

Part e)

i)

```
I_branches=I_skel;  
I_branches(I_code>2)=0;  
I_branches=bwlabel(I_branches);  
disp(['Number of branches is equal to ' num2str(max(max(I_branches)))])
```

Number of branches is equal to 497

```
figure  
subplot(1,2,1)  
imagesc(I_branches)  
axis equal tight off  
subplot(1,2,2)  
imshow(I_branches)
```



ii)

as it can be seen in the resulting branches image, some of actual bifurcations are removed. Hence result of this part is not used as input for next part.

```
Limit=3;  
pI_code=zeros(size(I_code)+2);  
pI_branches=zeros(size(I_code)+2);  
[m,n]=size(pI_code);  
pI_code(2:end-1,2:end-1)=I_code;  
pI_branches(2:end-1,2:end-1)=I_branches;  
index=find(pI_code>Limit);  
index=[index-m;index-m-1;index-m+1;index-1;index+1;index+m;index+m-1;index+m+1];  
index(index<1)=1;  
index(index>m*n)=m*n;  
rseg=unique(I_branches(index));  
I_branches3= repmat(I_branches,1,1,numel(rseg))- repmat(reshape(rseg,1,1,[ ]),size(I_code));  
I_branches3(I_branches3~=0)=1;  
I_branches3=prod(I_branches3,3);
```

```

I_skel3=I_skel.*I_branches3+double(I_code>2);
I_branches3=bwlabel(I_branches3);
disp(['Number of remaining branches is equal to ' num2str(max(max(I_branches3)))])

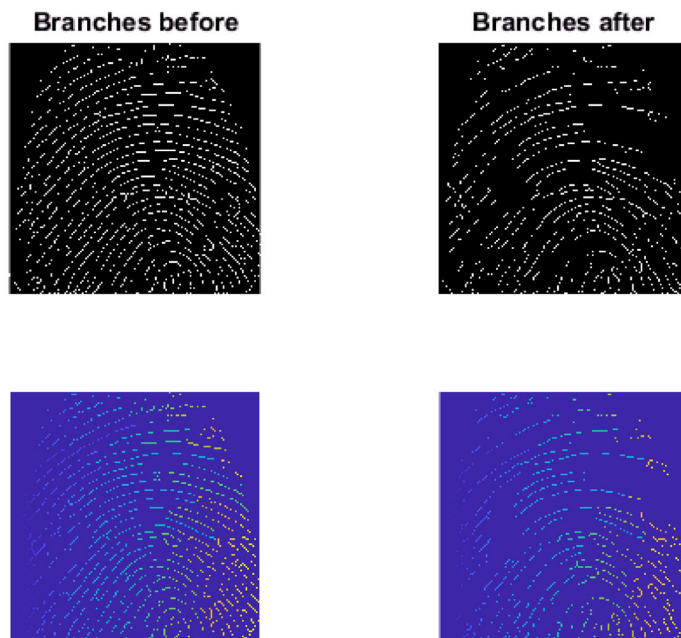
```

Number of remaining branches is equal to 438

```

figure,
subplot(2,2,1)
imshow(I_branches)
title('Branches before')
subplot(2,2,3)
imagesc(I_branches)
axis equal tight off
subplot(2,2,2)
imshow(I_branches3)
title('Branches after')
subplot(2,2,4)
imagesc(I_branches3)
axis equal tight off

```



```

I_code3=code_branches(I_skel3);

```

iii)

```

Unq=unique(I_branches);
Unq(1)=[];
Rep_branches= repmat(I_branches,1,1,numel(Unq));
Rep_values= repmat(reshape(Unq,1,1,[ ]),size(I_branches));
I_branches3a=double(Rep_branches==Rep_values);
Modfr=sum(sum(I_branches3a));
Modfr(Modfr<4)=0;
Modfr(Modfr~=0)=1;
Modfr= repmat(Modfr,size(I_branches));
I_branches3a=sum((I_branches3a.*Modfr),3);
I_skel3a=I_branches3a+double(I_code>2);
I_code3a=code_branches(I_skel3a);
I_branches3a=bwlabel(I_branches3a);

```

```
disp(['Number of remaining branches is equal to ' num2str(max(max(I_branches3a))))]
```

Number of remaining branches is equal to 263

```
figure
subplot(1,2,1)
imagesc(I_branches3a)
axis equal tight off
subplot(1,2,2)
imshow(I_branches3a)
```



iv and v)

Since in farina1999.pdf bridge and spur removal is done in one section, part "iv" and "v" are done together.

```
% setting lambda by visual inspection
lambda=11;
[m,n]=size(I_code3a);
[r,c]=find((I_code3a==3)+(I_code3a==4));
rmin1=r-3; rmax1=r+3; cmin1=c-3; cmax1=c+3;
rmin2=r-lambda-3; rmax2=r+lambda+3; cmin2=c-lambda-3; cmax2=c+lambda+3;

rmin1(rmin1<1)=1; cmin1(cmin1<1)=1;
rmin2(rmin2<1)=1; cmin2(cmin2<1)=1;
rmax1(rmax1>m)=m; cmax1(cmax1>n)=n;
rmax2(rmax2>m)=m; cmax2(cmax2>n)=n;

I_branches3b=I_branches3a;

for i=1: numel(r)
    %selection window is defined to select branches corresponding to minutia
    select_window=zeros(size(I_code3a));
    select_window(rmin1(i):rmax1(i),cmin1(i):cmax1(i))=1;
    select_branch=select_window.*I_branches3a;
    Unq=unique(select_branch);
    Unq(Unq==0)=[ ];
    if numel(Unq)==3
        % analysis window is defined to analyze branches in vicinity of minutia
        analysis_window=zeros(size(I_code3a));
```

```

analysis_window(rmin2(i):rmax2(i),cmin2(i):cmax2(i))=1;
analysis_branch=analysis_window.*I_branches3a;
Npix(1)=sum(sum(I_branches3a==Unq(1)));
Npix(2)=sum(sum(I_branches3a==Unq(2)));
Npix(3)=sum(sum(I_branches3a==Unq(3)));
sNpix=sort(Npix);
[x,y]=find(analysis_branch==Unq(1));
p1=polyfit(x,y,1);
u1=[p1(2)/p1(1),p1(2)]/sqrt(p1(2)^2/p1(1)^2+p1(2)^2);
[x,y]=find(analysis_branch==Unq(2));
p2=polyfit(x,y,1);
u2=[p2(2)/p2(1),p2(2)]/sqrt(p2(2)^2/p2(1)^2+p2(2)^2);
[x,y]=find(analysis_branch==Unq(3));
p3=polyfit(x,y,1);
u3=[p3(2)/p3(1),p3(2)]/sqrt(p3(2)^2/p3(1)^2+p3(2)^2);
% theta "i" is the dot product of branches "j" and "k"
theta(1)=dot(u2,u3);
theta(2)=dot(u1,u3);
theta(3)=dot(u1,u2);
theta=abs(theta);
thetac=theta;
thetac(theta==max(theta))=[];
index=find(theta==max(theta));
%(1)
if sNpix(1)>=lambda
    %(1_b) bridge length is assumed to be lambda*5/6
    if (max(theta)>0.85) && ((thetac(1)<=0.55) || (thetac(2)<=0.55))
        if numel(I_branches3b==Unq(index))<=round(5*lambda/6)
            I_branches3b(I_branches3b==Unq(index))=0;
        end
    end
    %(1_d) spur length is assumed to be lambda*3/2
    if (max(theta)>0.85) && ((thetac(1)>0.55 && thetac(1)<0.85) || (thetac(2)>0.55 && thetac(2)<0.85))
        if numel(I_branches3b==Unq(index))<=round(3*lambda/2)
            I_branches3b(I_branches3b==Unq(index))=0;
        end
    end
end
%(2)
if (sNpix(1)<lambda)
    if (max(theta)>0.8) && (thetac(1)<0.8) && (thetac(2)<0.8)
        I_branches3b(I_branches3b==Unq(index))=0;
    end
end
end
I_skel3b=double((I_branches3b~=0)+(I_code3a>2));
I_code3b=code_branches(I_skel3b);
figure
subplot(1,2,1)
imagesc(I_branches3b)
axis equal tight off
subplot(1,2,2)
imshow(I_branches3b)

```

