```
clear
close all
%%%%%%%%%%%%%%%%%%%%%%%%
%%%% INICIO DATOS %%%%
%%%%%%%%%%%%%%%%%%%%%%%%

%%%% DATOS  MALLA %%%%
Li=0;    %Extremo izquierdo dominio espacial
Ld=1;    %Extremo derecho dominio espacial
Ti=0;    %Tiempo inicial
Tf=0.1;    %Tiempo final
Mx=100;   %Numero de particiones del intervalo espacial
Nt=100;   %Numero de particiones del intervalo temporal
ncomp=6; % number of variables

%%%% DATOS  REACCION DIFUSION %%%%
% Parámetros reaccion
thetax = 0.02; %
alphac = 0.01; %
varphix = 0.09; %
k1 = 0.08; %
betac = 0.001; %
Lambdax = 0.03; %
psix = 0.09; %
muv = 0.01; %
muvstar = 0.002; %
k2 = 0.1;

% Parámetros difusion
d1=0;        %diffusion suceptible citrics
d2=0;        %diffusion latent citrics
d3=0;        %diffusion infected citrics
d4=1;      %diffusion suceptible vectors
d5=1;      %diffusion exposed vectors
d6=1;      %diffusion infected vectors


%%%%%%%%%%%%%%%%%%%%%%%%
%%%%  FIN   DATOS %%%%
%%%%%%%%%%%%%%%%%%%%%%%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%   INICIO PRE-PROCESO MALLA     %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
meshparam=[Li Ld Ti Tf Mx Nt];       % Numero de particones espacio y tiempo
paramr=[thetax  alphac  varphix  k1 betac Lambdax psix muv muvstar k2];%
Parametros reaccion
paramd=[d1 d2 d3 d4 d5 d6];        % Parametros difusion

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%      FIN PRE-PROCESO MALLA     %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

[x,t,u]=implicit_HLB_1d(meshparam,paramr,paramd,ncomp);

for n=1:Nt+1
   for i=1:Mx+1
      Sc(n,i)=u(n,1,i);
      Lc(n,i)=u(n,2,i);
      Ic(n,i)=u(n,3,i);
      Sv(n,i)=u(n,4,i);
      Ev(n,i)=u(n,5,i);
      Iv(n,i)=u(n,6,i);
   end
end

%%% initial condition
figure
plot(x,Sc(1,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $S_c^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sc_ic_example_2

figure
plot(x,Lc(1,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $L_c^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Lc_ic_example_2

figure
plot(x,Ic(1,:),'LineWidth', 3,'MarkerSize',10)
```

```
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $I_c^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ic_ic_example_2

figure
plot(x,Sv(1,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $I_v^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sv_ic_example_2

figure
plot(x,Ev(1,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $E_v^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ev_ic_example_2

figure
plot(x,Iv(1,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $I_v^0(x)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Iv_ic_example_2

%%% end simulation

figure
plot(x,Sc(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $S_c(x,T)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sc_end_example_2

figure
plot(x,Lc(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $L_c(x,T)$','FontSize',16,'Interpreter','latex')
```

```
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Lc_end_example_2

figure
plot(x,Ic(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $I_c(x,T)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ic_end_example_2

figure
plot(x,Sv(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $S_v(x,T)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sv_end_example_2

figure
plot(x,Ev(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $E_v(x,T)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ev_end_example_2

figure
plot(x,Iv(Nt,:),'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it $I_v(x,T)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Iv_end_example_2


%%% Full simulation

figure
mesh(x,t,Sc,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
zlabel('\it $S_c(x,t)$','FontSize',16,'Interpreter','latex')
```

```
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sc_example_2

figure
mesh(x,t,Lc,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
zlabel('\it $L_c(x,t)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Lc_example_2

figure
mesh(x,t,Ic,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
zlabel('\it $I_c(x,t)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ic_example_2

figure
mesh(x,t,Sv,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
zlabel('\it $S_v(x,t)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Sv_example_2

figure
mesh(x,t,Ev,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
zlabel('\it $E_v(x,t)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Ev_example_2

figure
mesh(x,t,Iv,'LineWidth', 3,'MarkerSize',10)
xlabel('\it x','FontSize',16,'Interpreter','latex')
ylabel('\it t','FontSize',16,'Interpreter','latex')
```

```
zlabel('\it $I_v(x,t)$','FontSize',16,'Interpreter','latex')
set([gca],'FontName','Times New Roman' );
set([gca],'FontSize', 16);
print -depsc2   -r300 FIGURAS2/Iv_example_2







%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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%%%%%%%%%%%%%%%
%%%% FUNCIONES PARA EL ESQUEMA IMPLICITO PARA EL HLB %%%%
%%%% INICIO                                  %%%%
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%%%%%%%%%%%%%%%

function [L0,L1,T0,T1,M,N,Dx,Dt,x,t]=mesh_calculus1d(meshparam)

   L0=meshparam(1);
   L1=meshparam(2);
   T0=meshparam(3);
   T1=meshparam(4);
   M=meshparam(5);
   N=meshparam(6);
   Dx=(L1-L0)/M;
   Dt=(T1-T0)/N;
   x=L0:Dx:L1;  % Particion del intervalo espacial
   t=T0:Dt:T1;  % Particion del intervalo temporal

end
```

```
function [u0] = icHLB_example1d(x)
    %suceptibles citric
    u0(1,:)=(0).*(x<0.25)+...
        -0.4*(4*x-1).*(4*x-3).*((x>0.25)&(x<=0.75))+...
        (0).*(x>0.75);
    %latent citric
    u0(2,:)=0.2.*ones(size(x));
    %infected citric
    u0(3,:)=0.8×x.×(x<=0.25)+...
        (-0.8*x+0.4).*((x>0.25)&(x<=0.5))+...
        (0).*(x>0.5);
    %suceptible vector
    u0(4,:)=(0).*(x<0.5)+...
        -3.2*(2*x-1).*(x-1).*((x>0.5)&(x<=1));
    %exposed vector
    u0(5,:)=0.5.*ones(size(x));
    %infected vector
    u0(6,:)=0×x.×(x<=0.25)+...
        (0.4*x-0.1).*((x>0.25)&(x<=0.5))+...
        -(0.4*x-0.3).*((x>0.5)&(x<=0.75))+...
        (0).*(x>0.75);

end

function EFE_rhs = efe_HLB1d_nc(x,t,u,paramr)

    thetax = paramr(1); %
    alphac = paramr(2); %
    varphix = paramr(3); %
    k1 = paramr(4); %
    betac = paramr(5); %
    Lambdax = paramr(6); %
    psix = paramr(7); %
    muv = paramr(8); %
    muvstar = paramr(9); %
    k2 = paramr(10);

    thetax = paramr(1)+0.01×cos(1.5×pi×x); %
    Lambdax = paramr(6)+0.001×cos(1.5×pi×x); %
    varphix = paramr(3)+0.01×cos(1.5×pi×x); %
    psix = paramr(7)+0.01×cos(1.5×pi×x); %

    Sc=u(1,:);
```

```
    Lc=u(2,:);
    Ic=u(3,:);
    Sv=u(4,:);
    Ev=u(5,:);
    Iv=u(6,:);

    Cc=Sc+Lc+Ic;
    Vv=Sv+Ev+Iv;

    EFE_rhs(1,:) = thetax.*Cc -alphac* Sc - varphix .* Iv.*Sc;
    EFE_rhs(2,:) = varphix .* Iv.*Sc-k1*Lc-alphac* Lc;
    EFE_rhs(3,:) = k1*Lc-alphac* Ic-betac* Ic;;
    EFE_rhs(4,:) = Lambdax.*Vv -psix.* Sv.*Ic - (muv+muvstar)*Sc;
    EFE_rhs(5,:) = psix.* Sv.*Ic -k2*Ev- (muv+muvstar)*Sc;
    EFE_rhs(6,:) =  k2*Ev - (muv+muvstar)*Sc;


end

function HDIFF_full=generate_matrix_H_HLB1d(L0,L1,T0,T1,M, ...
                N,Dx,Dt,x,t,paramd,ncomp)
    HDd=[0.5 ones(1,length(x)-2) 0.5];
    HDs=ones(1,length(x)-1);
    HDi=HDs;
    H= -diag(HDi,-1)+2*diag(HDd)-diag(HDs,1);
    mu_tmp=(Dt/(Dx*Dx))*paramd;
    dimH=ncomp×(N+1);
    HDIFF_full=zeros(dimH,dimH);

    for i=1:ncomp
        Indx=(i-1)×(M+1)+1:i*(M+1);
        HDIFF_tmp(Indx,Indx)=mu_tmp(i)*H;
    end
    HDIFF_full=eye(dimH)+HDIFF_tmp;

end

function Efe_full = efe_implicit_HLB(uvect,x,t,LFull,uold,paramr,paramd)
    Dt = t(2)-t(1);
    uold_vector = reshape(uold', [], 1);
    u_matrix_tmp = reshape(uvect, length(x), 6);
    u_matrix = u_matrix_tmp';
```

```
    EFE_rhs = efe_HLB1d_nc(x,t,u_matrix,paramr);
    EFE_rhs_vector = reshape(EFE_rhs', [], 1);

    Efe_full = LFull*uvect-Dt*EFE_rhs_vector-uold_vector;

end


function [x,t,u]=implicit_HLB_1d(meshparam,paramr,paramd,ncomp)


    %Malla
   [L0,L1,T0,T1,M,N,Dx,Dt,x,t]=mesh_calculus1d(meshparam);

    % Inicializar la matrix H y las matrices LS y LI
    HDIFF_full=generate_matrix_H_HLB1d(L0,L1,T0,T1,M, ...
        N,Dx,Dt,x,t,paramd,ncomp);


    u0 = icHLB_example1d(x);
    for i=1:M+1
        for j=1:ncomp
            u(1,j,i)=u0(j,i);
        end
    end



    for n=2:N+1
       % Inicializacion del punto para la solucion del sistema implicito.
       for i=1:M+1
           for j=1:ncomp
               uold(j,i)=u(n-1,j,i);
           end
       end
       uig=reshape(uold', [], 1);
       c1 =x;
       c2 =t;
       c3 =HDIFF_full;
       c4=uold;
       c5=paramr;
       c6=paramd;
       fun = @(uvect)efe_implicit_HLB(uvect,c1,c2,c3,c4,c5,c6);
       % Solucion del sistema implicito
```

```
        opts = optimset('Diagnostics','off', 'Display','off');
        unew = fsolve(fun,uig,opts);
        unew_matrix_tmp = reshape(unew, M+1, ncomp);

        unew_matrix = unew_matrix_tmp';

        for i=1:M+1
            for j=1:ncomp
                u(n,j,i)=unew_matrix(j,i);
            end
        end

    end


end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%
%%%% FUNCIONES PARA EL ESQUEMA IMPLICITO PARA EL HLB %%%%
%%%% FIN                                          %%%%
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```