Practice 4 Automatic Control Theory

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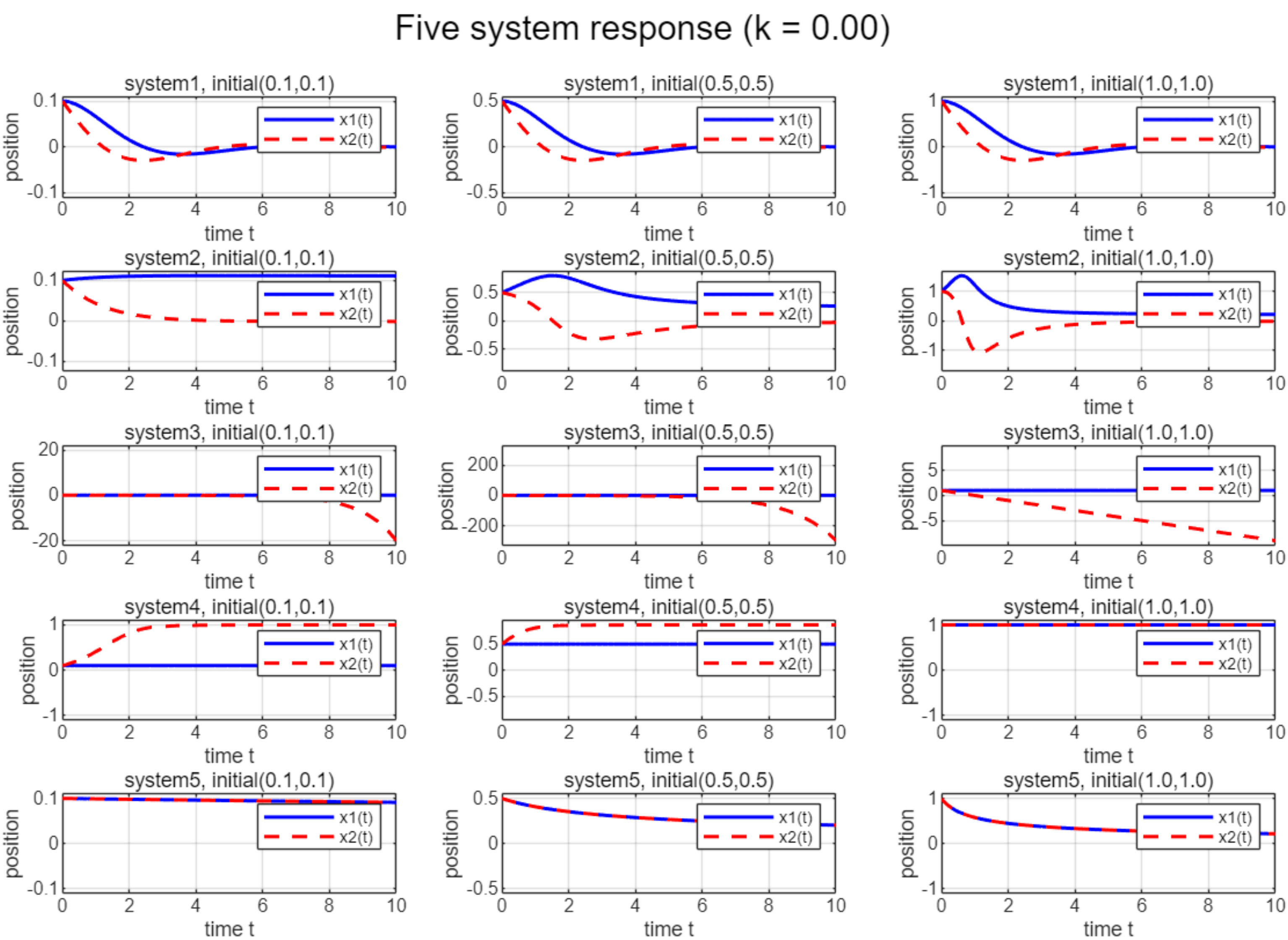
1 Discuss why these systems are nonlinear.

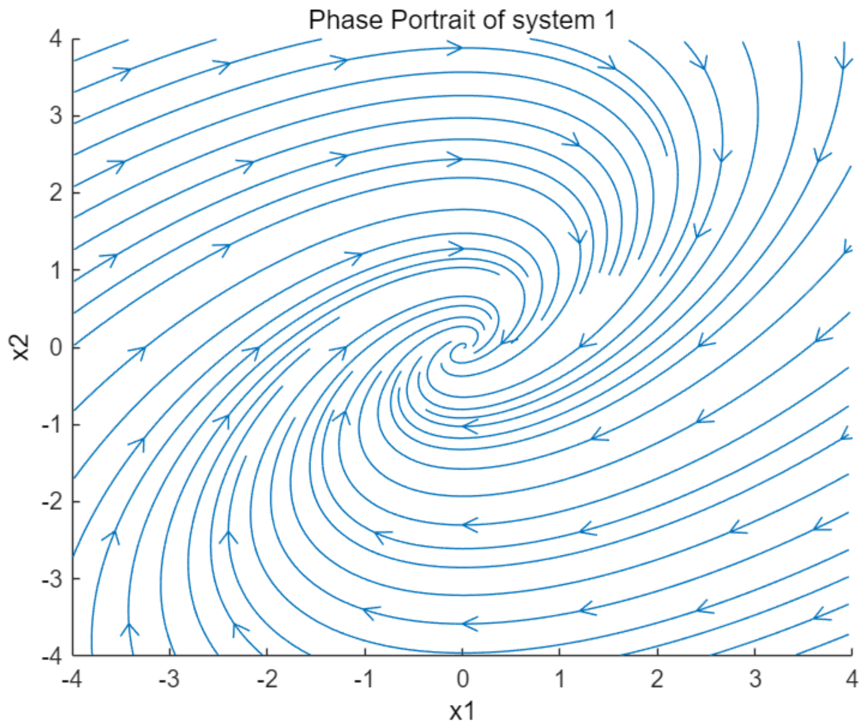
System	Nonlinear Terms	Type of Nonlinearity	Equilibrium Points
$\frac{dx_1}{dt} = -x_1 + x_2$ $\frac{dx_2}{dt} = -x_1$	None (linear)	Linear (unless typo)	(0,0)
$\frac{dx_1}{dt} = x_1 * x_2$ $\frac{dx_2}{dt} = -x_2 + x_2^2 + x_1 * x_2 - x_1^3$	$x_1 * x_2$, x_2^2, x_1^3	Polynomial, interaction	(0,0), (0,1)
$\frac{dx_1}{dt} = 0$ $\frac{dx_2}{dt} = -x_1 + x_2 * (1 - x_1^2)$	$x_2 * x_1^2$	Quadratic coupling	All $(x_1, \frac{x_1}{1 - x_1^2})$
$\frac{dx_1}{dt} = 0$ $\frac{dx_2}{dt} = (x_1 + x_2) * (1 - x_1^2 - x_2^2)$	(x_1+x_2)*(1$-x_1^2-x_2^2$)	Polynomial, limit cycle	All points on x_2=$-x_1$ or x_1^2 +x_2^2=1
$\frac{dx_1}{dt} = -x_1^3$ $\frac{dx_2}{dt} = -x_2^3$	x_1^3, x_2^3	Cubic dissipation	(0,0)

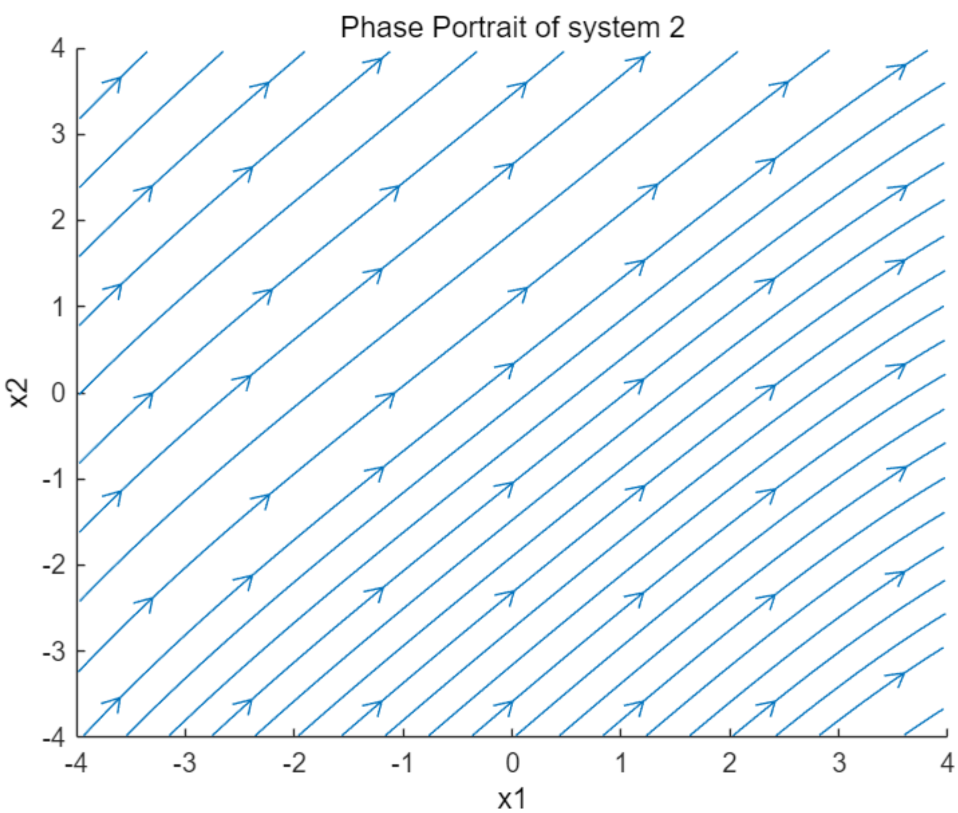
2. Simulation for three different sets of initial conditions:

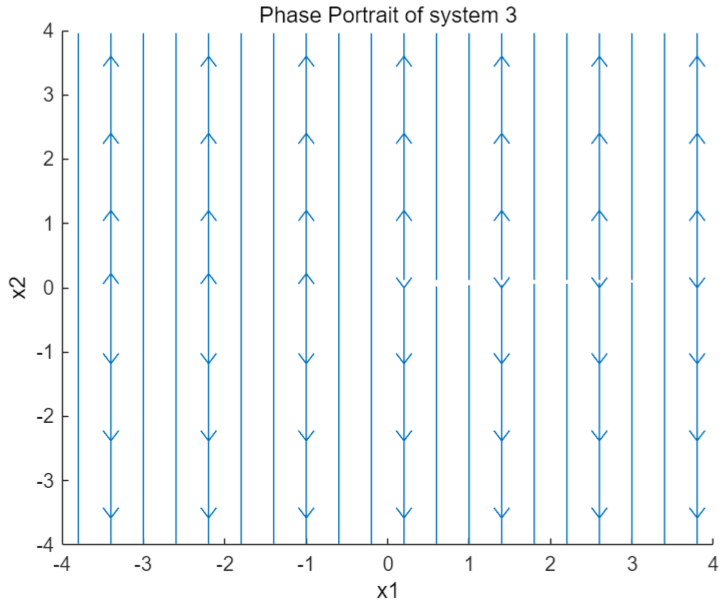
- first: [0.1 0.1]
- second: [0.5, 0.5]
- third: [1, 1]

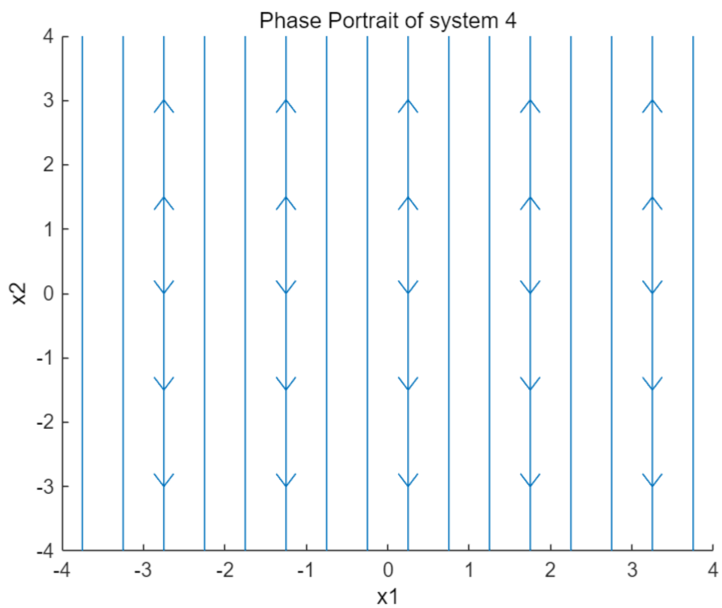


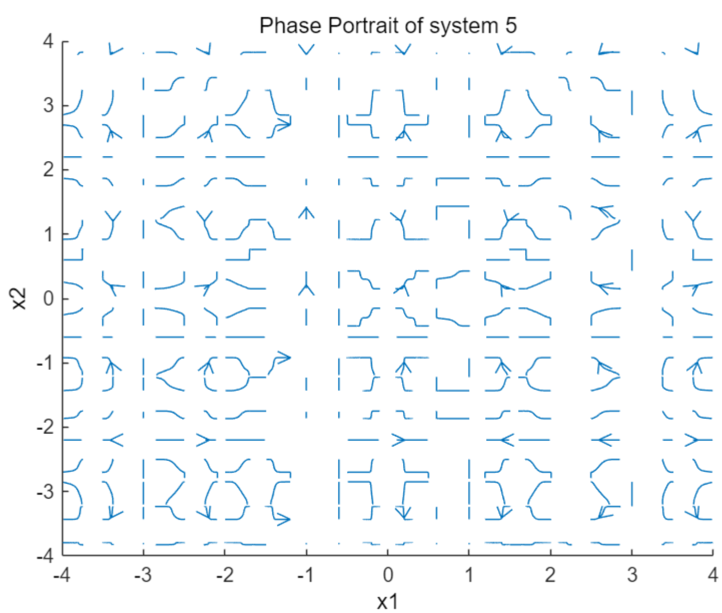
3. (Optional) Numerically construct a phase portrait of the system.






Phase Portrait of system 3
x2
x1
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4


Phase Portrait of system 4
x2
x1
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4


Phase Portrait of system 5
x2
x1
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

Conclusions

A linear system is a system whose mathematical model consists solely of linear expressions. In contrast, a nonlinear system is a system whose mathematical model includes at least one nonlinear expression.

In the analysis of nonlinear systems, the Jacobian matrix can be used to linearize the system around equilibrium points. By examining the eigenvalues and eigenvectors of the Jacobian matrix, we can determine the stability and behavior of these equilibrium points.