Observation + motion model

```
% Define the colors
colors = {'green', 'red', 'white', 'blue'};

% Perception probability =  [correct incorrect]
p_O_given_C = [0.999 0.001*(1/3)];

% The probability of each adjacent cell was the previous cell of the
% current cell
p_prev_cell = 1/4;
```

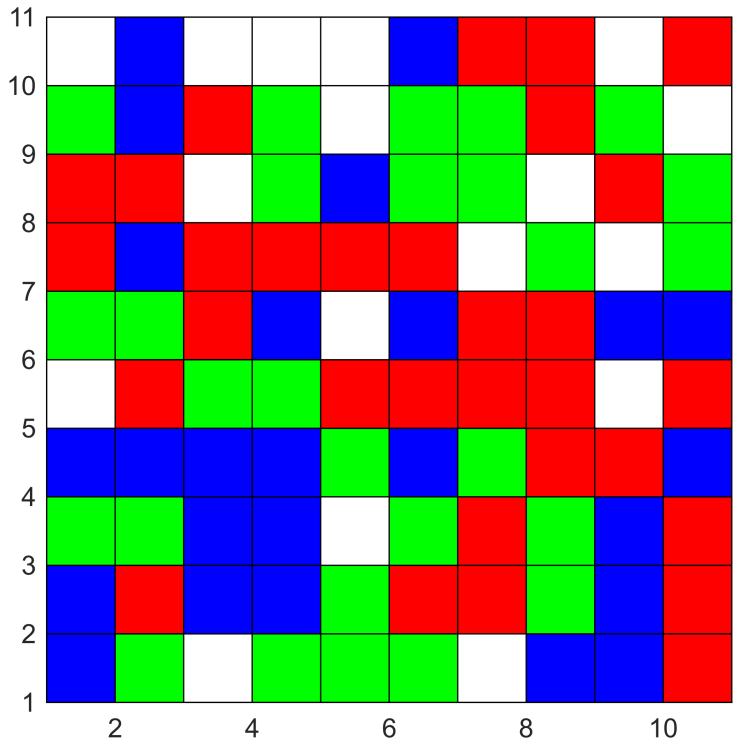
Making the map

```
% Define the size of the map
length = 10;
width = 10;

% Initialize the map with probabilities
map = ones(width, length) * 1/(length*width);
cells = cell(width, length);

% Plot each grid with its color
for i = 1:width
    for j = 1:length
        color_index = randi([1,4]); % Generate a random index between 1 and 4
        rectangle('Position', [j, i, 1, 1], 'FaceColor', colors{color_index}, 'EdgeColor', 'k')
        cells{i,j} = colors{color_index};
    end
end

% So the stored data match the figure
%cells = flipud(cells)
cells = rot90(cells, 3);
axis([1, length+1, 1, width+1]);
axis square;
```




```
% We generate ten real color sequence called O_n from the map, representing
% the observations we make as the vehicle moves. This is to verify the
% algorithm, and stay unknown to us in real life.
O_n = {cells{4,5}, cells{5,5}, cells{5,6}, cells{5,7}, cells{6,7}, cells{6,8}, cells{7,8}, cel
```

Simulating the model

```
format long
% Assume the initial observation is blue
O = 'blue';
step = 0;
% Init normalized factor
eta = 0;

% Before any movement, calculate the map probability.
for i = 1:width
    for j = 1:length
        if strcmp(cells{j,i}, O)
            map(i,j) = p_O_given_C(1).*map(i,j);
        else
            map(i,j) = p_O_given_C(2).*map(i,j);
        end
        eta = eta + map(i,j);
    end
end
```

```
disp(['Current cell color: ', O]);
```

```
Current cell color: blue
```

```
disp(['Current step: ', num2str(step)]);
```

```
Current step: 0
```

```
% Normalize
map = map./eta
```

```
map = 10×10
   0.000013333333333   0.039960000000000   0.000013333333333   0.000013333333333 ···
   0.000013333333333   0.039960000000000   0.000013333333333   0.000013333333333
   0.000013333333333   0.000013333333333   0.000013333333333   0.000013333333333
   0.000013333333333   0.039960000000000   0.000013333333333   0.000013333333333
   0.000013333333333   0.000013333333333   0.000013333333333   0.039960000000000
   0.000013333333333   0.000013333333333   0.000013333333333   0.000013333333333
   0.039960000000000   0.039960000000000   0.039960000000000   0.039960000000000
   0.000013333333333   0.000013333333333   0.039960000000000   0.039960000000000
   0.039960000000000   0.000013333333333   0.039960000000000   0.039960000000000
   0.039960000000000   0.000013333333333   0.000013333333333   0.000013333333333
```

```
% Once the moving starts, iterate until a cell has probability >= 0.9999
%O_n = ['r', 'w', 'g', 'r', 'r', 'r', 'r', 'b', 'g', 'w'];

for n = 1:size(O_n, 2)
    disp(['Current cell color: ', O_n{n}]);
    disp(['Current step: ', num2str(n)]);

    eta = 0;
    for i = 1:width
        for j = 1:length
            sum_previous_steps = 0;
            % Compare the color of the cell and observation to choose
            % proper probability for color perception
            if strcmp(cells{j,i}, O_n{n})
                map(i,j) = p_O_given_C(1);
            else
                map(i,j) = p_O_given_C(2);
            end

            % Calculate p_C for cells inside the map
            if 1 < j && j < length && 1 < i && i < width
                sum_previous_steps = map(j-1,i)+map(j+1,i) + map(j,i-1) + map(j,i+1) ;
            end

            % Calculate p_C for cells at the edges
            if 1 < j && j < length
```

```
                if i == 1
                    sum_previous_steps = map(j-1,i)+map(j+1,i) + map(j,i+1);
                elseif i == width
                    sum_previous_steps = map(j-1,i)+map(j+1,i) + map(j,i-1);
                end
            end
            if 1 < i && i < width
                if j == 1
                    sum_previous_steps = map(j,i-1) + map(j,i+1) + map(j+1,i);
                elseif j == length
                    sum_previous_steps = map(j,i-1) + map(j,i+1) + map(j-1,i);
                end
            end

            % Calculate p_C for cells in the corners
            if i == 1
                if j == 1
                    sum_previous_steps = map(j+1,i) + map(j,i+1);
                elseif j == length
                    sum_previous_steps = map(j-1,i) + map(j,i+1);
                end
            end

            if i == width
                if j == 1
                    sum_previous_steps = map(j+1,i) + map(j,i-1);
                elseif j == length
                    sum_previous_steps = map(j-1,i) + map(j,i-1);
                end
            end
            % Update the probability of the cell
            map(i,j) = map(i,j).*p_prev_cell*sum_previous_steps;
            eta = eta + map(i,j);
        end
    end


    map = map./eta
    if max(map(:)) >= 0.9999
        % Set the flag to true
        break;
    end
end
```

```
Current cell color: blue
Current step: 1
map = 10×10
   0.000031320852195   0.093876416409899   0.000000031341747   0.000031331299443 ···
   0.000031313017628   0.023516076234416   0.000033290972463   0.000000041788996
   0.000007828419890   0.000001970126363   0.000000023832923   0.000031331301430
   0.000000000008706   0.000031792006177   0.000007838053954   0.000031324116307
   0.000007830214790   0.000007830219143   0.000000007837396   0.023514099274194
```

```
   0.000000005225366   0.000007835435802   0.000007843261663   0.000000016355032
   0.023482788054036   0.000054759289050   0.000062579062685   0.000078213391554
   0.000000010442025   0.000000023488027   0.000078213391554   0.000062579062685
   0.000039109304978   0.000000015662167   0.000062576453484   0.023506252593342
   0.000015649984072   0.000000010441155   0.000000010442025   0.000000015658685
Current cell color: white
Current step: 2
map = 10×10
   0.987837032913196   0.000164886776648   0.000350113148372   0.000499144219116 ···
   0.000164888475616   0.000000151244908   0.000000139160782   0.000000061909402
   0.000000055347513   0.000000029277510   0.000412073537491   0.000000255899512
   0.000000036049833   0.000000083236645   0.000000151174358   0.000082532760897
   0.000000090076865   0.000000013778934   0.000000041660614   0.000000137476633
   0.000020694890475   0.000000055391278   0.000000013872157   0.000000109790164
   0.000000020642308   0.000000000139590   0.000000281241562   0.000000013933920
   0.000000013796621   0.000000178388115   0.000000013924743   0.000000384089210
   0.000000006921200   0.000000034420605   0.000000274376357   0.000000027581789
   0.000000027483397   0.000000000059505   0.000082470609411   0.000000109759709
Current cell color: red
Current step: 3
map = 10×10
   0.000020146328363   0.000000014299816   0.000010077206996   0.000000013969150 ···
   0.000000011758344   0.000000010292250   0.075471913882227   0.000000014068094
   0.018849117552261   0.075449060806656   0.000012601616476   0.000005050696254
   0.000002836808482   0.000006289749589   0.015114077576251   0.003823834671062
   0.000000000003386   0.000000000213890   0.049440967183878   0.000066048052222
   0.000000316176005   0.000000022279347   0.000000005780751   0.000016496403803
   0.000000003145879   0.000000317020869   0.000000000015409   0.000000643580814
   0.000000316915544   0.000000003153066   0.000001260616091   0.000000010062927
   0.000000003251155   0.003778691007029   0.000000000014598   0.000001260297579
   0.000000000420552   0.000000000110805   0.000001260293909   0.000000000008067
Current cell color: green
Current step: 4
map = 10×10
   0.000000000017525   0.000012676696346   0.000050744042464   0.000012680919501 ···
   0.000012694073908   0.000101501737128   0.000012697853004   0.182543611798533
   0.000000003171289   0.000015233129825   0.000010170469031   0.107375065158431
   0.000015216196497   0.000008952808246   0.000017785328228   0.000142126636184
   0.000011472505430   0.045593139080560   0.000017260622966   0.000000023923736
   0.000000000107592   0.000008309931938   0.000004335085337   0.024904947402629
   0.000000000004805   0.000000000693356   0.000008307161612   0.000000001344635
   0.000001269911249   0.000000017684661   0.000000001543481   0.000000000001495
   0.000000000001097   0.000000000847507   0.000000000001121   0.000000002992525
   0.000000000423639   0.000000003354719   0.000000000926620   0.000000000072262
Current cell color: blue
Current step: 5
map = 10×10
   0.000000013628451   0.000163416416783   0.000000023175399   0.000000010973597 ···
   0.000000054526893   0.000085793029263   0.000000017423600   0.000024517238886
   0.000000013620401   0.000000014657738   0.000057688366422   0.000000095234827
   0.000000004086660   0.000000037047837   0.000006202876999   0.000000018417351
   0.000000002656957   0.000006125806039   0.000000002242048   0.018342826932860
   0.000000004082820   0.000000003773156   0.000006121721715   0.000003344616504
   0.000007956223251   0.000006118214346   0.000006691443462   0.000000001261602
   0.000000000000171   0.000000000001119   0.000000000756116   0.000003347692349
   0.000000000005646   0.000000000000114   0.000000001799790   0.000004316035351
   0.000000000170835   0.000000000000001   0.000000000000479   0.000000002038495
Current cell color: green
Current step: 6
map = 10×10
   0.000050038628875   0.000026269676165   0.000000022428420   0.000000016322899 ···
   0.078717729916902   0.000006571820098   0.000017674527271   0.011327343137636
   0.000000003663377   0.000018602964801   0.000001930881820   0.000053421982799
   0.000000944103599   0.000000005927236   0.000001418110941   0.005618861453878
```

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   0.000000616306692   0.008442006209292   0.000000772320407   0.000001873007358
   0.000001404662595   0.000001887992461   0.009820125583499   0.002303603089450
   0.000001120490259   0.000002340544146   0.000001888471581   0.000023854805563
   0.000000935842595   0.003358682099768   0.000001266368061   0.000000000940881
   0.000000000341060   0.000000000266209   0.000000000773214   0.000000660505878
   0.000000000000009   0.000001293329377   0.000000330175749   0.000001136364460
Current cell color: red
Current step: 7
map = 10×10
   0.000066791243846   0.000000011143311   0.000066785541680   0.000000000530891 ···
   0.000000016705665   0.000000030773158   0.000004940517109   0.000007178355032
   0.000001236809780   0.000023388620231   0.000000048876535   0.000004766624102
   0.000020261333676   0.000000000809205   0.014289256205931   0.003579678709615
   0.000000000000532   0.000000003777253   0.009480025968742   0.000012800772927
   0.000000002879617   0.000001202961596   0.000002094240373   0.000003181871348
   0.000000711977989   0.000000003941196   0.000000000802399   0.000002130128228
   0.000000001954091   0.000000712452768   0.000000002141621   0.000000006069512
   0.000000712251529   0.000004317692596   0.000000000475342   0.000000000627882
   0.000000000000090   0.000000000511719   0.000000000548227   0.000000000000464
Current cell color: green
Current step: 8
map = 10×10
   0.000000000209154   0.000000009519951   0.000000327949900   0.000000009294899 ···
   0.000000774611724   0.000000212825786   0.000000009679708   0.322610611044496
   0.000000000002375   0.000026884629729   0.000107354702049   0.293979650855302
   0.000026884257601   0.000024504239729   0.000053786592530   0.000309624995907
   0.000017789841598   0.080610700689736   0.000042300074006   0.000000485166451
   0.000000003960733   0.000017800761374   0.001340570787052   0.053654200860293
   0.000000004932237   0.000000011885806   0.000017794830972   0.000000865015761
   0.000000016232578   0.000022794150519   0.000000012083907   0.000000000009242
   0.000000002675950   0.000000000010818   0.000000002676478   0.000000005064174
   0.000000000005406   0.000008021367174   0.000000000409864   0.000000005584890
Current cell color: green
Current step: 9
map = 10×10
   0.000000000891577   0.000000000242065   0.000000062017285   0.000000048089402 ···
   0.000000740949807   0.000000030641250   0.000000149929380   0.275060525107157
   0.000000000016522   0.000023043783054   0.000334325102044   0.001366241505728
   0.000022929356169   0.000000113879663   0.000023309392193   0.000000197385008
   0.000000051195728   0.138488306236495   0.000015377837522   0.000005828701049
   0.000023279497109   0.000015274996969   0.070911454032899   0.045776882517797
   0.000000016587976   0.000023652793316   0.000015280103603   0.000000381680264
   0.000000000025143   0.000075946101132   0.000000381309940   0.000000005150123
   0.000000008755180   0.000000000000007   0.000000011036307   0.000000001593629
   0.000000000000002   0.000033066522154   0.000000001220024   0.000006833873788
Current cell color: blue
Current step: 10
map = 10×10
   0.000000000802942   0.000000099736742   0.000000050605957   0.000000000178846 ···
   0.000000000037478   0.000075327657415   0.000000368579257   0.000150101170107
   0.000000000039041   0.000000380968520   0.000001505380342   0.000000017121649
   0.000000025018996   0.000000104711479   0.000056675365177   0.000000083485105
   0.000000004153898   0.000056706440266   0.000000008275120   0.169846257597850
   0.000000031418603   0.000000008300202   0.000056694231496   0.000012407458844
   0.000012490224472   0.000075878749782   0.000024850091454   0.000038384480075
   0.000000000006407   0.000000000034554   0.000019199031008   0.000012436126432
   0.000000059002903   0.000000000002204   0.000000066862240   0.000002969910807
   0.000000000000337   0.000000000016432   0.000000000000365   0.000000001878072
Current cell color: blue
Current step: 11
map = 10×10
   0.000000000156364   0.000353802092795   0.000000000636314   0.000000000170673 ···
   0.000000118052075   0.000091912061329   0.000000010182704   0.000000178325969
   0.000000029484371   0.000000010033454   0.000000088849024   0.000000000315311
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   0.000000000022327   0.000000002713602   0.000066545096992   0.000266262976041
   0.000000004893620   0.000066544990888   0.000000000010239   0.199635025413579
   0.000000000042051   0.000000004903351   0.000066567187507   0.000000019791016
   0.000014685616155   0.000000215449987   0.000000068131078   0.000066653162353
   0.000000000022331   0.000000000011411   0.000000144019813   0.000000053540028
   0.000000004984206   0.000000000015312   0.000000019591506   0.000003520844470
   0.000000000000005   0.000000000000033   0.000000000003283   0.000000000003846
Current cell color: blue
Current step: 12
map = 10×10
   0.000000471667225   0.000367340025557   0.000000000170729   0.000000000049432 ···
   0.000000122529965   0.000091854518267   0.000000007815862   0.000000177381752
   0.000000030612324   0.000000007787748   0.000000088685967   0.000000354858069
   0.000000000022186   0.000000090594327   0.000066867906195   0.000266058071435
   0.000000004891231   0.000066513073953   0.000000000059169   0.200469991616636
   0.000000000022221   0.000000004892877   0.000066535252450   0.000000000436212
   0.000014668805641   0.000000089028961   0.000000005043868   0.000066581055947
   0.000000000000064   0.000000000003289   0.000000069205298   0.000000000149446
   0.000000004899470   0.000000000000447   0.000000000086072   0.000003541438182
   0.000000000000019   0.000000000000005   0.000000000000798   0.000000000000015
Current cell color: white
Current step: 13
map = 10×10
   0.507206336720392   0.000084585676031   0.000179907372336   0.000174052142973 ···
   0.000084586569545   0.000000021284063   0.000000096669611   0.000061433345995
   0.000000021561207   0.000000060958579   0.092787213175033   0.000130309335107
   0.000007670749549   0.000000036924297   0.000137974389907   0.092328351890688
   0.000000026620492   0.000015362553660   0.000000023706793   0.000030934539458
   0.022944285856793   0.000000012679916   0.000015411035188   0.000000002036334
   0.000000001689906   0.000000010234348   0.000000001865711   0.000007709489991
   0.000000000009552   0.000000001734372   0.000000007953704   0.000000001329058
   0.000000000563555   0.000000000144855   0.000000000634926   0.000000003104591
   0.000000000000206   0.000000000000383   0.000000823235467   0.000000000027098
Current cell color: red
Current step: 14
map = 10×10
   0.000000155472784   0.000000000052332   0.000000084842402   0.000000000078214 ···
   0.000000000039587   0.000000000144871   0.255564431524533   0.000000148025414
   0.063827216805856   0.255564328596363   0.000042840621623   0.000084855286282
   0.000005329741932   0.000021304107248   0.254311208791580   0.063663405408944
   0.000000000000017   0.000000003546128   0.008655485322509   0.000011549745711
   0.000005269817318   0.000000000045717   0.000000016081081   0.000002880978564
   0.000000000000920   0.000005268064347   0.000000000000005   0.000000021682123
   0.000005266303028   0.000000000000917   0.000000000199335   0.000000000000483
   0.000000000001045   0.000000586806580   0.000000000000001   0.000000000194653
   0.000000000000063   0.000000000000130   0.000000000191651   0.000000000000000
Current cell color: red
Current step: 15
map = 10×10
   0.000000000000138   0.000095932677892   0.000384122681318   0.000095964697871 ···
   0.000000032010441   0.000768237493009   0.287991042774564   0.000766353910866
   0.071973689302544   0.000672174783233   0.000406414030396   0.000108761600951
   0.000287335509046   0.000024017400862   0.287160710559079   0.227526281370393
   0.000000009083830   0.000000095719527   0.023969558282793   0.000019025741805
   0.000000005935157   0.000006507196303   0.000000060876570   0.000007987703208
   0.000000000000001   0.000000010109187   0.000000001084825   0.000000053709036
   0.000000010107933   0.000000000000001   0.000000004395855   0.000000000000620
   0.000000000000002   0.000013174790083   0.000000000000000   0.000000000221891
   0.000000000000807   0.000000000000000   0.000000000220566   0.000000000000000
Current cell color: green
Current step: 16
map = 10×10
   0.000000049789859   0.000037741076669   0.000000497844328   0.000037354949648 ···
   0.001194706977775   0.000149871343736   0.000037578296121   0.448012429867466
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   0.000000009389527   0.000037557761828   0.000149051776890   0.391137803592027
   0.000037334423070   0.000032602099078   0.000155407851619   0.000082342488893
   0.000012440153185   0.111928421159819   0.000035704724248   0.000000023485345
   0.000000000034799   0.000003109713280   0.000037362871554   0.009317294359514
   0.000000000843619   0.000000000039670   0.000003108675669   0.000000000049893
   0.000000003422243   0.000002527481619   0.000000000029710   0.000000000000346
   0.000000000000000   0.000000000002280   0.000000000000000   0.000000000015722
   0.000000000001140   0.000000000000001   0.000000000001738   0.000000000000000
Current cell color: blue
Current step: 17
map = 10×10
   0.000002739695370   0.000999225934540   0.000002822281178   0.000000100148460 ···
   0.000000333623038   0.000750214590205   0.000000466349919   0.000249325501392
   0.000000083316036   0.000000414867865   0.000869833244622   0.000000407375044
   0.000000041753694   0.000000289781016   0.000062524529364   0.000000032975742
   0.000000008657429   0.000062310481119   0.000000003515897   0.186558774138768
   0.000000041482763   0.000000010384476   0.000062268976470   0.000005178367999
   0.000025881007036   0.000062182675164   0.000010378671070   0.000000041544822
   0.000000000000002   0.000000000003601   0.000000020745477   0.000005177708461
   0.000000002806917   0.000000000000001   0.000000004532347   0.000000030134476
   0.000000000001905   0.000000000000468   0.000000000000003   0.000000000000004
Current cell color: blue
Current step: 18
map = 10×10
   0.000001421417990   0.003198024753479   0.000000001123763   0.000000000542872 ···
   0.000001066956941   0.000802728787512   0.000001304366050   0.000000178170254
   0.000000266610805   0.000001303850431   0.000000089709309   0.000000000471450
   0.000000000022335   0.000000326129677   0.000066323907750   0.000265329938663
   0.000000009198629   0.000066323882912   0.000000000006221   0.198971355331478
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   0.000027590118486   0.000000154757312   0.000000033140129   0.000066509082750
   0.000000000014745   0.000000000009210   0.000000066364610   0.000000020245806
   0.000000009196387   0.000000000007377   0.000000007371265   0.000000032168901
   0.000000000000001   0.000000000000002   0.000000000000010   0.000000000000615
```