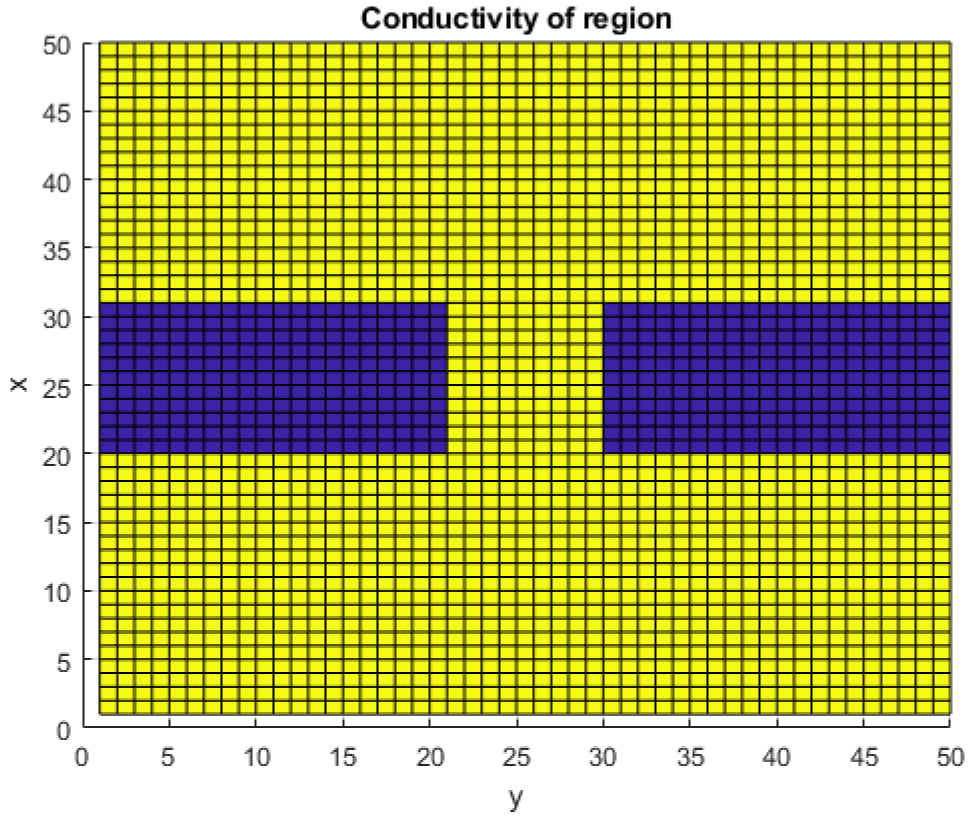
Assignment 2 Part 2 - Andrew Paul 100996250

The final section of this assignment also involeved using the finite difference method but to model the current flow of a rectangular region with limiting boxes. The boxes were given some conductivity value and the effect of the "bottle-neck" effect on the current was investigated.

```
clear

nx = 50;
ny = 50;

% Create sparse G matrix
G = sparse(nx*ny,nx*ny);

% Conductivity outside box
sigma1 = 1;
% Conductivity inside box
sigma2 = 10^-2;

% Generate F matrix to set boundary conditions
F = zeros(nx*ny,1);

% Change for difference in bottle neck width
Lb = 0.4;
Wb = 0.6;

% Create matrix for mapping the conductivity and loop through to
 assign
% conductivity values for the given conditions
condMap = zeros(nx,ny);

for i = 1:nx
    for j = 1:ny
        if (i>=Lb*nx && i<=Wb*nx && j<=Lb*ny) || (i>=Lb*nx && i<=Wb*nx
 && j>=Wb*ny)
            condMap(i,j) = sigma2;
        else
            condMap(i,j) = sigma1;
        end
    end
end

% Loop through to set boundary conditions

for i = 1:nx
    for j = 1:ny
        n = j + (i-1)*ny;

        if i == 1
            G(n,:) = 0;
            G(n,n) = 1;
            F(n) = 1;
```

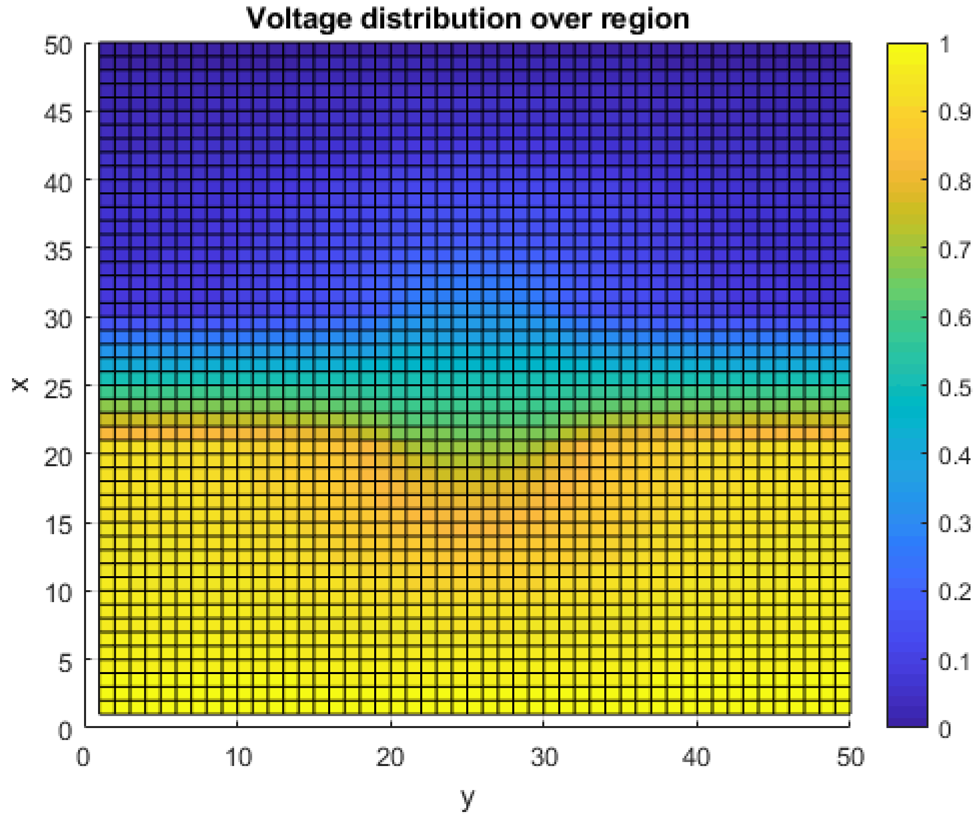
```
    elseif i == nx
        G(n,:) = 0;
        G(n,n) = 1;

    elseif j == 1
        nxm = j+(i-2)*ny;
        nxp = j+(i)*ny;
        nyp = j+1+(i-1)*ny;

        rxm = (condMap(i,j) + condMap(i-1,j))/2;
        rxp = (condMap(i,j) + condMap(i+1,j))/2;
        ryp = (condMap(i,j) + condMap(i,j+1))/2;

        G(n,n) = -(rxm+rxp+ryp);
        G(n,nxm) = rxm;
        G(n,nxp) = rxp;
        G(n,nyp) = ryp;

    elseif j == ny
        nxm = j+(i-2)*ny;
        nxp = j+(i)*ny;
        nym = j-1+(i-1)*ny;

        rxm = (condMap(i,j) + condMap(i-1,j))/2;
        rxp = (condMap(i,j) + condMap(i+1,j))/2;
        rym = (condMap(i,j) + condMap(i,j-1))/2;

        G(n,n) = -(rxm+rxp+rym);
        G(n,nxm) = rxm;
        G(n,nxp) = rxp;
        G(n,nym) = rym;

    else
        nxm = j+(i-2)*ny;
        nxp = j+(i)*ny;
        nym = j-1+(i-1)*ny;
        nyp = j+1+(i-1)*ny;

        rxm = (condMap(i,j) + condMap(i-1,j))/2;
        rxp = (condMap(i,j) + condMap(i+1,j))/2;
        rym = (condMap(i,j) + condMap(i,j-1))/2;
        ryp = (condMap(i,j) + condMap(i,j+1))/2;

        G(n,n) = -(rxm+rxp+ryp+rym);
        G(n,nxm) = rxm;
        G(n,nxp) = rxp;
        G(n,nym) = rym;
        G(n,nyp) = ryp;

    end

end
```

```
end

% Find voltage values using matrix operations
V = G\F;

% Create matrix to map voltage and loop through matrix to assign
 values
% from calculated voltage matrix
VMap = zeros(nx,ny);

for i = 1:nx
    for j = 1:ny
        n = j + (i-1)*ny;

        VMap(i,j) = V(n);
    end
end

% Plots

% Conductivity plot
figure(1)
surf(condMap)
title('Conductivity of region')
xlabel('y')
ylabel('x')
zlabel('Conductivity (ohm meters)')
view(0,90)
```



The plot above shows the the conductivity has one constant value inside the boxes and a constant value outisde of the boxes which is expected as these were the conditions set to the system.

```
% Voltage plot
figure(2)
surf(VMap)
title('Voltage distribution over region')
xlabel('y')
ylabel('x')
colorbar
view(0,90)
```



The voltage plot shown above gives the expected distribution as one side of the region has a voltage of V0 where the other side is set to zero. The barrier in the middle blocks uniform distribution to the other side of the region which is expected. As the conductivity inside the boxes is less than the conductivity outside the barrier boxes.

```
% Gradient used to plot electric field lines
[Ex,Ey] = gradient(VMap);

% Electric field plot
figure(3)
quiver(Ex,Ey)
title ('Electric Field Lines')
xlabel('x')
ylabel('y')
xlim([0 50])
ylim([0 50])
```

The plot above shows that the electric field lines are strongest between the areas which have a lower conductivity. This is execpted as it is similar to the model of a parallel plate capcitor which has two plates of a larger conductivity seperated by a region with a lower conductivity creating a stronger electric field between the two higher conductivity regions.

```
% Calculation of current density
jx = condMap.*Ex;
jy = condMap.*Ey;

% Current density plot
```

```
figure(4)
quiver(jx, jy)
title('Current Density Inenstiy Lines')
xlim([0 50])
ylim([0 50])
```

The current density plot shows the largest current density is between the boxes which is expected as there is the same amount of current being squeezed through a smaller region.

```
% Calculation of current flow
Ex = -Ex;
Ey = -Ey;

xflow = condMap.*Ex;
yflow = condMap.*Ey;

x0sum = sum(xflow(:,1));
xsum = sum(xflow(:,nx));
y0sum = sum(yflow(:,1));
ysum = sum(yflow(:,nx));

xCurrent = (x0sum + xsum)/2;
yCurrent = (y0sum + ysum)/2;
% output the current for each condition
totCurrent = sqrt(xCurrent^2 + yCurrent^2)

meshMultiple = [1 2 3 4 5];
% mesh current was cacluclated using different mesh multiples
meshCurrent = [0.1628 0.1719 0.175 0.1765 0.1775];

figure(5)
plot(meshMultiple, meshCurrent)
title('Current vs Mesh Densities')
xlabel('Mesh density')
ylabel('Current (A)')
```

The plot above shows how the current saturates as the mesh becomes finer with a multiplier, this is expected as a finer mesh grid will allow for a more accurate solution of how the current is responding which will ultimaltly converge to be one finite value.

```
width = [0.4 0.2 0.16 0.12 0.08 0.04];
% different current values were calculated using different bottle-neck
% widths
widthCurrent = [0.255 0.1628 0.1442 0.1344 0.101 0.0707];

figure(6)
plot(width, widthCurrent, '-o')
title('Current vs Bottle-neck Width')
xlabel('Bottle-neck Width')
ylabel('Current (A)')
```

The figure above displays what happens to the current as the bottle neck becomes smaller, as expected the current gets smaller as the bottle neck becomes smaller as it is restricting the amount of current which can flow through the region. More points could be added to show a better trend which would begin to satruate.

```
cond = [0.2 0.5 1 2 3];
% different current values were calculated using different
 conductivities
condCurrent = [0.0576 0.0985 0.1628 0.2897 0.4162];

figure(7)
plot(cond, condCurrent, '-o')
title('Current vs Conductivity')
xlabel('Conductivity (ohm meter)')
ylabel('Current (A)')
```

Finally, the figure above shows that the conductivity is inversely proportional to the current and thus the current decreases when the conductivity increases and increases when the conductivity decreases. This is expected

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