EECE 8395

Project 7

LevelSets

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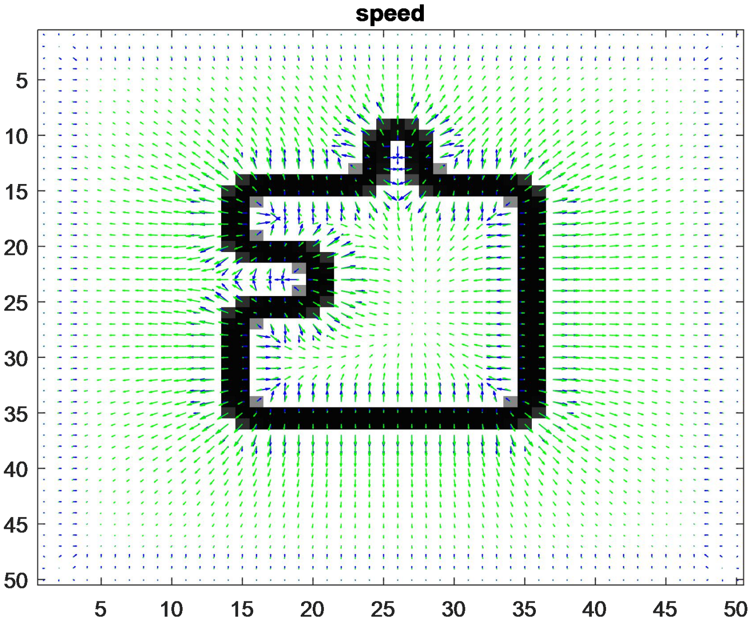
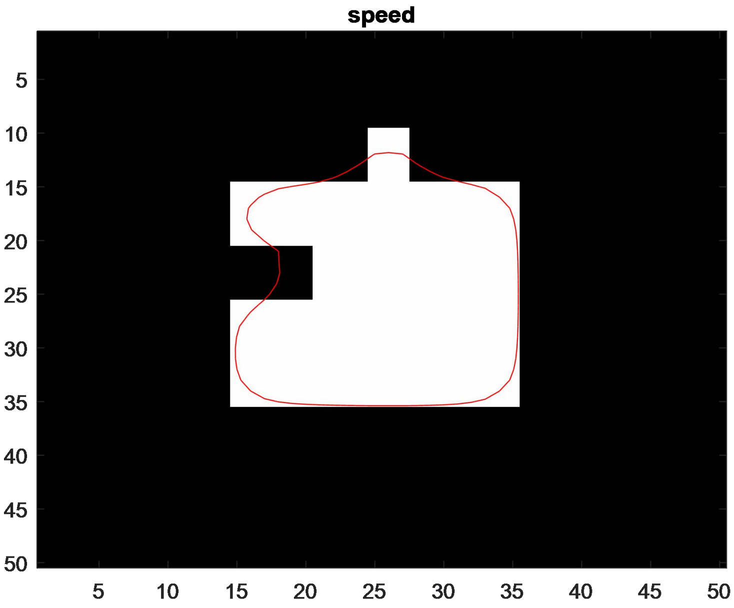
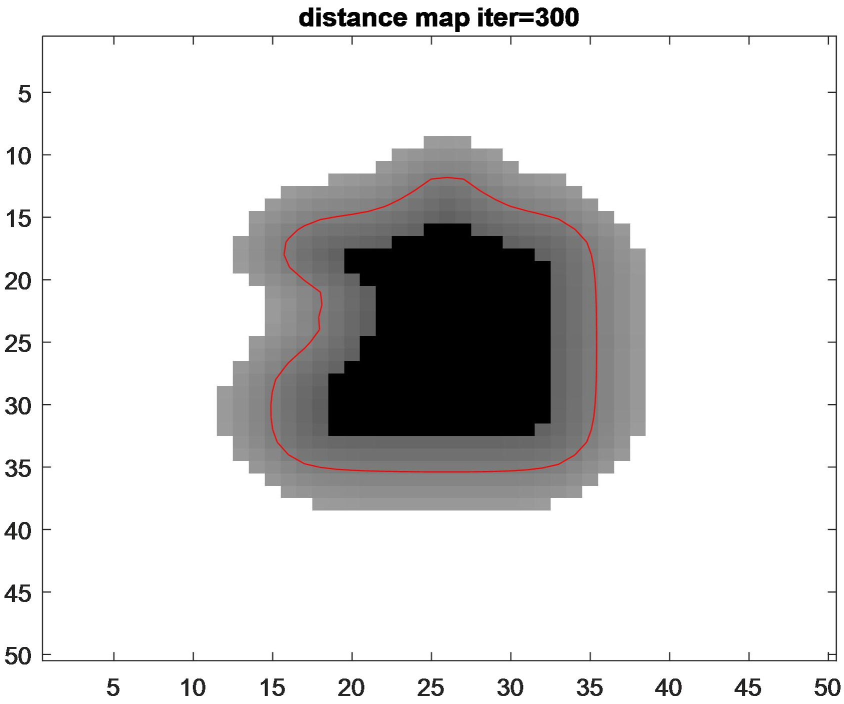
Levelset-GVF on small test image:

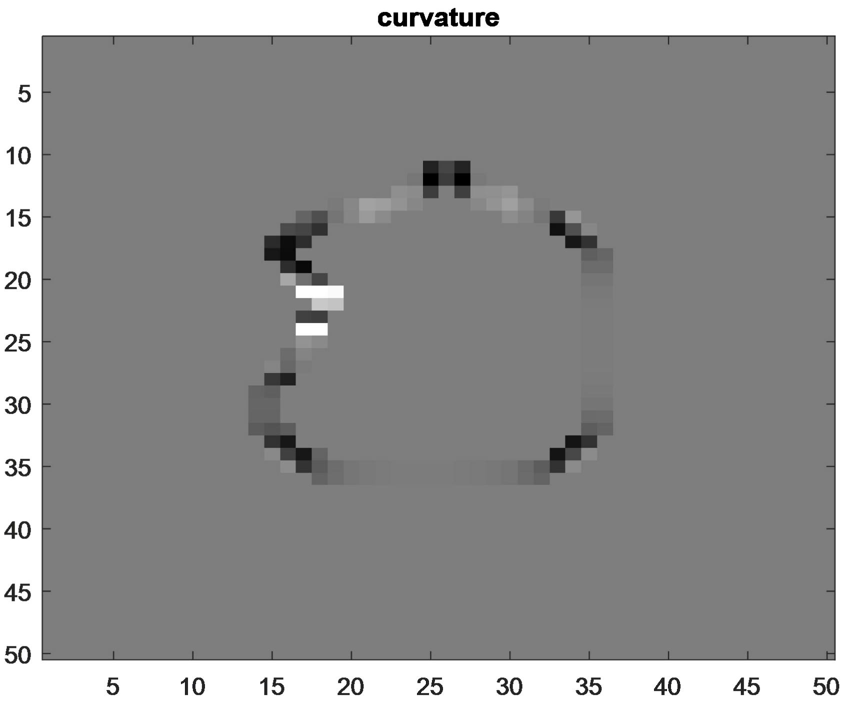
The GVF field



Result after 300 iterations.

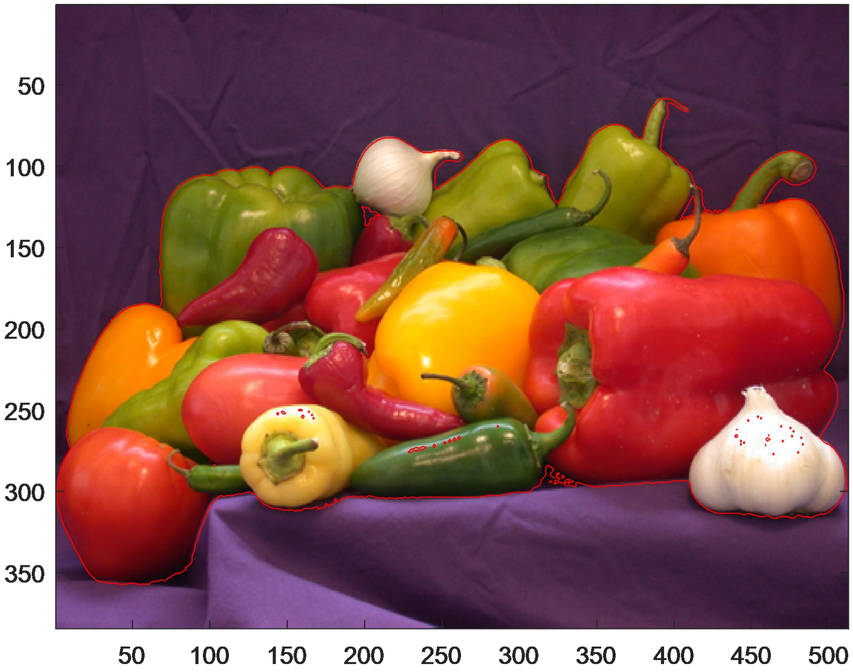



distance map iter=300

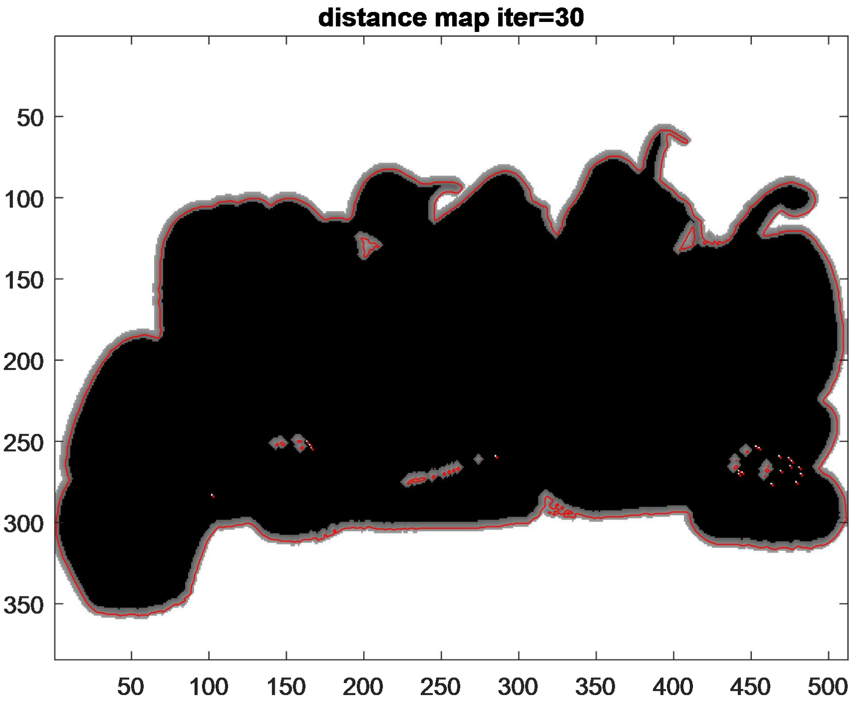

curvature

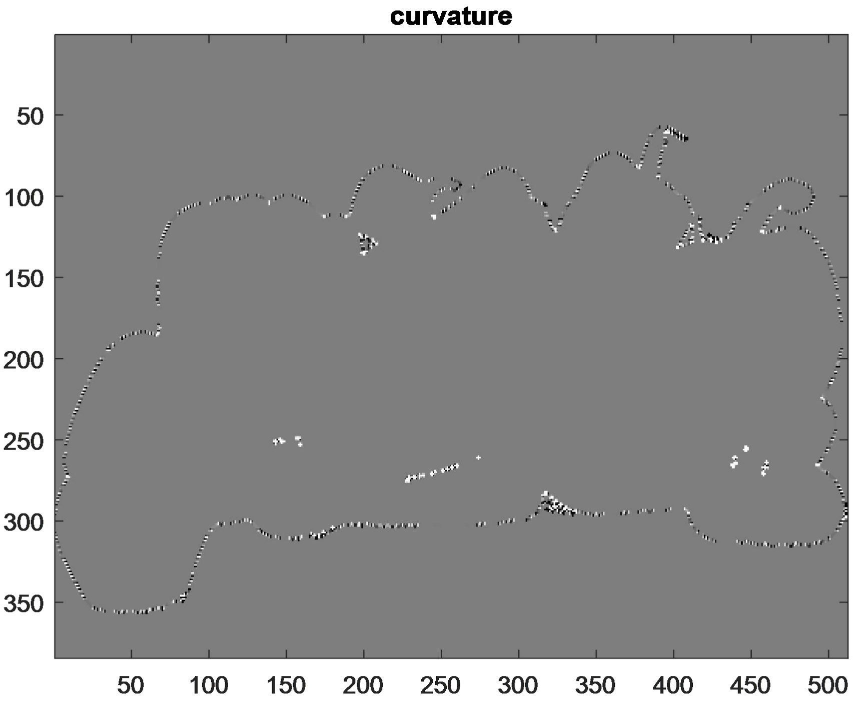
The error decreases but gets stuck at a high value of 1.4.

LevelSet Applied on Pepper image:



There are small one pixel contours that won’t go away.


distance map iter=30


curvature

Code

FastMarch

```
function [dmapout,nbin,nbout]=FastMarch(img,maxdist,getnb,nbi)
global dmap Active dmapi heap
[r,c]=size(img);
d=1;
heap = HeapInit2(10000);
dmapi=img;
dmap = 3e8*ones(r,c,d);
dmap(dmapi(:)==0)=0;
Active = ones(r,c);
if nargin<4 || isempty(nbi)
    nbi.q = [1:r*c; dmap(:)'];
    nbi.len = length(nbi.q);
end
InsertBorderVoxelsIntoHeap(dmapi,1,nbi)
if getnb
    nb.q = zeros(2,r*c*d);
    nb.len=0;
end
[node,dist]=HeapPop2;
while ~isempty(node) && dist<maxdist
    if getnb
        nb.len = nb.len+1;
        nb.q(:,nb.len) = [node;dist];
    end
    Active(node)=0;
    ProcessNeighborsEikonal(node,dmapi,1)
    [node,dist] = HeapPop2();
    while (~isempty(node))&&Active(node)==0
        [node,dist] = HeapPop2();
    end
end

% That gives us our foreground distance map. Now we do it again for background.
dmapin = dmap;
dmap = 3e8*ones(r,c,d);
dmap(dmapi(:)==0)=0;
Active = ones(r,c,d);

% background
InsertBorderVoxelsIntoHeap(dmapi,-1,nbi);
if getnb
    nbin = nb;
    nb.len=0;
end
[node,dist] = HeapPop2();

while ~isempty(node) && dist<maxdist
    if getnb
        nb.len = nb.len+1;
        nb.q(:,nb.len) = [node;dist];
    end
    Active(node)=0;
    ProcessNeighborsEikonal(node,dmapi,-1);

    [node,dist] = HeapPop2();
    while (~isempty(node))&&Active(node)==0
        [node,dist] = HeapPop2();
    end
end
%Then we combine the two results into our output distance map:
```

```
dmapout = dmap;
dmapout(dmapi(:)<0) = -dmapin(dmapi(:)<0);
if getnb
    nbout = nb;
end
% mean(abs(dmapout(:)-img(:)));
% max(abs(dmapout(:)-img(:)));

function InsertBorderVoxelsIntoHeap(dmapi,mode,nbi)
global dmap Active Edges
if nargin<3 || isempty(nbi)
    nbi=struct;
    nbi.len=length(Active(:));
    nbi.q=1:length(Active(:));
end
if mode==1
    nodes =find(dmapi(:)<0); %foreground pixels
end
if mode==-1
    nodes = find(dmapi(:)>0); %background pixels
end
if ~isempty(nbi)
    nodes=intersect(nodes,nbi.q(1,1:nbi.len));
end
for i_nodes=1:length(nodes)
    node=nodes(i_nodes);
    node_dist=dmapi(node);
    neibs=Edges(node,:);
    for i_neibs=1:length(neibs)
        if neibs(i_neibs)
            neib_dist=dmapi(neibs(i_neibs));
            if neib_dist*node_dist<0
```

```
%% get valid neighbours of the opposite class
if neibs(1) && sign(dmapi(neibs(1)))==mode
    R=neibs(1);
else
    R=0;
end
if neibs(2) && sign(dmapi(neibs(2)))==mode
    L=neibs(2);
else
    L=0;
end
if neibs(3) && sign(dmapi(neibs(3)))==mode
    D=neibs(3);
else
    D=0;
end
if  neibs(4) && sign(dmapi(neibs(4)))==mode
    U=neibs(4);
else
    U=0;
end
%% calculate distance from neighbours
%% LR
if L==0 && R
    x=abs(node_dist)/(abs(dmapi(R))+abs(node_dist));
end
if R==0 && L
    x=abs(node_dist)/(abs(dmapi(L))+abs(node_dist));
end
if R==0 && L==0
    x=Inf;
end
```

```
                if L&&R
                    x=min([abs(node_dist)/(abs(dmapi(L))+abs(node_dist)) ...
                        abs(node_dist)/(abs(dmapi(R))+abs(node_dist))]);
                end
                %% DU
                if D&&U
                    y=min([abs(node_dist)/(abs(dmapi(D))+abs(node_dist))...
                        abs(node_dist)/(abs(dmapi(U))+abs(node_dist))]);
                end
                if D==0 && U
                    y=abs(node_dist)/(abs(dmapi(U))+abs(node_dist));
                end
                if U==0 && D
                    y=abs(node_dist)/(abs(dmapi(D))+abs(node_dist));
                end
                if D==0 && U==0
                    y=Inf;
                end

                dist=sqrt((1/x^2+1/y^2)^-1);
                dmap(node)=dist;
                HeapInsert2(node,dist);
                Active(node)=2;
            end
        end
    end
end
```

```
function ProcessNeighborsEikonal(node,dmapi,mode)
global Edges Active dmap
neibs=Edges(node,:);
neibs=neibs(neibs~=0); % take nonzero neighbors
if mode==1
    neibs=neibs(dmapi(neibs)<0); %foreground
end
if mode==-1
    neibs=neibs(dmapi(neibs)>0); %background
end
for i=1:length(neibs)
    if Active(neibs(i))==1
        dist=dist_calc(neibs(i));

        if dmap(neibs(i))>dist
            dmap(neibs(i))=dist;
            HeapInsert2(neibs(i),dist)
        end
    end
end



function dist=dist_calc(node)
global dmap Edges

neibs=Edges(node,:);

if neibs(3)==0
    U_ud=dmap(neibs(4));
end
if neibs(4)==0
    U_ud=dmap(neibs(3));
```

```
end

if neibs(3) && neibs(4)
    U_ud=min(dmap(neibs(3)),dmap(neibs(4)));
end

if neibs(1)==0
    U_lr=dmap(neibs(2));
end
if neibs(2)==0
    U_lr=dmap(neibs(1));
end
if neibs(1) && neibs(2)
    U_lr=min(dmap(neibs(1)),dmap(neibs(2)));
end

Us=[U_ud,U_lr];
Us=sort(Us);
dist=Us(1)+1;
if dist > Us(2)
    dist = (Us(1) + Us(2) + sqrt(2-(Us(1)-Us(2))^2))/2;
End
```

LevelSet

```
function res = LevelSetGVF(img,res, sigma, errthrsh, maxiter, mu, gamma)
global Edges
mindist=2.1;
[r,c]=size(img);
d=1;
img = .5 - img;
```

```
g = fspecial('gaussian',[5,5],sigma);
imgblur = conv2(img,g,'same');

[Y,X]  = meshgrid(1:c,1:r);
Y = Y(:);
X = X(:);
Edges =[Y<c,Y>1,X<r,X>1].*(repmat([1:r*c]',[1,4]) +repmat([r,-r,1,-
1],[r*c,1]));

grad = Gradient(imgblur,1:r*c*d);
ngrad = reshape(sum(grad.*grad),[r,c]);
speed = exp(-ngrad/(.08));
figure(1); clf; colormap(gray(256));
image(speed*1000);
hold on;
title('speed');

gradspeed = Gradient(speed,1:r*c);
quiver(reshape(gradspeed(1,:),[r,c]),reshape(gradspeed(2,:),[r,c]),'b')

gradspeed = GVF(gradspeed,mu,[r,c]);
hold on
quiver(reshape(gradspeed(1,:),[r,c]),reshape(gradspeed(2,:),[r,c]),'g')

iter = 0;
nb = [];

while iter<maxiter
    iter = iter+1;
    figure(2);clf; colormap(gray(256))
    hold off
    image(speed*1000);
    hold on;
    contour(res,[0,0],'r');
    title('speed');
    drawnow;

    [res,nbin,nbout] = FastMarch(res,mindist,1,nb);

    if iter>1
        err = sum(abs(-res(nbinold.q(1,1:nbinold.len))-
nbinold.q(2,1:nbinold.len)))+...
            sum(abs(res(nboutold.q(1,1:nboutold.len))-
nboutold.q(2,1:nboutold.len)))
        if err<errthrsh
            break;
        end
    end
    nboutold = nbout;
    nbinold = nbin;


    figure(3);clf; colormap(gray(256))
    hold off;
    image(res*10+127);
    hold on;
    contour(res,[0,0],'r');
    title(['distance map iter=',num2str(iter)])
    drawnow;

    nb.q = [nbin.q(:,1:nbin.len),nbout.q(:,1:nbout.len)];
    nb.len = size(nb.q,2);

    nbspeed.q = nb.q(:,nb.q(2,1:nb.len)<=1);
    nbspeed.len = size(nbspeed.q,2);

    [kappa,ngrad,grad] = Curvature2(res,nbspeed);
    node = nbspeed.q(1,1:nbspeed.len);
    speedc=-speed(node).*(max(ngrad,0.001)).*(kappa+gamma) +
sum(grad.*gradspeed(:,node));
    dt = 0.5/max(abs(speedc(:)));
    res(node) = res(node) + dt*speedc;

    figure(4); clf; colormap(gray(256))
    curvature = zeros(size(res));
    curvature(node)=kappa;
    image(curvature*500+127);
    title('curvature');
    drawnow;
end

[res,~,~] = FastMarch(res,mindist,1,nb);

function ngradspeed = GVF(gradspeed, mu,dims)

r=dims(1);
c=dims(2);
slc = r*c;
[Y,X]  = meshgrid(1:c,1:r);
Y = Y(:);
X = X(:);
gs_mag_squared=sum(gradspeed.*gradspeed);
node = [1:slc]';
rws = [reshape(repmat(node',[5,1]),[5*slc,1])];
cols = rws + [repmat([0;-1;1;-r;r],[slc,1])];
% rws defines the row indices, cols defines the column indices.
```

```
s = repmat([0;-.25*mu;-.25*mu;-.25*mu;-.25*mu],[slc,1]);
first_col= upsample(mu+(1-mu)*gs_mag_squared,5)';
s=s+first_col;
I = zeros(slc*5,1);
N = find(X(:)==1);
I((N-1)*5+2)=1;
I((N-1)*5+4)=1;
I((N-1)*5+5)=1;

N = find(X(:)==r);
I((N-1)*5+3)=1;
I((N-1)*5+4)=1;
I((N-1)*5+5)=1;

N = find(Y(:)==1);
I((N-1)*5+2)=1;
I((N-1)*5+3)=1;
I((N-1)*5+4)=1;

N = find(Y(:)==c);
I((N-1)*5+2)=1;
I((N-1)*5+3)=1;
I((N-1)*5+5)=1;

rws = rws(~I(:));
cols = cols(~I(:));
s = s(~I(:));

% Now we construct sparse matrix A and solve A*x=bx and A*y=by
A = sparse(rws,cols,s,slc,slc);
x = A\bx;
y = A\by;
```

```
ngradspeed=[x y]';


function [kappa,ngrad,grad]=Curvature2(img,nb)
nodes=nb.q(1,1:nb.len);
kappa=[];
grad=[];
ngrad=[];
for i_nodes = 1: length(nodes)
    node=nodes(i_nodes);
    grad_node=0.5*Gradient(img,node);
    ngrad_node=sqrt(sum(grad_node.*grad_node));
    hess=Hessian(img,node);
    kappa_node=(grad_node' * hess * grad_node - ngrad_node^2 *
trace(hess))/(2*ngrad_node^3);
    kappa=[kappa kappa_node];
    grad=[grad grad_node];
    ngrad=[ngrad ngrad_node];
end



function grad=Gradient(img, nodes)
global Edges

grad=[];
for i_nodes=1:length(nodes)
    node=nodes(i_nodes);
    neibs=Edges(node,:);
    %% calculate gradient in x direction
    if neibs(1)&& neibs(2)
        grad_x=img(neibs(1))-img(neibs(2));
    end
    if neibs(1)==0
```

```
        grad_x=img(node)-img(neibs(2));
    end
    if neibs(2)==0
        grad_x=img(neibs(1))-img(node);
    end
    %% calculate gradient in y direction
    if neibs(3)&& neibs(4)
        grad_y=img(neibs(3))-img(neibs(4));
    end
    if neibs(3)==0
        grad_y=img(node)-img(neibs(4));
    end
    if neibs(4)==0
        grad_y=img(neibs(3))-img(node);
    end

    grad=[grad [grad_x grad_y]'];
end
    function hess=Hessian(img,node)
global Edges
[r,c]=size(img);
neibs=Edges(node,:);
L=neibs(1);
R=neibs(2);
D=neibs(3);
U=neibs(4);
%% calculate dderiv_x,dderiv_y, dderiv_xy
if L&&R
    dderiv_x=img(R)-2*img(node)+img(L);
end
if L==0
    dderiv_x=img(R)-2*img(node)+img(node);
```

```
end


if R==0
    dderiv_x=img(node)-2*img(node)+img(L);
end


if D&&U
    dderiv_y=img(D)-2*img(node)+img(U);
end
if D==0
    dderiv_y=img(node)-2*img(node)+img(U);
end
if U==0
    dderiv_y=img(D)-2*img(node)+img(node);
end
RU=R-1;
if RU<0
    RU=node;
end
LU=L-1;
if LU<0
    LU=node;
end
RD=R+1;
if RD>r*c
    RD=node;
end
LD=L+1;
if LD>r*c
    LD=node;
end
```

```
dderiv_xy=1/4*(RD-RU-LD+LU);

hess=[dderiv_x dderiv_xy;dderiv_xy dderiv_y];

function heap=HeapInit2(initlen)
if nargin<1
    initlen=1000;
end
heap=struct;
heap.q=[-1*ones(1,initlen); 3e8*ones(1,initlen)];
heap.len=0;

function HeapInsert2(node,dist)
global heap;
% if the tree root is at index 1,
% with valid indices 1 through n,
% then each element a at index i has
% children at indices 2i and 2i +1
% its parent at index floor(i ? 2).
for i_node=1:length(node)
    heap.len=heap.len+1;
    heap.q(:,heap.len)=[node(i_node),dist(i_node)]';
    curr_ind=heap.len;
    parent_ind=floor(heap.len/2);
    while parent_ind>0
        if heap.q(2,parent_ind)< heap.q(2,curr_ind)
            break
        else
            temp=heap.q(:,parent_ind);
            heap.q(:,parent_ind)=heap.q(:,curr_ind);
            heap.q(:,curr_ind)=temp;
            curr_ind=parent_ind;
            parent_ind=floor(curr_ind/2);
        end

    end
end

function [root_node, root_value]=HeapPop2()
global heap

if heap.len==0
    root_node=[];
    root_value=[];
    return
end
root_node=heap.q(1,1);
root_value=heap.q(2,1);
last_element=heap.q(:,heap.len);
heap.len=heap.len-1;
if heap.len==0
    return
end

heap.q(:,1)=last_element;
curr_ind=1;
while 2*curr_ind<=heap.len
    if 2*curr_ind+1<=heap.len % element has two childs
        if heap.q(2,curr_ind)< heap.q(2,2*curr_ind) && heap.q(2,curr_ind)<
heap.q(2,2*curr_ind+1)
            break
        else
            % get the minimum of childs
            ind_childs=[2*curr_ind,2*curr_ind+1];
            [~,ind_min]=min(heap.q(2,ind_childs));
            temp=heap.q(:,ind_childs(ind_min));
            heap.q(:,ind_childs(ind_min))=heap.q(:,curr_ind);
            heap.q(:,curr_ind)=temp;
            curr_ind=ind_childs(ind_min);
        end
    else
        if heap.q(2,curr_ind)< heap.q(2,2*curr_ind+1)
            break
        else
            temp=heap.q(:,2*curr_ind+1);
            heap.q(:,2*curr_ind+1)=heap.q(:,curr_ind);
            heap.q(:,curr_ind)=temp;
            curr_ind=2*curr_ind+1;

        end
    end
end
```