Université Libre de Bruxelles

INFO-F410 - Embedded Systems Design

Electric-Bike Project (XCos)

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Chapter 1

XCos

1.1 Xcos introduction

This part of the project focuses on XCos, which is a Scilab package "for modeling and simulation of explicit and implicit dynamical systems, including both continuous and discrete sub-systems".[1]

1.2 Task X0

1.2.1 Lipschitz-continuity (a)

Definition of Lipschitz-continuity In the ... book, the Lipschitz continuity is intuitively defined as a constant upper bound that limits how fast a function changes. More precisely, a function $f : \mathbf{R}^n \rightarrow \mathbf{R}^n$ is said to be Lipschitz continuous if there exists a constant K such that for all vectors u and v in $\mathbf{R}^n$,

$$||f(u) - f(v)|| \leq K||u - v||$$

To better understand this condition, we can rewrite it as follows:

$$||\frac{f(u) - f(v)}{u - v}|| \leq K$$

This actually tells us, that the slope (more precisely the absolute value of it) must be smaller than a certain constant, which in other words means that the slope must not grow indefinitely.

Bike dynamics without all the multipliers The bike dynamics function without all of the multiplies looks as follows:

$$\frac{dv}{dt} = F_e + F_h - sin(\alpha) - cos(\alpha) - v^2$$

In order to check if it actually respects the Lipschitz-condition, we will check all of the five summands above.

(i) First, we have that both $-sin(\alpha)$ and $-cos(\alpha)$ respect the condition as sinusoidal functions are bounded between -1 and 1.

(ii) Next, we have F_e and F_h that are simply the inputs.

(iii) And finally, we have $-v^2$. By definition, as the slope of a negative quadratic function over $\mathbf{R}^n$ decreases infinitely, we could never find such a constant that could limit it. However, the given variable v describes the speed of a bicycle. Even as the interval of the possible speeds is not explicitly described in the project instructions (despite being positive), we can easily suppose that the bike speed will always be lower than the speed of light. In consequence, such a constant K can be found.

As all the summands respect the Lipschitz continuity condition, the above equation also respects the condition.

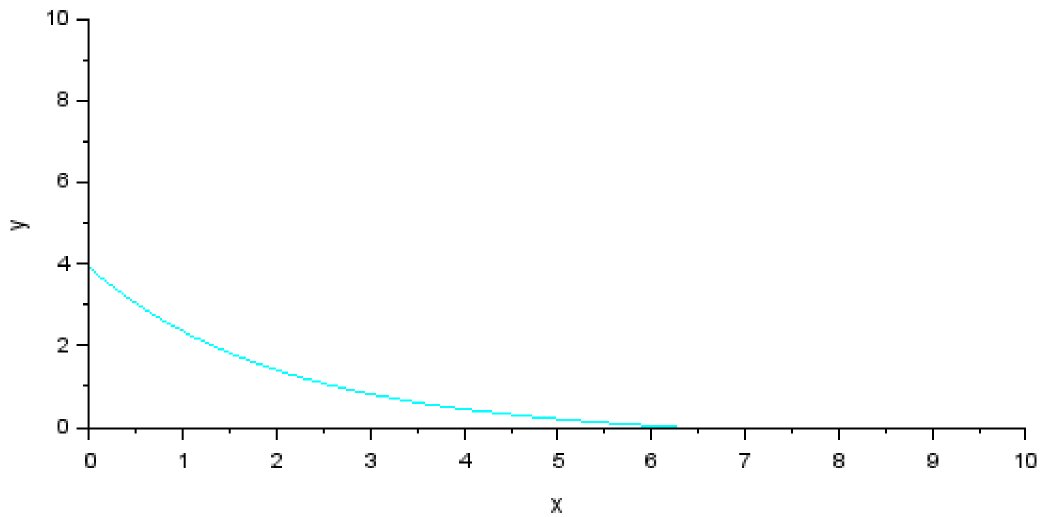
[1] Source:https://en.wikipedia.org/wiki/Scilab

1.2.2 Acceleration vs Speed (b)

In this task we are supposed to plot "derivative vs speed" on respectively the y and x axes, and then study the equilibrium of the speed variable.

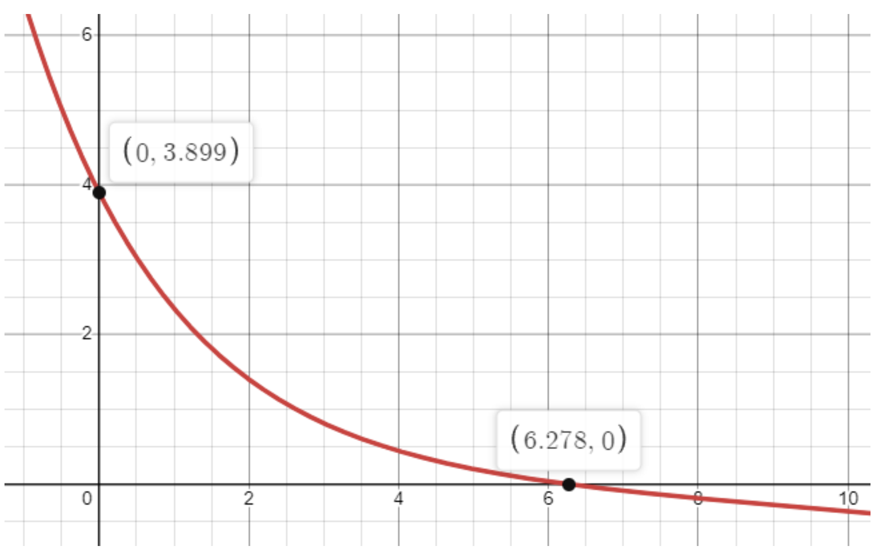
In order to obtain the inputs to our plot, the acceleration (i.e. the derivative) is simply obtained using the bike dynamics equation. The speed can be obtained by simply integrating the obtained acceleration.

This gives us the following graph:



Task X0b: Acceleration (Y) vs Speed (X)

However, as the produced plot is in my opinion hard to read, here is the equivalent plotted with the Desmos graphic calculator[2]:

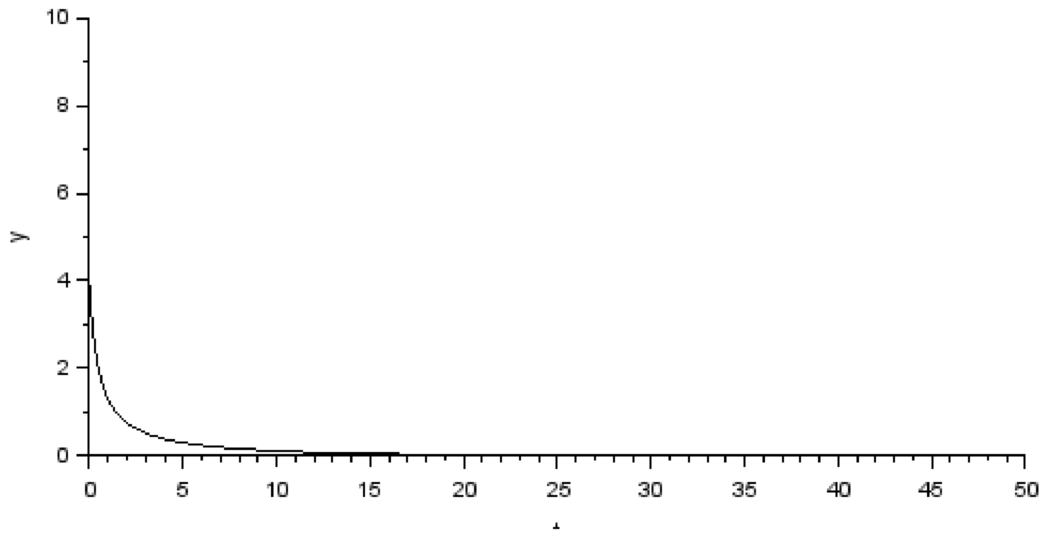


Task X0b: Acceleration (Y) vs Speed (X) (Desmos)

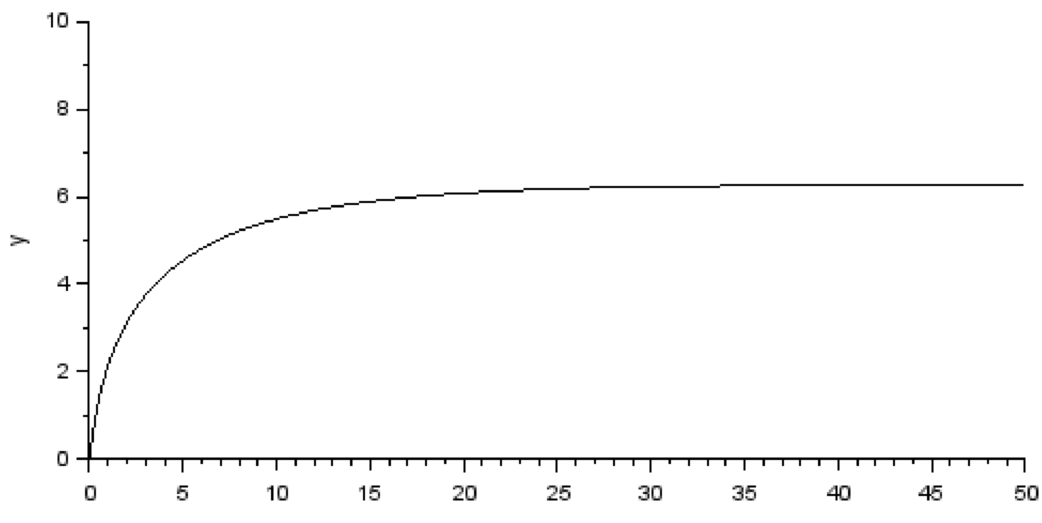
Which clearly indicates the limit value of the speed, that is of 6.278 (I suppose m/s).

[2]Image source: https://www.desmos.com/calculator

Additionally, the two plots below were added to better understand the behaviour of the acceleration and the speed over time:



Task X0b: Acceleration over time

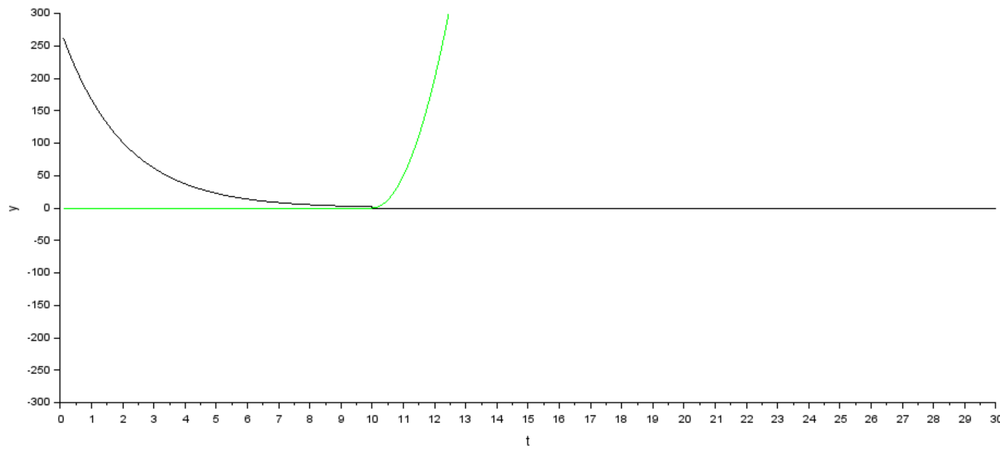


Task X0b: Speed over time

We can thus observe and confirm that as the acceleration decreases to 0, the speed tends to approximately 6.278. As the speed get closer and closer towards that value over time, we can conclude that that equilibrium is asymptotically stable.

1.3 Task X1

The below graph plots *effort vs speed*, where effort is represented on the Y axis by the human effort F_h colored in black and the braking colored in green. The speed has been modeled using the clock going from 0 to 30.

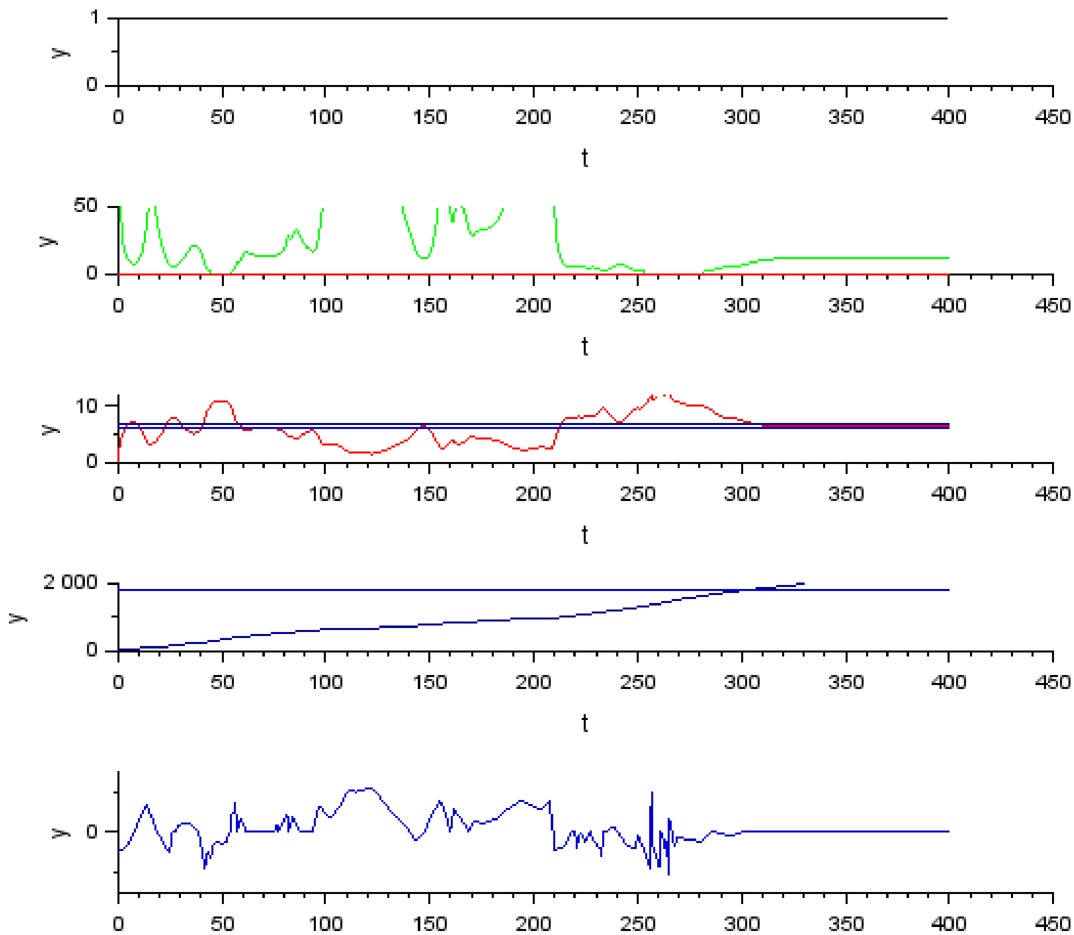


Task X1 : Black=F_h, Green=brake_request

As expected, we observe a drastic change of both functions at 10 m/s.

1.4 Task X2

This part implements the dynamics of the bike.

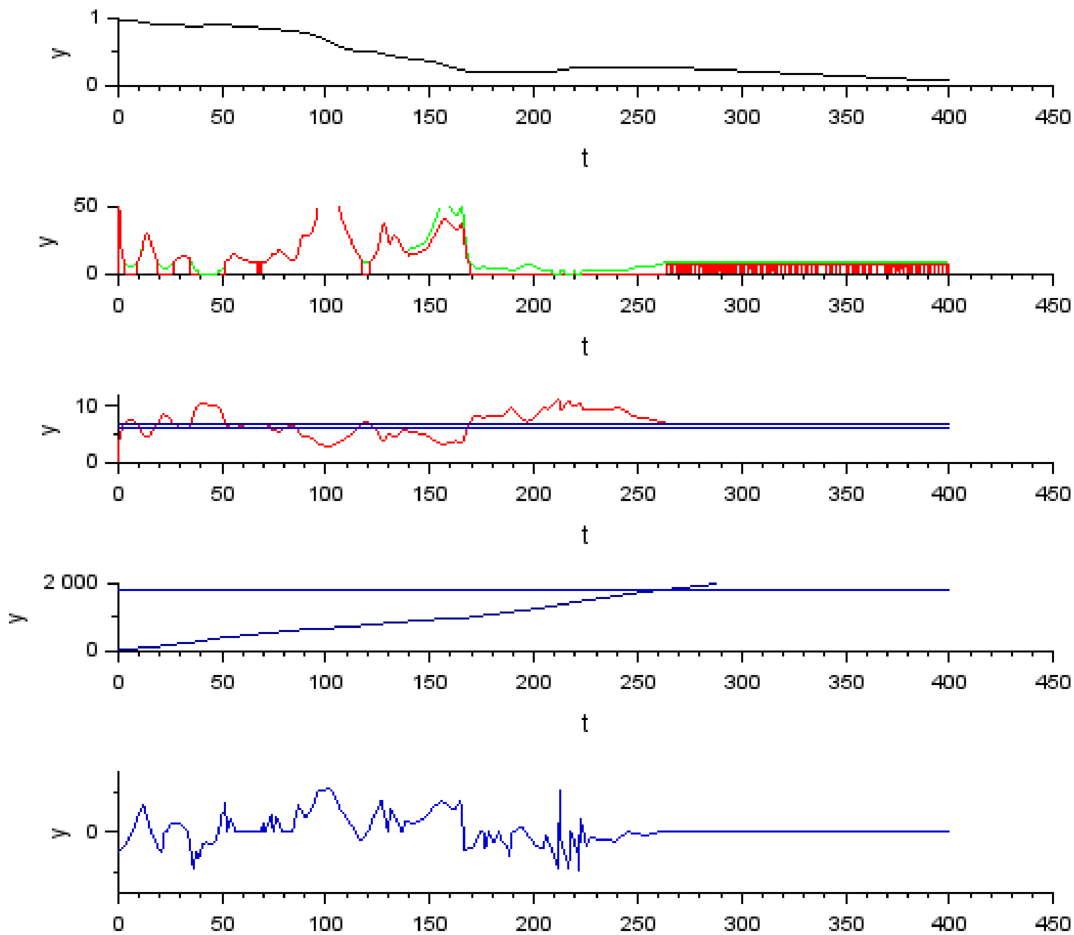


Task X2 : BL, F_h and F_e, speed, position, slope

The biker has a to travel a total distance of 1800m, as shown by the constant function in the fourth plot. This destination is reached after 300 seconds (plus some insignificant decimals), which gives an average speed of 6m/s.

1.5 Task X3

In this part we have added the basic model of electrical assistance. The simulation diagrams are given below.



Task X3 : BL, F_h and F_e, speed, position, slope

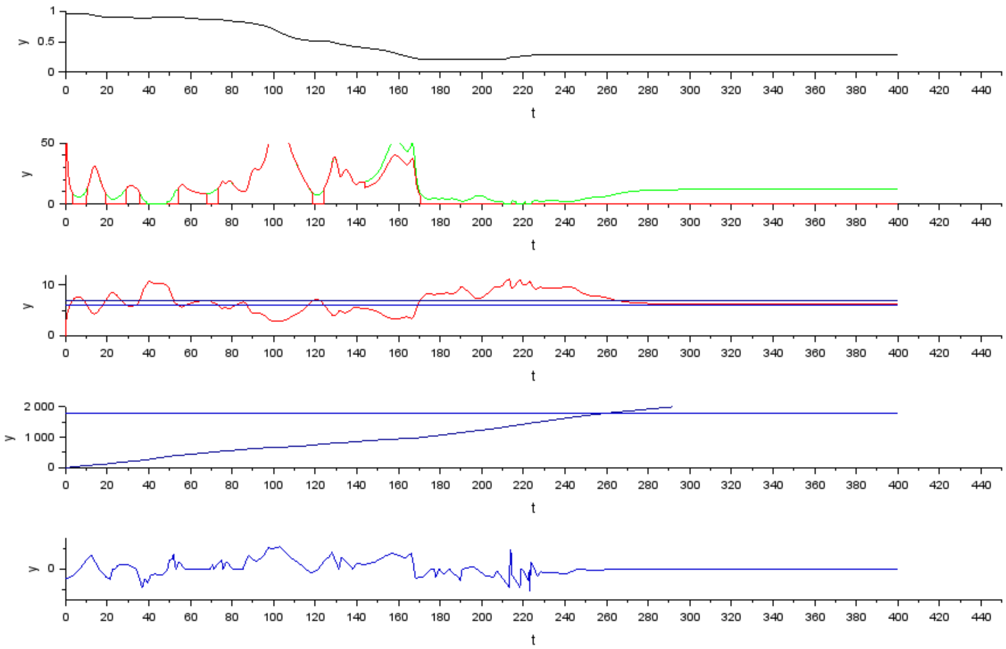
The destination is reached after 260s (around 259.97), which divided my the total distance gives the average of 6.92 m/s.

Additionally, we can observe a lot of red rectangles in the second plot after around t=260s, or even at around t=70. Those are due to the fact that the assistance is turned off on speeds above 7m/s, and that the speed is constantly fluctuating around that speed value, making the assistance frequently turning ON and OFF. This behaviour is clearly not ideal for a real-world model and it will be corrected by the advanced model implemented in the Tash X4.

1.6 Task X4

This task implements a slightly more advanced model of the electrical assistance implemented in task X3.

We have added a hysteresis behavior, which corrects the unwanted behaviour explained in the task X3.



Task X4 : BL, F_h and F_e, speed, position, slope

The travelled distance of 1800m is reached after 261S (around 261.297s), which gives an average speed of 6.89m/s.

This is slightly slower than the results obtained in in task X3: 1s total time difference and a drop of speed of around 0.03m/s. This is probably due to the fact that the assistance is off until we drop from 7m/s to 6m/s.