0], imageMatrix));

end

%% the FOV Mask function

function fovMask = fovMask(inputMatrix)

[rows, cols] = size(inputMatrix);
xRadius = ceil(rows/2);
yRadius = ceil(cols/2);
[X, Y] = meshgrid(-(xRadius):(rows-(xRadius+1)), -yRadius:(cols-
(yRadius + 1)));
a = 4;
b = 5;
term1 = (X./a).^2;
term2 = (Y./b).^2;
radius = sqrt(term1 + term2);
normalizer = sqrt((xRadius/a)^2 + (0/b)^2);
normalizedRadius = radius/normalizer;
mask = normalizedRadius < 0.93;

inputMatrix(mask) = 0;
fovMask = inputMatrix;

end

%% the FOV penalty function

function fov = fov(x)

x = fovMask(x);
mag = abs(x) .^ 2;
fov = sum(mag(:));

end

%% the gradient of the FOV function

function gradFOV = gradFOV(x)

```

```

x = fovMask(x);
gradFOV = 2 .* x;

end

%% the POS function

function posResidual = getPosResidual(x)

mask = x < 0;
posMatrix = (x .* mask) .^ 2;
posResidual = sum(posMatrix(:));

end

%% gradient of the POS function

function posGradient = getPosGradient(x)

mask = x < 0;
posGradient = 2 * (x .* mask);

end

%% the laplacian function

function laplacianResidual = getLaplacianResidual(imageMatrix)

laplacianX = filter2([1 -2 1], imageMatrix);
laplacianY = filter2([1; -2; 1], imageMatrix);
mag = sqrt( (abs(laplacianX) .^ 2) + abs((laplacianY) .^ 2));
laplacianResidual = sum(mag(:));

end

%% the gradient of the laplacian

function laplacianGradient = getLaplacianGradient(imageMatrix)

laplacianGradient = filter2([0 -1 1],filter2([1 -2 1],
imageMatrix))+filter2([0;-1;1],filter2([1; -2; 1],
imageMatrix));

end

```

The script:

```
close all; clear all;

addpath /Users/swrangsarbasumatary/Desktop/
imageProcessingProject2/

load sim_8ch_data

disp('data loaded');

inputImage = anatomy_orig;

numberOfSpokes = 8;

% generating the data vector

theta = 0:numberOfSpokes-1;
theta = theta .* (180/numberOfSpokes);
dataMatrix = radon(inputImage, theta);
dataMatrix = fft(dataMatrix, [], 1);
imageMatrix = ifft(dataMatrix, [], 1);
imageMatrix = iradon(imageMatrix, theta, 'linear', 'Ram-Lak', 1,
size(inputImage, 1));

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Reconstruction Parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

param.TVWeight = 0.0001;    % Weight for TV penalty
param.FOVWeight = 1;
param.POSWeight = 5;
param.LaplacianWeight = 0.23;

res = imageMatrix; %Initial degraded image supplied to fnlcn
function
figure(300), imshow(abs(res), []);
title(['Initial image estimate using ', num2str(numberOfSpokes),
' spokes']);

% do iterations
```

```

tic
for n=1:5
    [res, repetitionCounter] =
fnlCg(res,numberOfSpokes,dataMatrix, param); %initialize fnlCg
    im_res = res;
    figure(100), imshow(abs(im_res),[]), drawnow;
    title(['Image estimate using ', num2str(numberOfSpokes), '
spokes']);

    if repetitionCounter > 7
        break;
    end;
end
toc

rmpath /Users/swrangsarbasumatary/Desktop/
imageProcessingProject2/

```