# Lab #4: Simulation of Mobile Robots

EE 552: Robotic Control System

by

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1. Phase plot for the dynamics given bellow.

$$\dot{x_1} = x_1 + x_1 x_2$$

$$\dot{x_2} = -x_2 + x_2^2 + x_1 x_2 + x_1^3$$

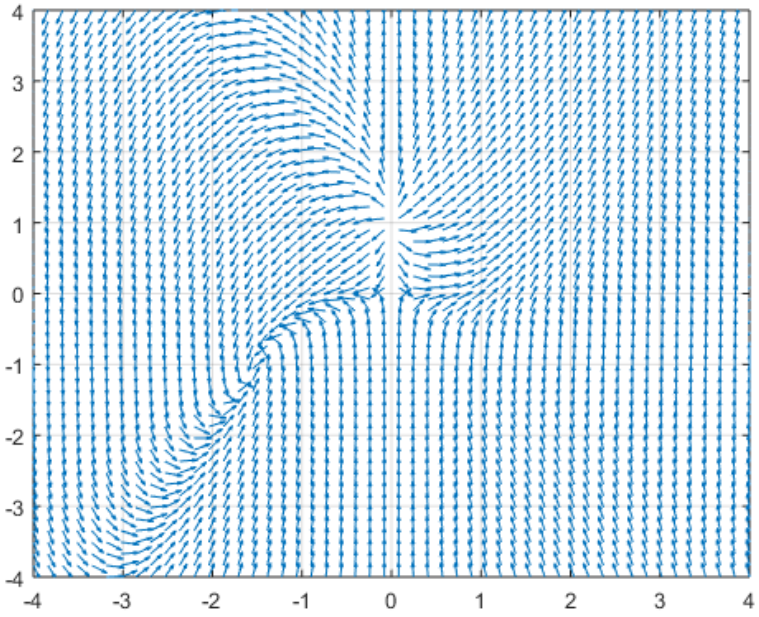


Figure: Phase plot for the above dynamics with resolution, Ts = 50

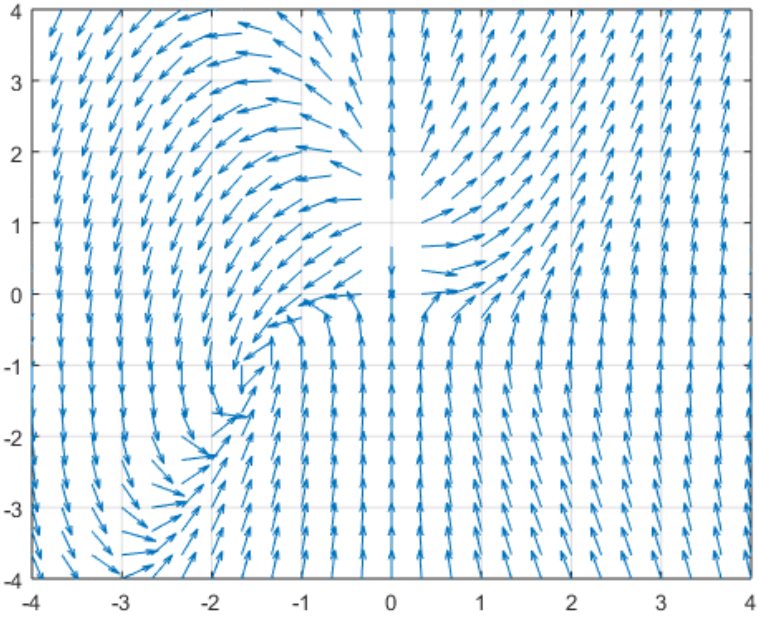


Figure: Phase plot for the above dynamics with resolution, Ts = 50/2

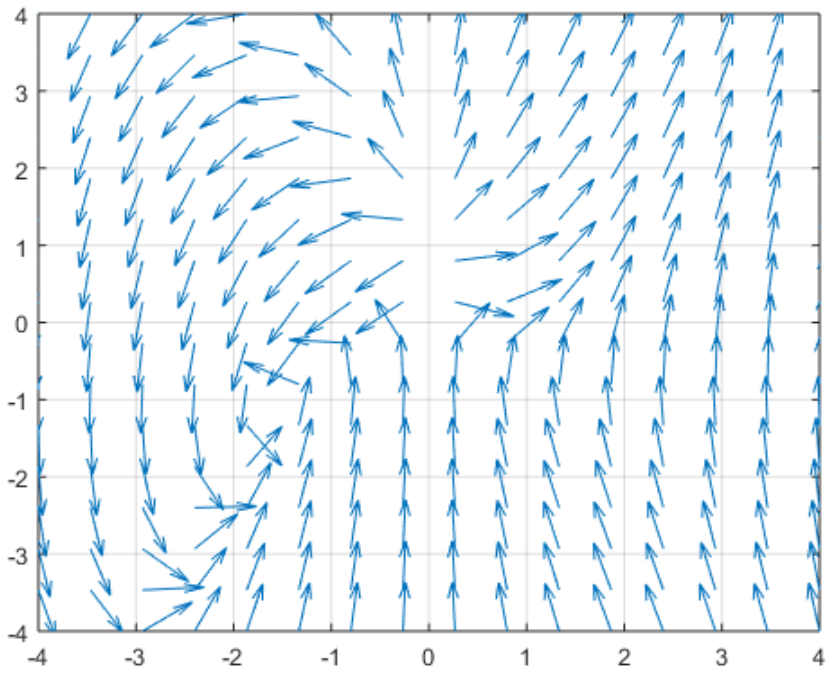


Figure: Phase plot for the above dynamics with resolution, Ts = 50/3

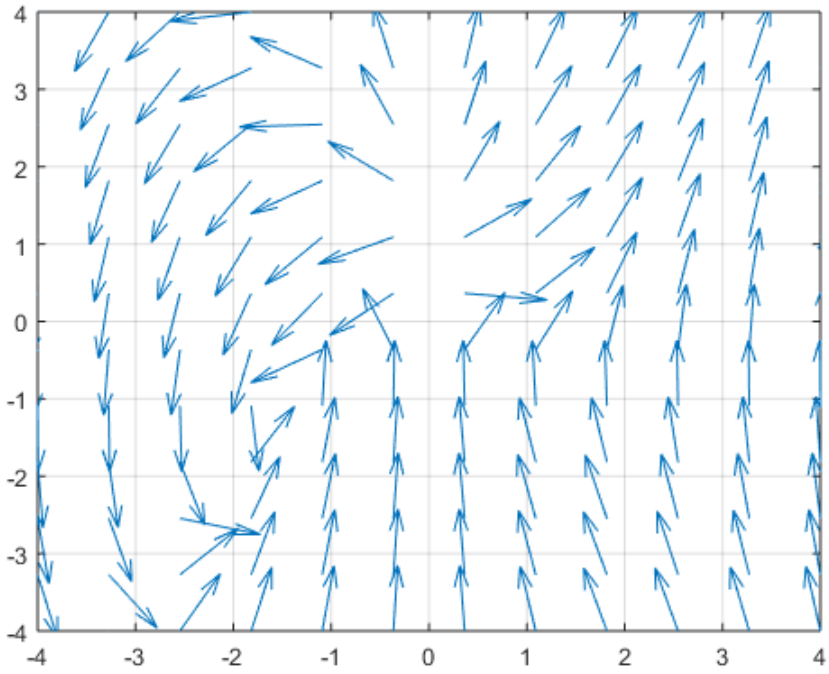


Figure: Phase plot for the above dynamics with resolution, Ts = 50/4

Matlab codes for phase plot:

```
pplane2(50)
pplane2(50/2)
pplane2(50/3)
pplane2(50/4)

function pplane2(ts)
    Ts = linspace(-4,4,ts);
    [x1,x2] = meshgrid(Ts,Ts);
    dx1= x1 + x1.*x2;
    dx2= -x2 + x2.^2 + x1.*x2 + x1.^3;
    xdot1 = dx1./(sqrt((dx1).^2 + (dx2).^2));
    xdot2 = dx2./(sqrt((dx1).^2 + (dx2).^2));
    figure
    quiver(x1,x2,xdot1,xdot2)
    % quiver(x1,x2,dx1,dx2)
    axis([-4 4 -4 4])
    grid on
end
```

2. Phase plot with trajectories (same dynamics as above)

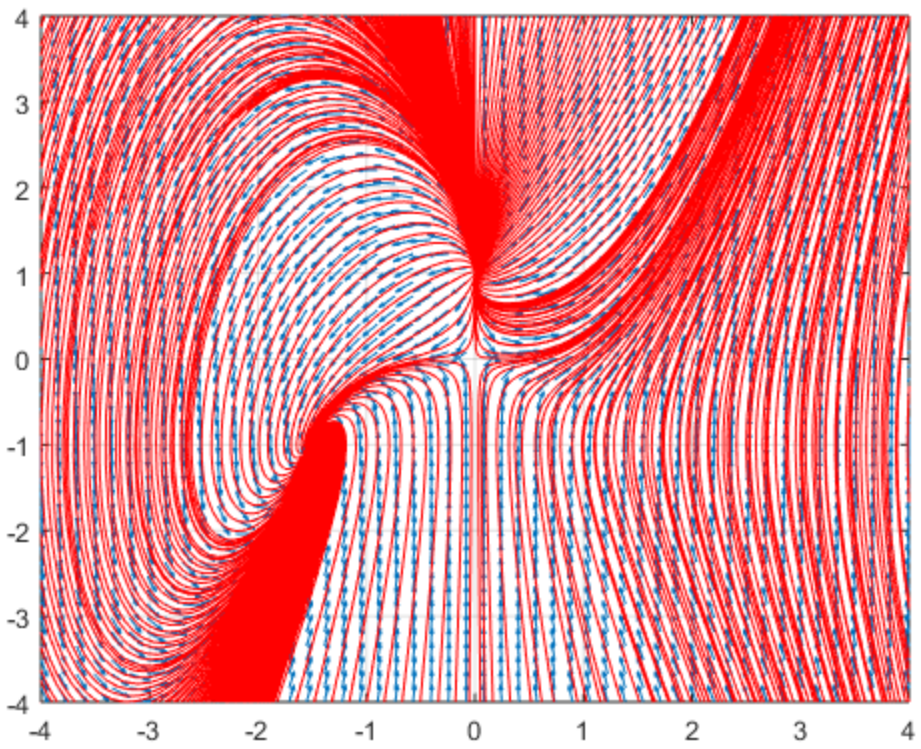


Figure: Phase plot with trajectories

Matlab codes:

```
clc
clear
close all
warning off

g = 9.8;
l = 1;
Ts = linspace(-4,4,50);
[x1,x2] = meshgrid(Ts,Ts);
dx1= x2;
dx2= -(g/l)*sin(x1);
xdot1 = dx1./(sqrt((dx1).^2 + (dx2).^2));
xdot2 = dx2./(sqrt((dx1).^2 + (dx2).^2));
figure
quiver(x1,x2,xdot1,xdot2)
% quiver(x1,x2,dx1,dx2)
axis([-4 4 -4 4])
grid on
hold on

options = odeset('RelTol',1e-4,'AbsTol',[1e-5 1e-5]);
```

```
for i = -10:10
    [~,X] = ode45(@plane,[0 10],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[0 10],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
end

function [dx] = plane(t,x)
dx = zeros(2,1);
dx(1)= x(2);
dx(2)= -(9.8)*sin(x(1));
end
```

3.

a) Phase plot with trajectories for the linear system below.

$$\dot{x_1} = -0.313x_1 + 56.7x_2$$

$$\dot{x_2} = -0.0139x_1 - 0.426x_2$$

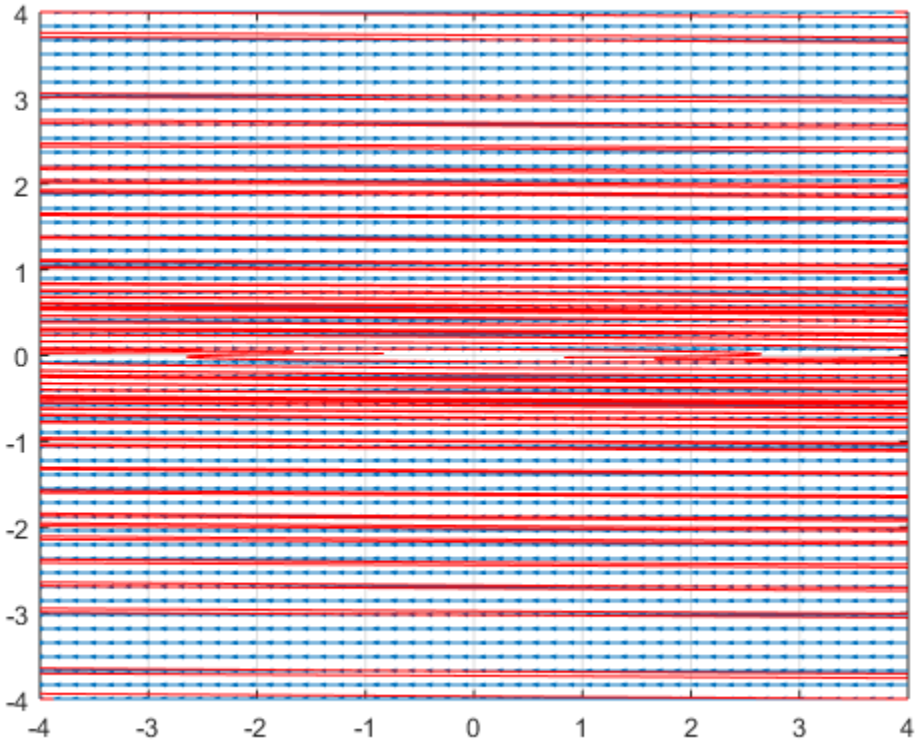


Figure: Phase plot with trajectories for the linear system above

Matlab codes:

```
clc
clear
close all
warning off

Ts = linspace(-4,4,50);
[x1,x2] = meshgrid(Ts,Ts);
dx1= -0.313*x1 + 56.7*x2;
dx2= -0.0139*x1 - 0.426*x2;
xdot1 = dx1./(sqrt((dx1).^2 + (dx2).^2));
xdot2 = dx2./(sqrt((dx1).^2 + (dx2).^2));
figure
quiver(x1,x2,xdot1,xdot2)
% quiver(x1,x2,dx1,dx2)
axis([-4 4 -4 4])
```

```
grid on
hold on

options = odeset('RelTol',1e-4,'AbsTol',[1e-5 1e-5]);

for i = -10:10
    [~,X] = ode45(@plane,[0 10],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[0 10],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
end

function [dx] = plane(t,x)
dx = zeros(2,1);
dx(1)= -0.313*x(1) + 56.7*x(2);
dx(2)= -0.0139*x(1) - 0.426*x(2);
end
```

b) Phase plot with trajectories for the nonlinear system below.

$$\dot{x_1} = x_2$$

$$\dot{x_2} = x_1^2$$

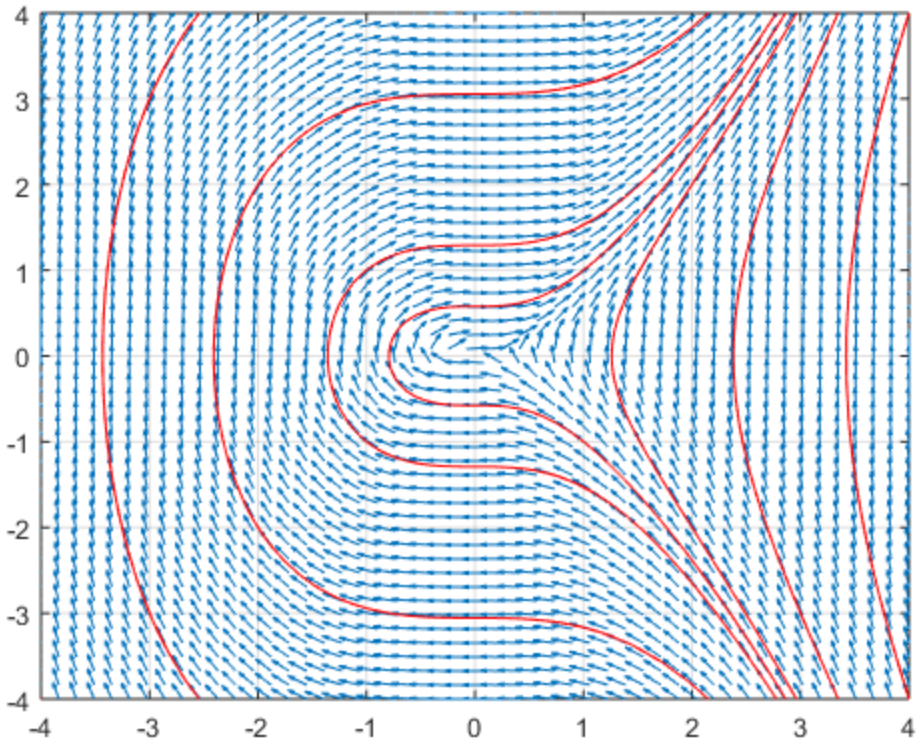


Figure: Phase plot with trajectories for the nonlinear system above

Matlab codes:

```
clc
clear
close all
warning off

Ts = linspace(-4,4,50);
[x1,x2] = meshgrid(Ts,Ts);
dx1= x2;
dx2= x1.^2;
xdot1 = dx1./(sqrt((dx1).^2 + (dx2).^2));
xdot2 = dx2./(sqrt((dx1).^2 + (dx2).^2));
figure
quiver(x1,x2,xdot1,xdot2)
% quiver(x1,x2,dx1,dx2)
axis([-4 4 -4 4])
grid on
```

```
hold on

options = odeset('RelTol',1e-4,'AbsTol',[1e-5 1e-5]);

for i = -10:10
    [~,X] = ode45(@plane,[0 10],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[0 10],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
end

function [dx] = plane(t,x)
dx = zeros(2,1);
dx(1)= x(2);
dx(2)= x(1).^2;
end
```

c) Phase plot with trajectories for pendulum.

$$\dot{x_1} = x_2$$

$$\dot{x_2} = -(g/l)\sin(x_1)$$

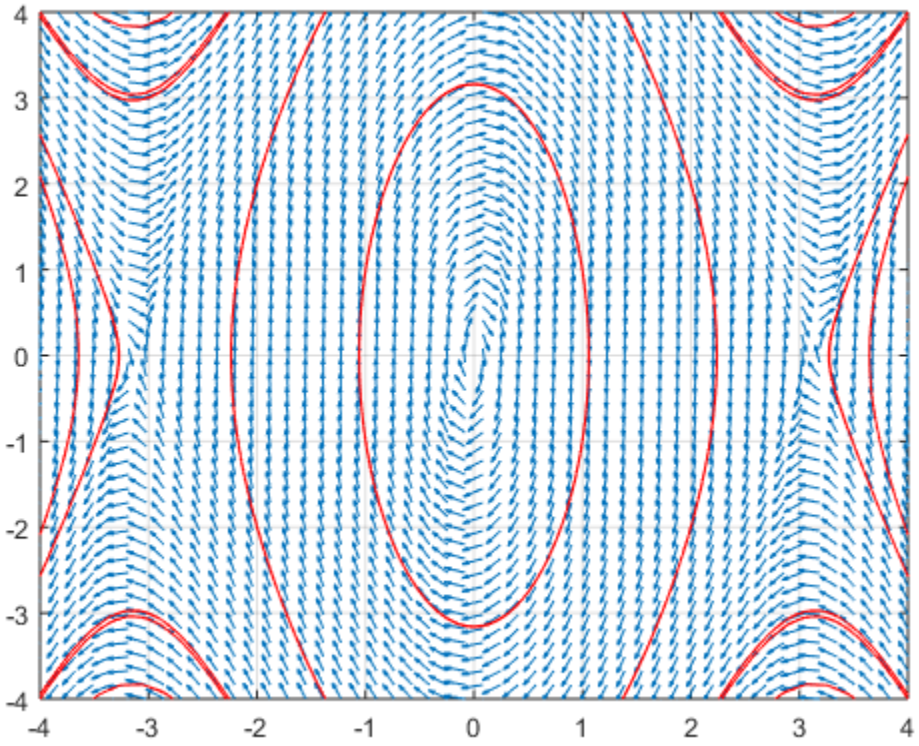


Figure: Phase plot with trajectories for pendulum

Matlab codes:

```
clc
clear
close all
warning off

g = 9.8;
l = 1;
Ts = linspace(-4,4,50);
[x1,x2] = meshgrid(Ts,Ts);
dx1= x2;
dx2= -(g/l)*sin(x1);
xdot1 = dx1./(sqrt((dx1).^2 + (dx2).^2));
xdot2 = dx2./(sqrt((dx1).^2 + (dx2).^2));
figure
quiver(x1,x2,xdot1,xdot2)
% quiver(x1,x2,dx1,dx2)
```

```
axis([-4 4 -4 4])
grid on
hold on

options = odeset('RelTol',1e-4,'AbsTol',[1e-5 1e-5]);

for i = -10:10
    [~,X] = ode45(@plane,[0 10],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[0 10],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
    [~,X] = ode45(@plane,[10 0],[-i,i]',options);
    plot(X(:,1),X(:,2),'r')
    hold on
end

function [dx] = plane(t,x)
dx = zeros(2,1);
dx(1)= x(2);
dx(2)= -(9.8)*sin(x(1));
end
```