

Solving a system of ODEs

- The following is a shortcut approach for 2×2 systems, mostly for insight.

Solving a system of ODEs

- The following is a shortcut approach for 2×2 systems, mostly for insight.
- Find the general solution to the system of equations

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):



Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$\pencil \quad x_1'' = x_1' + x_2' = x_1' + 4x_1 + x_2$$

$$x_2 = x_1' - x_1$$

$$x_1'' = x_1' + 4x_1 + x_1' - x_1$$

$$x_1'' - 2x_1' - 3x_1 = 0$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$
$$r = -1, 3$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$



Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations


$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

 $x_2 = x_1' - x_1 = -C_1 e^{-t} + 3C_2 e^{3t} - C_1 e^{-t} - C_2 e^{3t}$
 $= -2C_1 e^{-t} + 2C_2 e^{3t}$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

$$x_2 = -2C_1 e^{-t} + 2C_2 e^{3t}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

$$x_2 = -2C_1 e^{-t} + 2C_2 e^{3t}$$

$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = C_1 e^{-t} \begin{pmatrix} 1 \\ -2 \end{pmatrix} + C_2 e^{3t} \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

$$x_2 = -2C_1 e^{-t} + 2C_2 e^{3t}$$

$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = C_1 e^{-t} \begin{pmatrix} 1 \\ -2 \end{pmatrix} + C_2 e^{3t} \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

- Recall:

$$\lambda_1 = -1$$

$$\mathbf{v}_1 = \begin{pmatrix} 1 \\ -2 \end{pmatrix}$$

$$\lambda_2 = 3$$

$$\mathbf{v}_2 = \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

$$x_2 = -2C_1 e^{-t} + 2C_2 e^{3t}$$

$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = C_1 e^{-t} \begin{pmatrix} 1 \\ -2 \end{pmatrix} + C_2 e^{3t} \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

- Recall:

$$\lambda_1 = -1$$

$$\mathbf{v}_1 = \begin{pmatrix} 1 \\ -2 \end{pmatrix}$$

$$\lambda_2 = 3$$

$$\mathbf{v}_2 = \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

Solving a system of ODEs

- The following is a shortcut approach for 2x2 systems, mostly for insight.
- Find the general solution to the system of equations

$$\begin{aligned}x_1' &= x_1 + x_2 \\x_2' &= 4x_1 + x_2\end{aligned}\quad \text{or equivalently} \quad \mathbf{x}' = \begin{pmatrix} 1 & 1 \\ 4 & 1 \end{pmatrix} \mathbf{x}$$

- Convert this into a second order equation in only one unknown (x_1):

$$x_1'' - 2x_1' - 3x_1 = 0 \quad \rightarrow \quad r^2 - 2r - 3 = 0$$

$$r = -1, 3$$

$$x_1 = C_1 e^{-t} + C_2 e^{3t}$$

$$x_2 = -2C_1 e^{-t} + 2C_2 e^{3t}$$

$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = C_1 e^{-t} \begin{pmatrix} 1 \\ -2 \end{pmatrix} + C_2 e^{3t} \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

- Recall:

$$\lambda_1 = -1$$

$$\mathbf{v}_1 = \begin{pmatrix} 1 \\ -2 \end{pmatrix}$$

$$\lambda_2 = 3$$

$$\mathbf{v}_2 = \begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

Solving a system of ODEs

- You can use the second order trick for 2×2 but in general,

Solving a system of ODEs

- You can use the second order trick for 2×2 but in general,
 - Find eigenvalues and eigenvectors of A ,

Solving a system of ODEs

- You can use the second order trick for 2x2 but in general,
 - Find eigenvalues and eigenvectors of A ,
 - Assemble general solution by summing up terms of the form

$$C_n e^{\lambda_n t} \mathbf{v}_n$$

Solving a system of ODEs

- You can use the second order trick for 2x2 but in general,
 - Find eigenvalues and eigenvectors of A,
 - Assemble general solution by summing up terms of the form

$$C_n e^{\lambda_n t} \mathbf{v}_n$$

- This works when eigenvalues are distinct or, if there are repeated eigenvalues still giving N independent eigenvectors.

Solving a system of ODEs

- You can use the second order trick for 2x2 but in general,
 - Find eigenvalues and eigenvectors of A,
 - Assemble general solution by summing up terms of the form

$$C_n e^{\lambda_n t} \mathbf{v}_n$$

- This works when eigenvalues are distinct or, if there are repeated eigenvalues still giving N independent eigenvectors.
- Other cases (not enough e-vectors or complex e-values) next class.