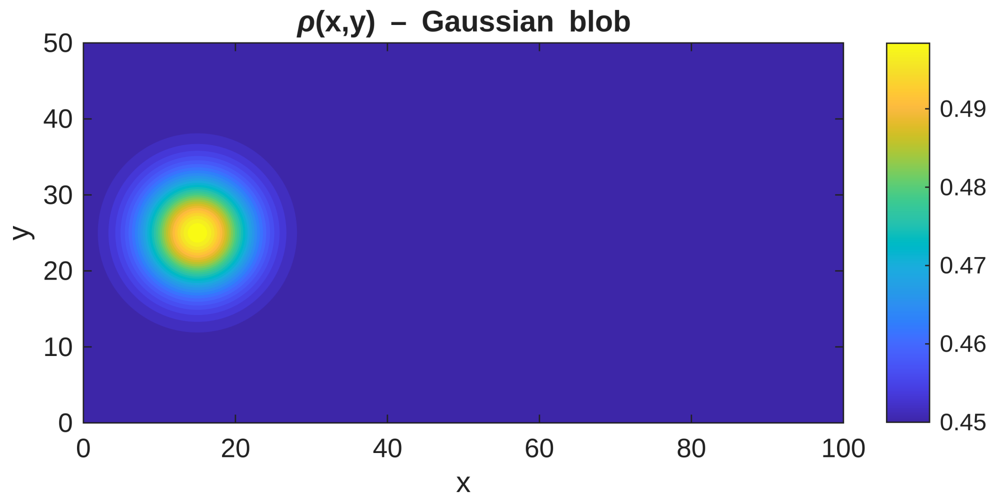
```
% Grid
global Nx Ny;
Nx = 400; Ny = 200;
Lx = 100; Ly = 50;
dx = Lx / Nx; dy = Ly / Ny;

h = 0;
if dx == dy
    h = dx;
end

x = linspace(0, Lx, Nx);
y = linspace(0, Ly, Ny);

[X, Y] = meshgrid(x, y);

INFINITE = 10^12;
eta = 10^-6;
error_eta = 10^-9;

% To track the error for each iterations
iteration_error = [];
% Center of the blob
x0 = 10;
y0 = 25;
CFL = 0.5;


% Initial Condition (Gaussian Blob)
xc = 15;
yc = 25;
sigma = 5;
rho_gauss = 0.05*exp( -((X-xc).^2 + (Y-yc).^2) / (2*sigma^2) ) + 0.45;

% Lets say there is no obstacle on the way
obstacle = false(Ny, Nx);

% obstacle(80:120,200:240) = true;
rho_gauss(obstacle) = 0;
figure(1); clf
contourf(X, Y, rho_gauss, 30, 'LineColor', 'none');
colorbar
axis equal tight
xlabel('x'); ylabel('y');
title('\rho(x,y) - Gaussian blob');
```

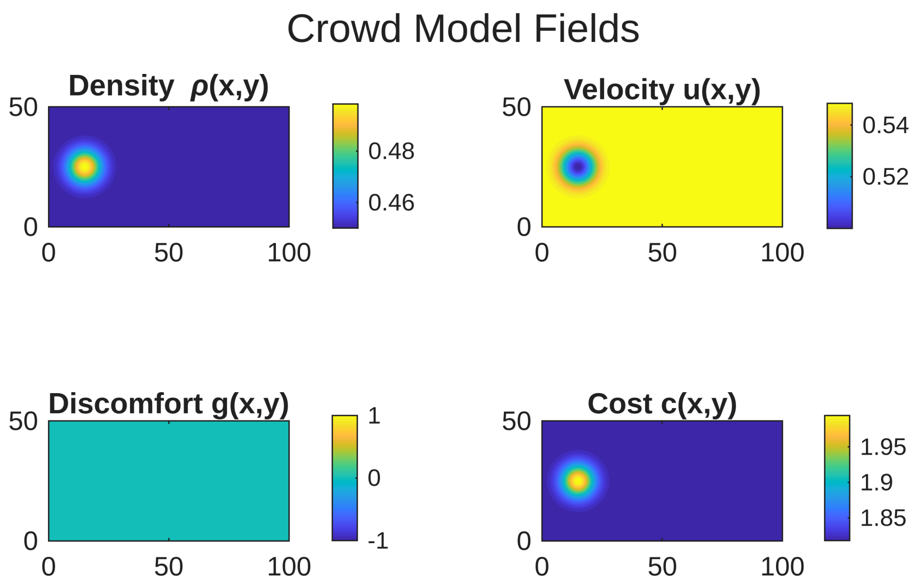



```
% Velocity
u = (1 - rho_gauss);
u = max(u, 1e-6);
% Discomfort
g = 0.00 * rho_gauss.^2;
% Cost
c = 1./u + g;
figure(1); clf;
%---------------- Density ----------------%
subplot(2,2,1);
contourf(X, Y, rho_gauss, 30, 'LineColor','none');
colorbar;
axis equal tight;
title('Density \rho(x,y)');
%---------------- Velocity ----------------%
subplot(2,2,2);
contourf(X, Y, u, 30, 'LineColor','none');
colorbar;
axis equal tight;
title('Velocity u(x,y)');
%---------------- Discomfort ----------------%
subplot(2,2,3);
contourf(X, Y, g, 30, 'LineColor','none');
```

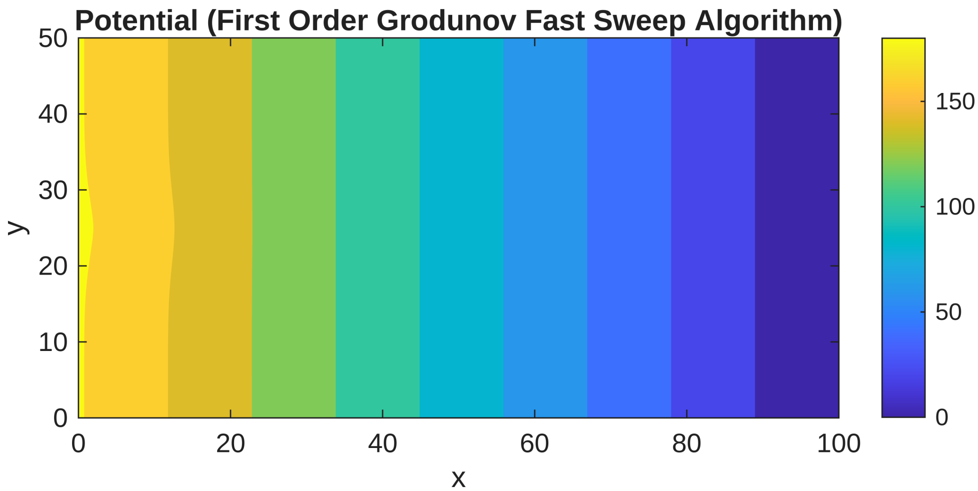
```
Warning: Contour not rendered for constant ZData
```

```
colorbar;
axis equal tight;
title('Discomfort g(x,y)');
%---------------- Cost ----------------%
```

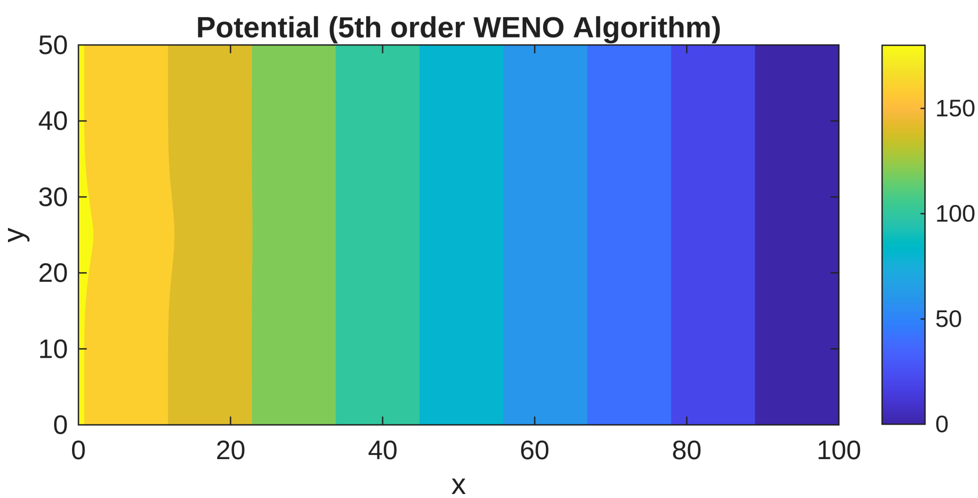
```
subplot(2,2,4);
contourf(X, Y, c, 30, 'LineColor','none');
colorbar;
axis equal tight;
title('Cost c(x,y)');
sgtitle('Crowd Model Fields');
```




```
% Returns the phi values at the current time step
phi_first_order =
First_order_Godunov_Fast_Sweep_Algorithm(c,dx,obstacle,INFINITE);
figure;
contourf(X, Y, phi_first_order, 'LineColor', 'none');
colorbar;
axis equal tight;
title('Potential (First Order Grodunov Fast Sweep Algorithm)');
xlabel('x'); ylabel('y');
```




```
phi_initial =
weno_fastsweep(c,dx,obstacle,eta,error_eta,INFINITE,phi_first_order,iteration
_error);
figure;
contourf(X, Y, phi_initial, 'LineColor', 'none');
colorbar;
axis equal tight;
title('Potential (5th order WENO Algorithm)');
xlabel('x'); ylabel('y');
```



```
function phi =
First_order_Godunov_Fast_Sweep_Algorithm(c,h,obstacle_dash,INFINITE)
    global Nx Ny;
    phi = INFINITE*ones(Ny, Nx);
    phi(:,Nx) = 0;

    for sweep = 1:200
        % === Sweep 1
        for i = 2:Nx-1
            for j = 2:Ny-1
                if ~obstacle_dash(j, i)
                    phi = update_phi(phi, c, i, j, h);
                end
            end
        end
        % === Sweep 2
        for i = Nx-1:-1:2
            for j = 2:Ny-1
                if ~obstacle_dash(j, i)
                    phi = update_phi(phi, c, i, j, h);
                end
            end
        end
        % === Sweep 3
        for i = Nx-1:-1:2
            for j = Ny-1:-1:2
                if ~obstacle_dash(j, i)
                    phi = update_phi(phi, c, i, j, h);
                end
            end
        end
        % === Sweep 4
        for i = 2:Nx-1
            for j = Ny-1:-1:2
                if ~obstacle_dash(j, i)
                    phi = update_phi(phi, c, i, j, h);
                end
            end
        end
        phi(:,Nx) = 0;
        phi(:,1) = phi(:,2);
        phi(1, :) = phi(2, :);
        phi(Ny, :) = phi(Ny-1,:);
    end
end

% Subfunction: Update one grid point using Godunov scheme
function phi = update_phi(phi, c, i, j, dx)
    a = min(phi(j, i-1), phi(j, i+1)); % x-direction neighbors
    b = min(phi(j-1, i), phi(j+1, i)); % y-direction neighbors
```

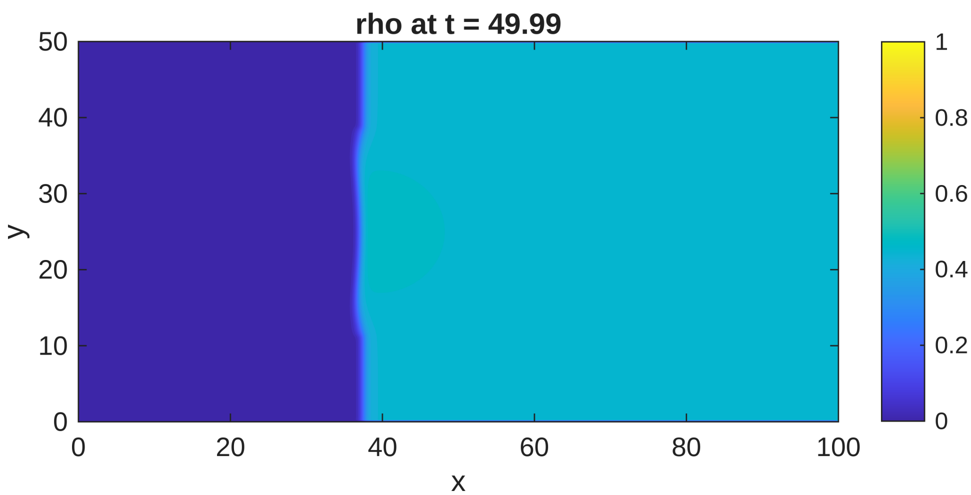
```
    c_i = c(j, i); % Local inverse speed
    if abs(a - b) >= c_i * dx
        phi(j, i) = min(a, b) + c_i * dx;
    else
        inside = 2 * (c_i * dx)^2 - (a - b)^2;
        if inside >= 0
            phi(j, i) = (a + b + sqrt(inside)) / 2;
        end
    end
end
```

```
function phi =
weno_fastsweep(c,h,obstacle_dash,eta,error_eta,INFINITE,initial_guess,iterati
on_error)
    global Nx Ny;

    % Phi is intialised with infinity
    phi = initial_guess;
    phi_old = INFINITE * ones(size(phi));
    % Iterations
    iterations = 0;
    loop_safety = 0;
    % Exit
    phi(:,Nx) = 0;
    % Iterations
    while (sum(abs(phi(:)-phi_old(:))) > error_eta && loop_safety<200)
        %fprintf("Iteration = %d ",iterations);
        err = sum(abs(phi(:)-phi_old(:)));
        %fprintf("Error = %0.10f\n",err);
        phi_old = phi;
        iterations = iterations + 1;
        iteration_error(iterations) = err;
        loop_safety = loop_safety + 1;
        for sweep = 1:4
            switch sweep
                case 1
                    ix = 3:1:Nx-2; jy = 3:1:Ny-2;
                case 2
                    ix = 3:1:Nx-2; jy = Ny-2:-1:3;
                case 3
                    ix = Nx-2:-1:3; jy = 3:1:Ny-2;
                case 4
                    ix = Nx-2:-1:3; jy = Ny-2:-1:3;
            end
            for i = ix
                for j = jy
                    %if the point is outside the obstacle
                    if(~obstacle_dash(j,i))
                        %------------Calcualting the phix_min---------_%
```

```
                        r_back = (eta + (phi(j,i) - 2*phi(j,i-1) +
phi(j,i-2))^2)/(eta + (phi(j,i+1) - 2*phi(j,i) + phi(j,i-1))^2);
                        r_front = (eta + (phi(j,i) - 2*phi(j,i+1) +
phi(j,i+2))^2)/(eta + (phi(j,i+1) - 2*phi(j,i) + phi(j,i-1))^2);
                        % Calculate the w
                        w_front = 1/(1+2*(r_front^2));
                        w_back = 1/(1+2*(r_back^2));
                        % Dell phi by Dell x plus and minus
                        phix_minus = (1-w_back)*((phi(j,i+1)-phi(j,i-1))/
(2*h)) + w_back*((3*phi(j,i) - 4*phi(j,i-1) + phi(j,i-2))/(2*h));
                        phix_plus = (1-w_front)*((phi(j,i+1)-phi(j,i-1))/
(2*h)) + w_front*((-3*phi(j,i)+4*phi(j,i+1)-phi(j,i+2))/(2*h));
                        phix_min = min((phi(j,i) - h*phix_minus),(phi(j,i)
+h*phix_plus));
                        %-----------calculating the phiy_min---------%
                        r_back = (eta + (phi(j,i) - 2*phi(j-1,i) +
phi(j-2,i))^2) / (eta + (phi(j+1,i) - 2*phi(j,i) + phi(j-1,i))^2);
                        r_front = (eta + (phi(j,i) - 2*phi(j+1,i) +
phi(j+2,i))^2) / (eta + (phi(j+1,i) - 2*phi(j,i) + phi(j-1,i))^2);
                        % Calculate the w
                        w_front = 1 / (1 + 2*(r_front^2));
                        w_back = 1 / (1 + 2*(r_back^2));
                        % Dell phi by Dell x plus and minus
                        phiy_minus = (1-w_back) * ((phi(j+1,i)-phi(j-1,i))/
(2*h)) + w_back * ((3*phi(j,i) - 4*phi(j-1,i) + phi(j-2,i))/(2*h));
                        phiy_plus = (1-w_front) * ((phi(j+1,i) - phi(j-1,i))/
(2*h)) + w_front * ((-3*phi(j,i) + 4*phi(j+1,i) - phi(j+2,i))/(2*h));
                        phiy_min = min((phi(j,i) - h*phiy_minus), (phi(j,i)+
h*phiy_plus));
                        if abs(phix_min - phiy_min) >= c(j,i)*h
                            phi(j,i) = min(phiy_min,phix_min) + c(j,i)*h;
                        else
                            phi(j,i) = ((phix_min + phiy_min)
+(2*(c(j,i)*h)^2 - (phix_min - phiy_min)^2)^0.5)/2;
                        end
                        % If the point is inside the obstacle
                    else
                        phi(j,i) = INFINITE;
                    end
                end
            end
        end
        phi(:,Nx) = 0;
        phi(:,1) = phi(:,2);
        phi(1, :) = phi(2, :);
        phi(Ny, :) = phi(Ny-1,:);
    end
end
```

```
rho = rho_gauss;
dt_i = [];
t_total = 50;
%-----------MAIN SOLVER------------%
t = 0;
step = 0; % For plotting at regular interval
while t< t_total

    % Updating the Spped, Discomfort and Cost
    speed = 1 - rho;
    discomfort = 0.000 * rho.^2;
    cost = 1./speed + discomfort;

    %-- Calculate Initial Phi guess using Lower order Fast Sweep
    phi = First_order_Godunov_Fast_Sweep_Algorithm(cost,h,obstacle,INFINITE);

    %-- Calculate The final phi using higher ordfer scheme and above intial
guess
    phi =
weno_fastsweep(cost,h,obstacle,eta,error_eta,INFINITE,phi,iteration_error);

    %--Calculate the Components of Velocity
    [phi_x, phi_y] = gradient(phi, h, h); % partial derivatives of phi in x
and y
    mag_phi = sqrt(phi_x.^2 + phi_y.^2);
    mag_phi = max(mag_phi, eta);

    % To be safe with denominator
    for i = 1:1:Nx
        for j = 1:1:Ny
            x_velocity(j,i) = speed(j,i) * (- phi_x(j,i))/mag_phi(j,i);
            y_velocity(j,i) = speed(j,i) * (- phi_y(j,i))/mag_phi(j,i);
        end
    end

    % Updating the delta_t with proper CFL condition (Wiki Pedia)
    u_max = max(abs(x_velocity(:)));
    v_max = max(abs(y_velocity(:)));
    dt = CFL / ( u_max/h + v_max/h + 1e-12 );

    % Updating the value of rho
    rho = upwind_update(rho, x_velocity, y_velocity, dx, dy, dt);
    step = step+1;
    dt_i(step) = dt;

    %--Ploting the rho_next;
    if mod(step, 10) == 0
        figure(6);
        contourf(x, y, rho, 20, 'LineColor', 'none');
        colorbar;
```

```
        clim([0,1]);
        title(sprintf('rho at t = %.2f', t));
        xlabel('x'); ylabel('y');
        axis equal tight;
        drawnow;
    end

    %fprintf('dt = %0.2f\n',dt);
    % Updating the time
    t = t + dt;
end
```




```
dt_i
```

```
dt_i = 1×800
    0.1136    0.0625    0.0625    0.0625    0.0625    0.0625    0.0625    0.0625 ···
```

```
function rho_new = upwind_update(rho, vx, vy, dx, dy, dt)
    global Nx Ny;

    % Boundary Condition
    for j = 2 : Ny-1
        rho(j,1) = 0;
        rho(j,Nx) = rho(j,Nx-1);
    end
    for i = 2 : Nx-1
        rho(1,i) = 0;
        rho(Ny,i) = 0;
    end

    % Initalizing the flux values to be zero intially.
```

```
    flux_xp = zeros(Ny,Nx);
    flux_xm = zeros(Ny,Nx);
    flux_yp = zeros(Ny,Nx);
    flux_ym = zeros(Ny,Nx);

    % Upwinding scheme implementation
    for j = 2 : Ny-1
        for i = 2 : Nx-1
            % x-direction fluxes
            flux_xp(j,i) = max(vx(j,i),0)*rho(j,i)+min(vx(j,i),0)*rho(j,i+1);
            flux_xm(j,i) = max(vx(j,i),0)*rho(j,i-1)
+min(vx(j,i),0)*rho(j,i);
            % y-direction fluxes
            flux_yp(j,i) = max(vy(j,i),0)*rho(j,i) +
min(vy(j,i),0)*rho(j+1,i);
            flux_ym(j,i) = max(vy(j,i),0)*rho(j-1,i) +
min(vy(j,i),0)*rho(j,i);
        end
    end

    % Finite difference equation obtained form discritization of continuity
equation.
    rho_new = rho - (dt/dx) * (flux_xp - flux_xm) - (dt/dy) * (flux_yp -
flux_ym);
end
```