hw07 - q02a - lyapunov control design

@author Bardia Mojra @date 11/25/2021 @title hw07 - q02a - lyapunov control design @class ee5323 - Nonlinear Systems @professor Dr. Frank Lewis

```matlab
clc
clear
close all
%warning('off','all')
%warning

syms f(x1,x2) x1 x2
f(x1,x2) = [0; (x1^3)*(x2^7)];
x1_ICs = -20:2:20;
x2_ICs = -20:2:20;

J = jacobian(f(x1,x2),[x1;x2]); % instantiate symbolic jacobian
F = solve(f==0,[x1,x2]); % solve jacobian symbolically
eps = [double(F.x1),double(F.x2)]; % solve numerical solutions, eq.
 points (eps)
%eps(any(imag(eps),2),:) = []; % remove imaginary roots, they are not
 eps.
eps = unique(eps,'rows');
eps_x1 = eps(:,1);
eps_x2 = eps(:,2);
fprintf('Equilibrium Points:\n\t x1\t\tx2\n')
for i = 1:numel(eps_x1)
    fprintf('%6.4g %6.4g\n',eps_x1(i),eps_x2(i));
end

% create quiver plot
figure('color','white');
grid
mesh = -20:2:20;
[x1g,x2g] = meshgrid(mesh,mesh);
U = zeros(size(x1g)); % create directional components
V = U;
t = 0;

for i = 1:numel(x1g)-1
    xp = q02a_sys(t,[x1g(i);x2g(i)]);
    U(i) = xp(1);
    V(i) = xp(2);
end
qaxis = quiver(x1g,x2g,U,V);

grid on
grid minor
axis([-10 10 -10 10])

U = qaxis.UData;
V = qaxis.VData;
```

```matlab
X = qaxis.XData;
Y = qaxis.YData;

headWidth = 6;
headLength = 9;
LineLength = 1;
tr = [0 20];

hold on
plot(nan,nan,'o','linewidth',1,'markeredgecolor','r','markerfacecolor','r')
legend('Trajectory of
 I.C.','location','northwest','AutoUpdate','off','Interpreter','latex')
for x1 = x1_ICs
    for x2 = x2_ICs
        out = ode23(@(t,x) q02a_sys(t,x),tr,[x1 x2]);
        plot(out.y(1,:),out.y(2,:))
    end
end

plot(eps_x1,eps_x2,'o','MarkerSize',
 8,'linewidth',1,'markeredgecolor','r','markerfacecolor','r')
ylabel('$x_2$','Interpreter','latex');
xlabel('$x_1$','Interpreter','latex');
title('System Trajectories - Phase Plane','Interpreter','latex');

Equilibrium Points:
  x1   x2
    0      0
Warning: Failure at t=3.261913e-10.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.271806e-25)
at time t.
Warning: Failure at t=6.137864e-10.  Unable to meet integration
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without reducing the step size below the smallest value allowed
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at time t.
Warning: Failure at t=1.244321e-09.  Unable to meet integration
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at time t.
Warning: Failure at t=2.772580e-09.  Unable to meet integration
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without reducing the step size below the smallest value allowed
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at time t.
Warning: Failure at t=6.991411e-09.  Unable to meet integration
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without reducing the step size below the smallest value allowed
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at time t.
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Warning: Failure at t=2.087624e-08. Unable to meet integration
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Warning: Failure at t=7.963654e-08. Unable to meet integration
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at time t.
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Warning: Failure at t=1.208116e-11. Unable to meet integration
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without reducing the step size below the smallest value allowed
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Warning: Failure at t=2.273283e-11. Unable to meet integration
*   tolerances*
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Warning: Failure at t=4.608596e-11. Unable to meet integration
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Warning: Failure at t=1.026881e-10. Unable to meet integration
*   tolerances*
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Warning: Failure at t=2.589411e-10. Unable to meet integration
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*   (8.271806e-25)*
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Warning: Failure at t=7.731941e-10. Unable to meet integration
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*   (6.617445e-24)*
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Warning: Failure at t=1.657223e-08. Unable to meet integration
*   tolerances*
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Warning: Failure at t=8.083324e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(2.584939e-26)
at time t.
Warning: Failure at t=3.627758e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(6.462349e-27)
at time t.
Warning: Failure at t=1.789465e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(3.231174e-27)
at time t.
Warning: Failure at t=9.509949e-13. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(3.231174e-27)
at time t.
Warning: Failure at t=6.370923e-13. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.615587e-27)
at time t.
Warning: Failure at t=1.198802e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(3.231174e-27)
at time t.
Warning: Failure at t=2.430314e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(6.462349e-27)
at time t.
Warning: Failure at t=5.415195e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.292470e-26)

```
at time t.
Warning: Failure at t=1.365510e-11.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (2.584939e-26)
at time t.
Warning: Failure at t=4.077391e-11.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.033976e-25)
at time t.
Warning: Failure at t=1.555401e-10.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (4.135903e-25)
at time t.
Warning: Failure at t=8.739264e-10.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.654361e-24)
at time t.
Warning: Failure at t=9.954567e-09.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (2.646978e-23)
at time t.
Warning: Failure at t=6.370923e-07.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.694066e-21)
at time t.
Warning: Failure at t=6.370923e-07.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.694066e-21)
at time t.
Warning: Failure at t=9.954567e-09.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (2.646978e-23)
at time t.
Warning: Failure at t=8.739264e-10.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.654361e-24)
at time t.
Warning: Failure at t=1.555401e-10.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (4.135903e-25)
at time t.
Warning: Failure at t=4.077391e-11.  Unable to meet integration
 tolerances
```

without reducing the step size below the smallest value allowed
(1.033976e-25)
at time t.
Warning: Failure at t=1.365510e-11. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(2.584939e-26)
at time t.
Warning: Failure at t=5.415195e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.292470e-26)
at time t.
Warning: Failure at t=2.430314e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(6.462349e-27)
at time t.
Warning: Failure at t=1.198802e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(3.231174e-27)
at time t.
Warning: Failure at t=6.370923e-13. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.615587e-27)
at time t.
Warning: Failure at t=4.474503e-13. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(8.077936e-28)
at time t.
Warning: Failure at t=8.419567e-13. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.615587e-27)
at time t.
Warning: Failure at t=1.706887e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(3.231174e-27)
at time t.
Warning: Failure at t=3.803265e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(1.292470e-26)
at time t.
Warning: Failure at t=9.590413e-12. Unable to meet integration
tolerances
without reducing the step size below the smallest value allowed
(2.584939e-26)
at time t.

Warning: Failure at t=2.863682e-11. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (5.169879e-26)
at time t.
Warning: Failure at t=1.092408e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (2.067952e-25)
at time t.
Warning: Failure at t=6.137864e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.654361e-24)
at time t.
Warning: Failure at t=6.991411e-09. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.323489e-23)
at time t.
Warning: Failure at t=4.474503e-07. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.470329e-22)
at time t.
Warning: Failure at t=4.474503e-07. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.470329e-22)
at time t.
Warning: Failure at t=6.991411e-09. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.323489e-23)
at time t.
Warning: Failure at t=6.137864e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.654361e-24)
at time t.
Warning: Failure at t=1.092408e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
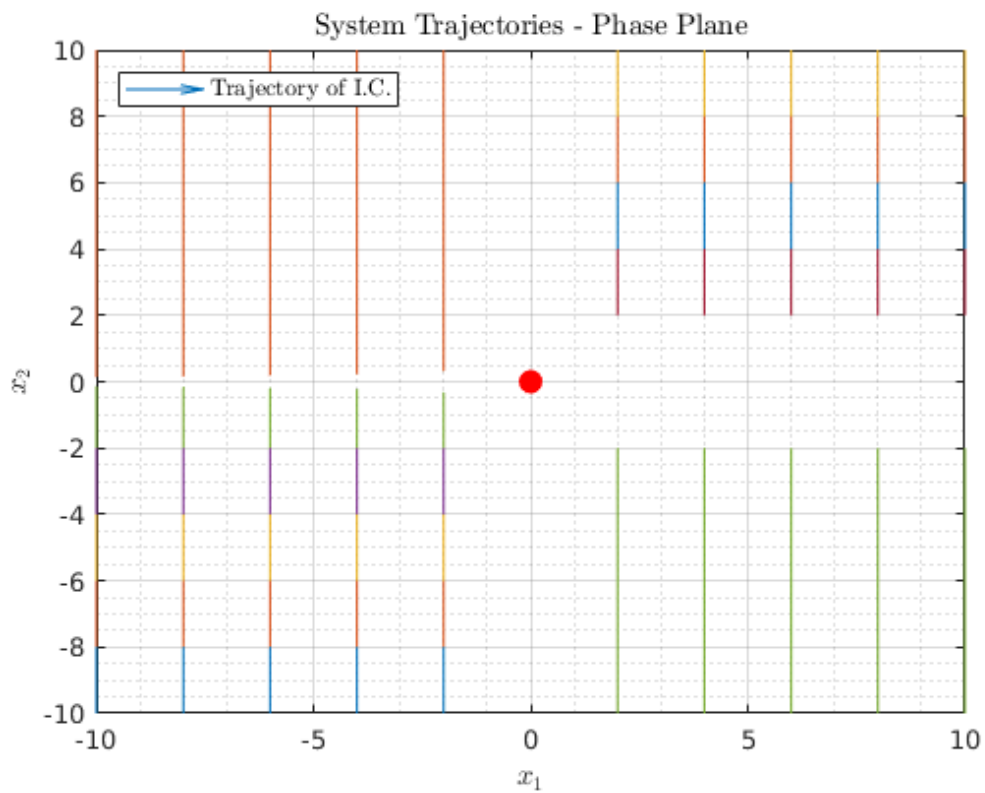 *(2.067952e-25)*
at time t.
Warning: Failure at t=2.863682e-11. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (5.169879e-26)
at time t.
Warning: Failure at t=9.590413e-12. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (2.584939e-26)

```
at time t.
Warning: Failure at t=3.803265e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.292470e-26)
at time t.
Warning: Failure at t=1.706887e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (3.231174e-27)
at time t.
Warning: Failure at t=8.419567e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.615587e-27)
at time t.
Warning: Failure at t=4.474503e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.077936e-28)
at time t.
Warning: Failure at t=3.261913e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.077936e-28)
at time t.
Warning: Failure at t=6.137864e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.615587e-27)
at time t.
Warning: Failure at t=1.244321e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (3.231174e-27)
at time t.
Warning: Failure at t=2.772580e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (6.462349e-27)
at time t.
Warning: Failure at t=6.991411e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.292470e-26)
at time t.
Warning: Failure at t=2.087624e-11.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (5.169879e-26)
at time t.
Warning: Failure at t=7.963654e-11.  Unable to meet integration
 tolerances
```

without reducing the step size below the smallest value allowed
(2.067952e-25)
at time t.
Warning: Failure at t=4.474503e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(8.271806e-25)
at time t.
Warning: Failure at t=5.096739e-09. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(1.323489e-23)
at time t.
Warning: Failure at t=3.261913e-07. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(8.470329e-22)
at time t.
Warning: Failure at t=3.261913e-07. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(8.470329e-22)
at time t.
Warning: Failure at t=5.096739e-09. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(1.323489e-23)
at time t.
Warning: Failure at t=4.474503e-10. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(8.271806e-25)
at time t.
Warning: Failure at t=7.963654e-11. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(2.067952e-25)
at time t.
Warning: Failure at t=2.087624e-11. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(5.169879e-26)
at time t.
Warning: Failure at t=6.991411e-12. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(1.292470e-26)
at time t.
Warning: Failure at t=2.772580e-12. Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
(6.462349e-27)
at time t.

```
Warning: Failure at t=1.244321e-12.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (3.231174e-27)
at time t.
Warning: Failure at t=6.137864e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (1.615587e-27)
at time t.
Warning: Failure at t=3.261913e-13.  Unable to meet integration
 tolerances
without reducing the step size below the smallest value allowed
 (8.077936e-28)
at time t.
```


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