Lunar Scout - Task 0B - Modeling of non-linear Dynamical Systems (Part 1)

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Hyperactive Leader Aug 2023

Modeling of non-linear Dynamical Systems

In mathematics and science, a non-linear system is a system in which the change of the output is not linearly proportional to the change of the input. Non-linear problems are of interest to engineers, biologists, mathematicians etc because most systems that occur in nature are inherently non-linear.

Non-linear dynamical systems that describe changes in variable over time may often appear chaotic, unpredictable or counter-intuitive in nature, contrasting with much simpler linear systems.

Typically the behavior of a non-linear system is described as a set of simultaneous equations in which the unknowns (or unknown functions in the case of differential equations) appear as variables of a polynomial of degree higher than one. Such a system is called a **non-linear system of equations.**

We will deal with dynamical systems that are modeled by a finite number of coupled first order ordinary differential equations

$$\dot{x}_1 = f_1(t, x_1, \ldots\ldots, x_n, u_1, \ldots\ldots, u_p)$$

$$\dot{x}_2 = f_2(t, x_1, \ldots\ldots, x_n, u_1, \ldots\ldots, u_p)$$

$$\vdots$$

$$\dot{x}_n = f_n(t, x_1, \ldots\ldots, x_n, u_1, \ldots\ldots, u_p)$$

Here $\dot{\mathbf{x}}_1$, $\dot{\mathbf{x}}_2, \ldots \dot{\mathbf{x}}_n$ denote the derivative of $\mathbf{x}_1$, $\mathbf{x}_2 \ldots \mathbf{x}_n$ respectively with respect to time variable t and $\mathbf{u}_1$, $\mathbf{u}_2, \ldots$ $\mathbf{u}_p$ etc are specified input variables. We call the variables $\mathbf{x}_1$, $\mathbf{x}_2$, $\ldots \mathbf{x}_n$ the **state variables**.

State Variables are used to to represent the memory the dynamical system has of its past or the desired variable of interest. We usually use vector notation to write these equations in a compact form.

$$x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_n \end{bmatrix}, u = \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ \vdots \\ u_p \end{bmatrix}, f(t,x,u) = \begin{bmatrix} f_1(t,x,u) \\ f_2(t,x,u) \\ \vdots \\ \vdots \\ f_n(t,x,u) \end{bmatrix}$$

We can rewrite the n first-order differential equations as one n-dimensional first-order vector differential equation

$$\dot{x} = f(t,x,u)$$

We call above equation as the **State Equation** of the system and refer to x as the **state** and u as the **input**.

Take the following quiz before moving forward:

Task 0B - Part 1 - Quiz

Lunar Scout: Task 0 [original]

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