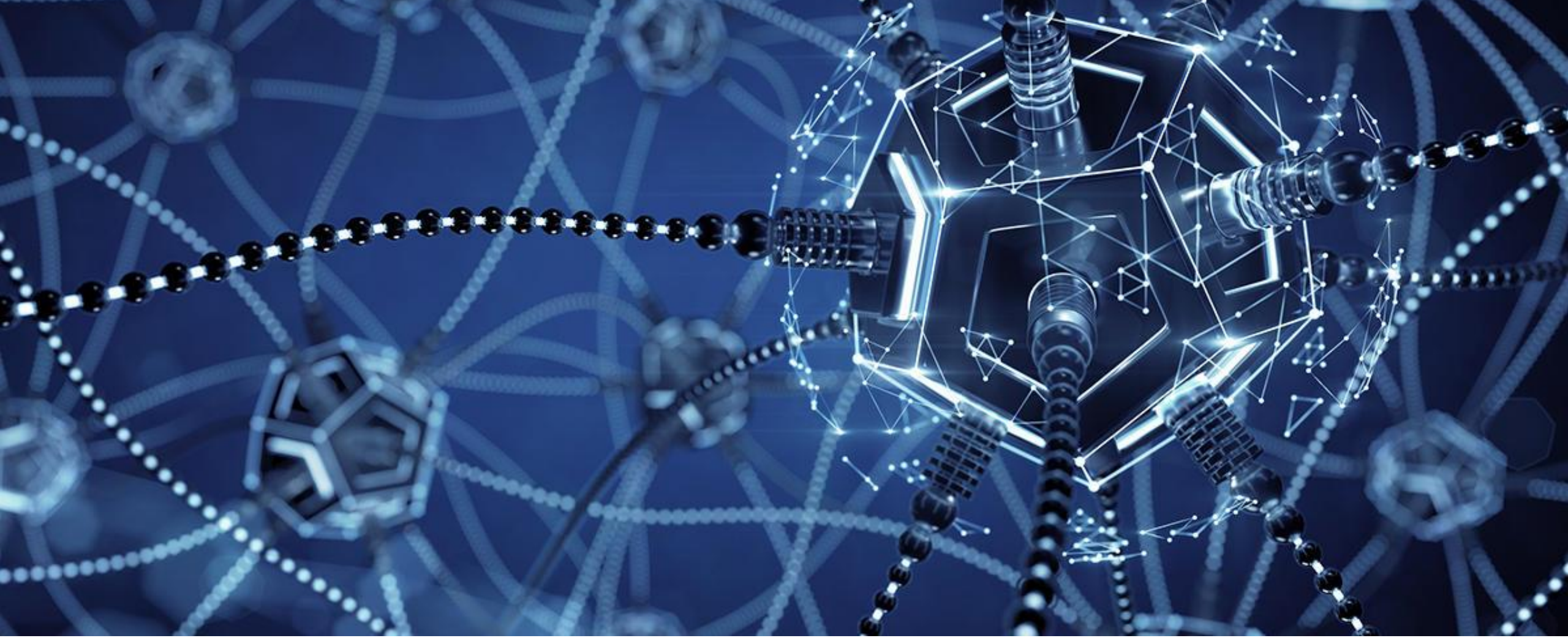


Neuromorphic systems

GeePS
Génie électrique et électronique de Paris

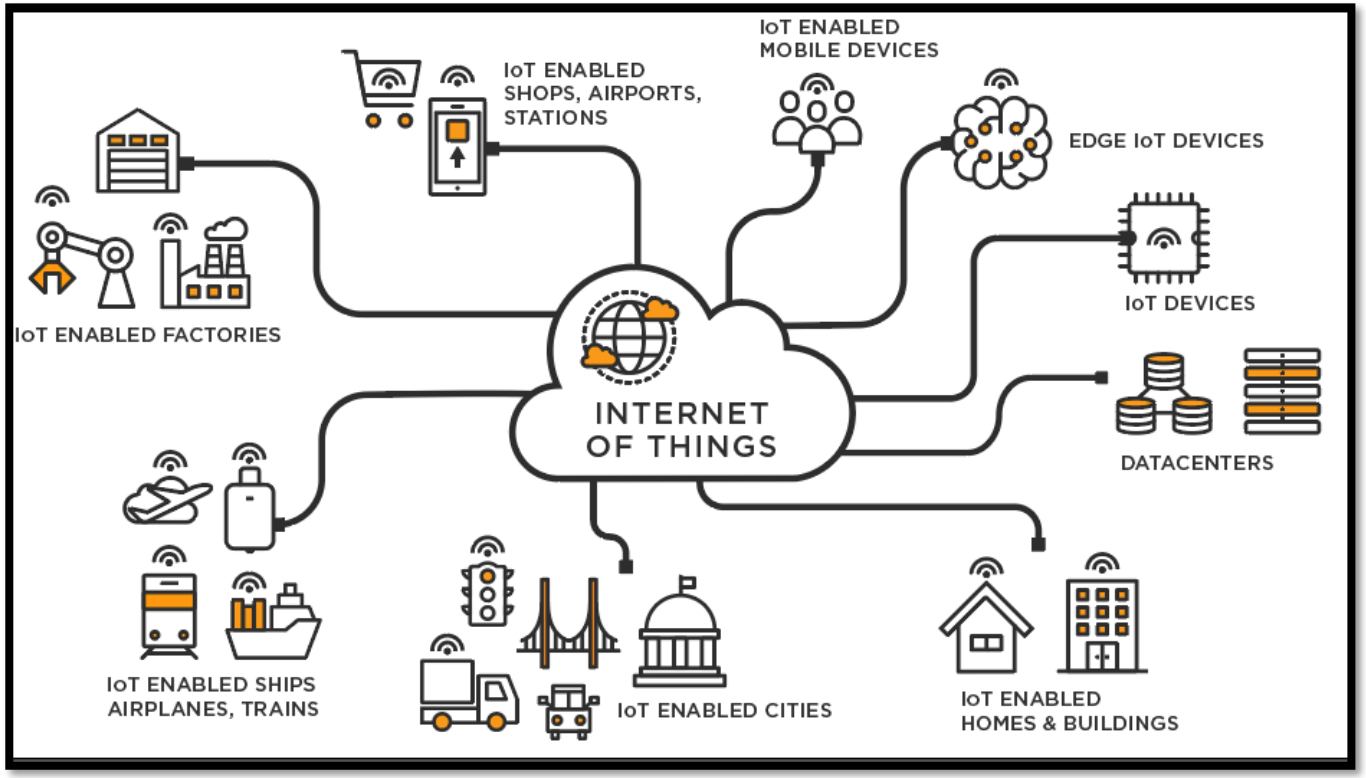
Presented by : Yousri Aboudaoud

SORBONNE UNIVERSITÉ

Summary

- Context
  - The world of today
  - The biological neuron
  - Neural models
  - The LIF model
- Modeling in Matlab
  - Modeling the LIF function
  - Interpolate the measurements of the parameters associated with the function
  - Use the interpolation polynomial in the LIF function

The world of today



Data transmission via CLOUD[1]

The world of today

How can we reduce this consumption?

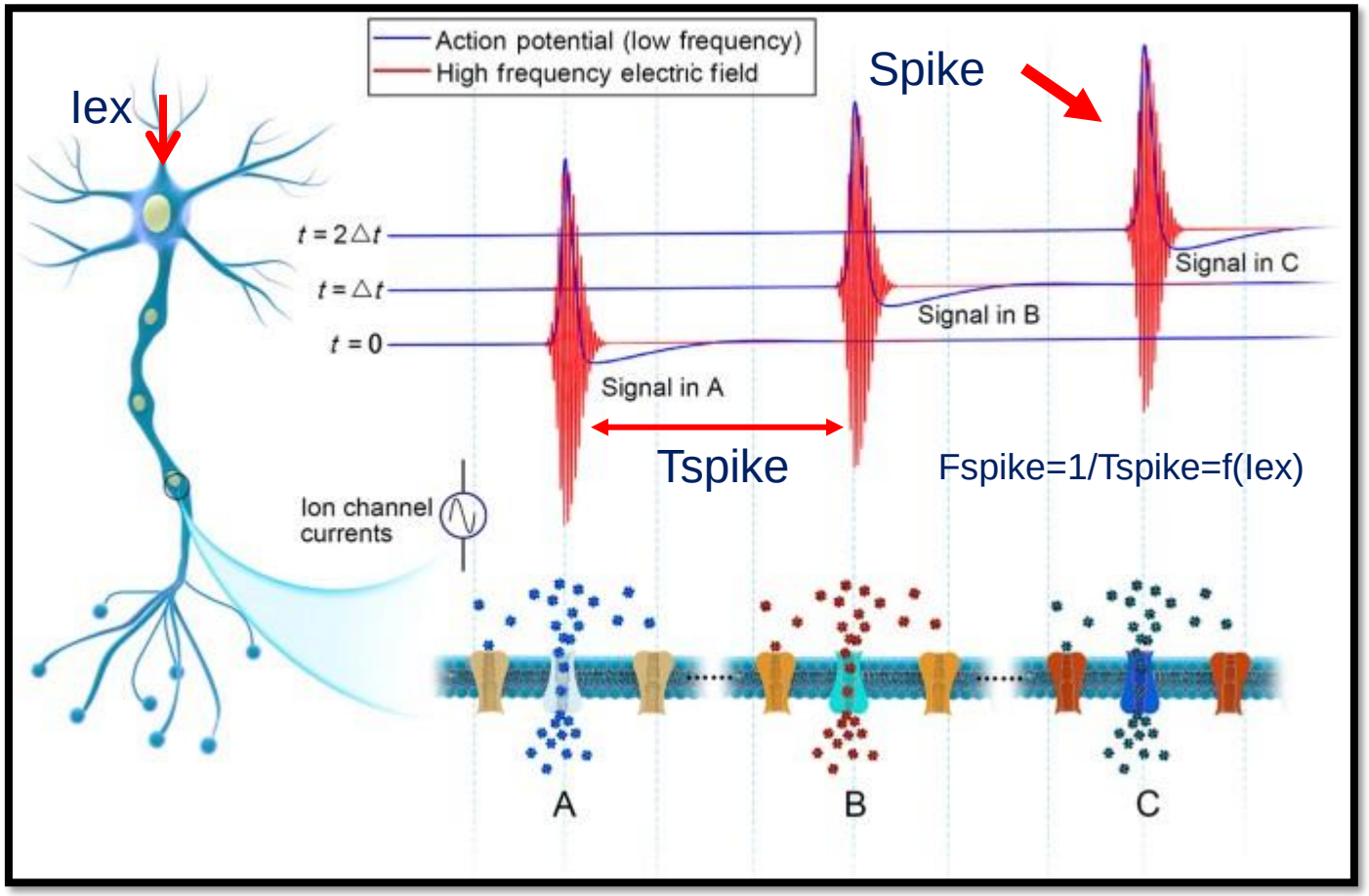
The world of today

Neuromorphic approach [2]

Reaction time: 100 ms

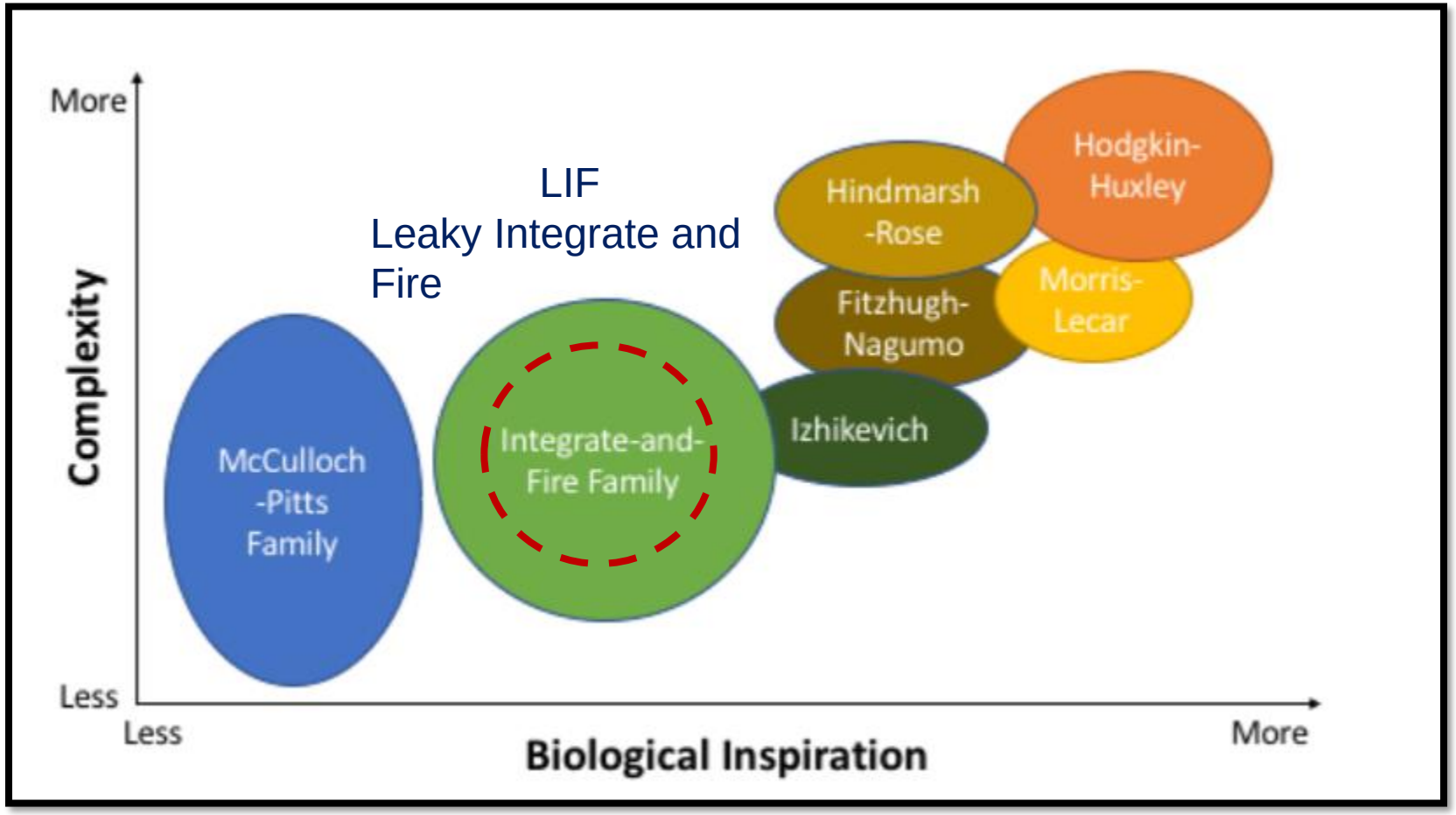
Power consumption: 20 W

The biological neuron



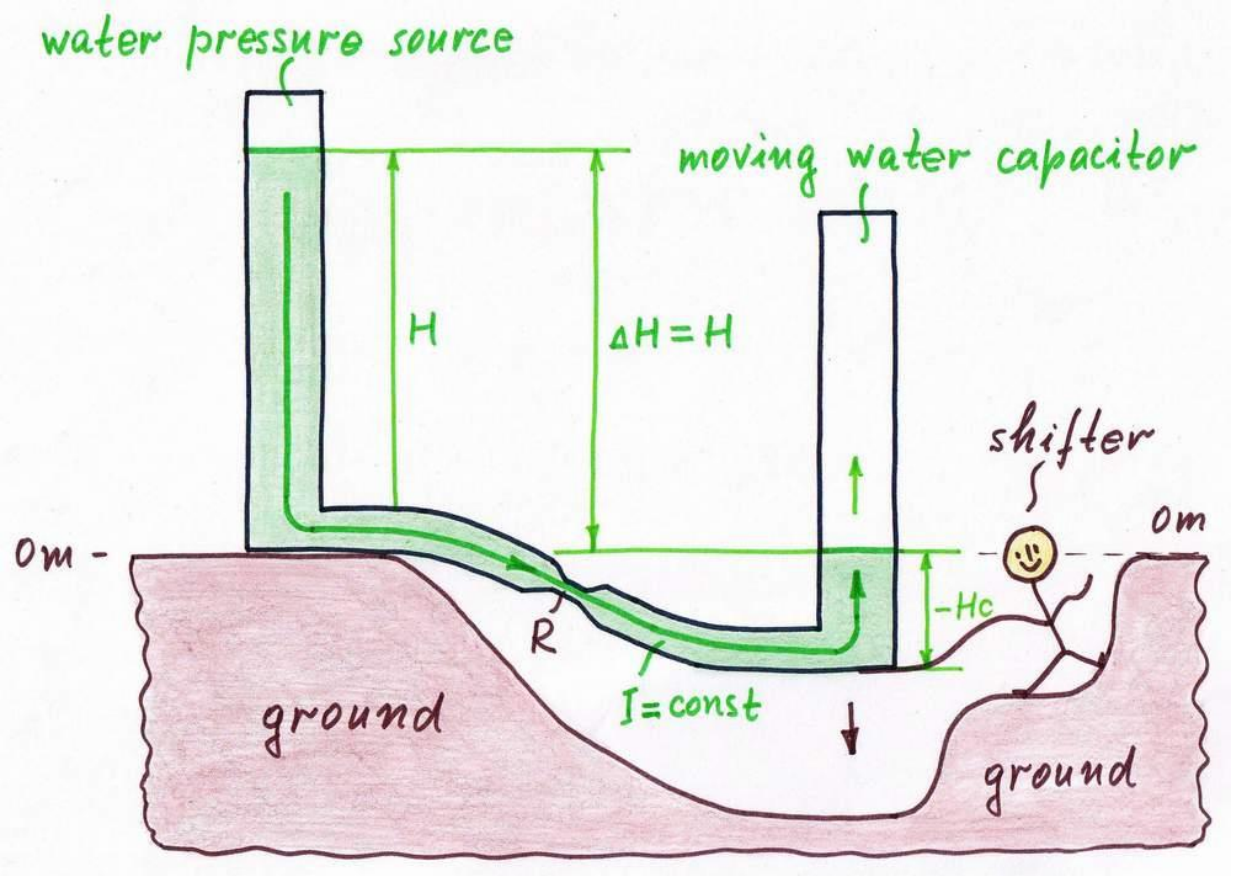
Action potential transmission procedure [3]

Neural models



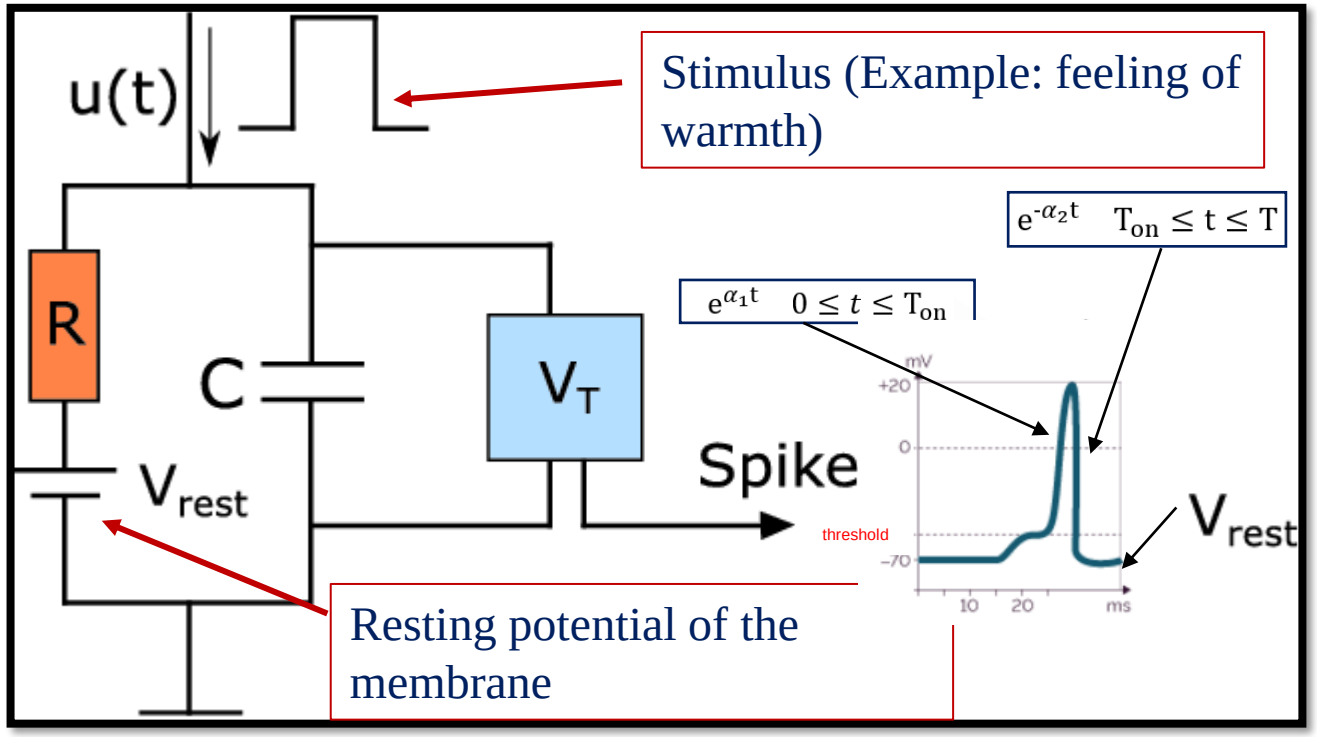
A qualitative comparison of neural models in terms of biological inspiration and neural model complexity[4]

An intuitive approach to Electronic



Water analogy of electricity [10]

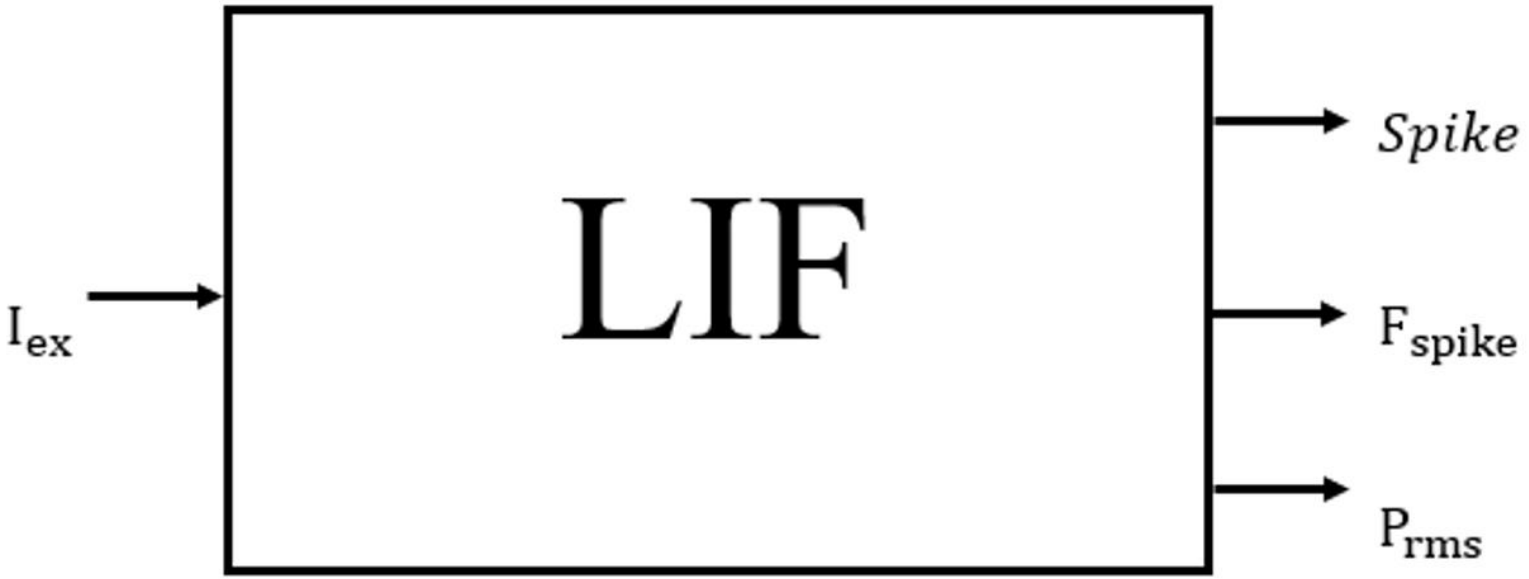
The LIF model



The Vt component has the following function: to emit an output peak if the threshold is reached, while resetting the voltage [5] & [7]

The LIF model

Modeling in Cadence?



Strength: Accurate

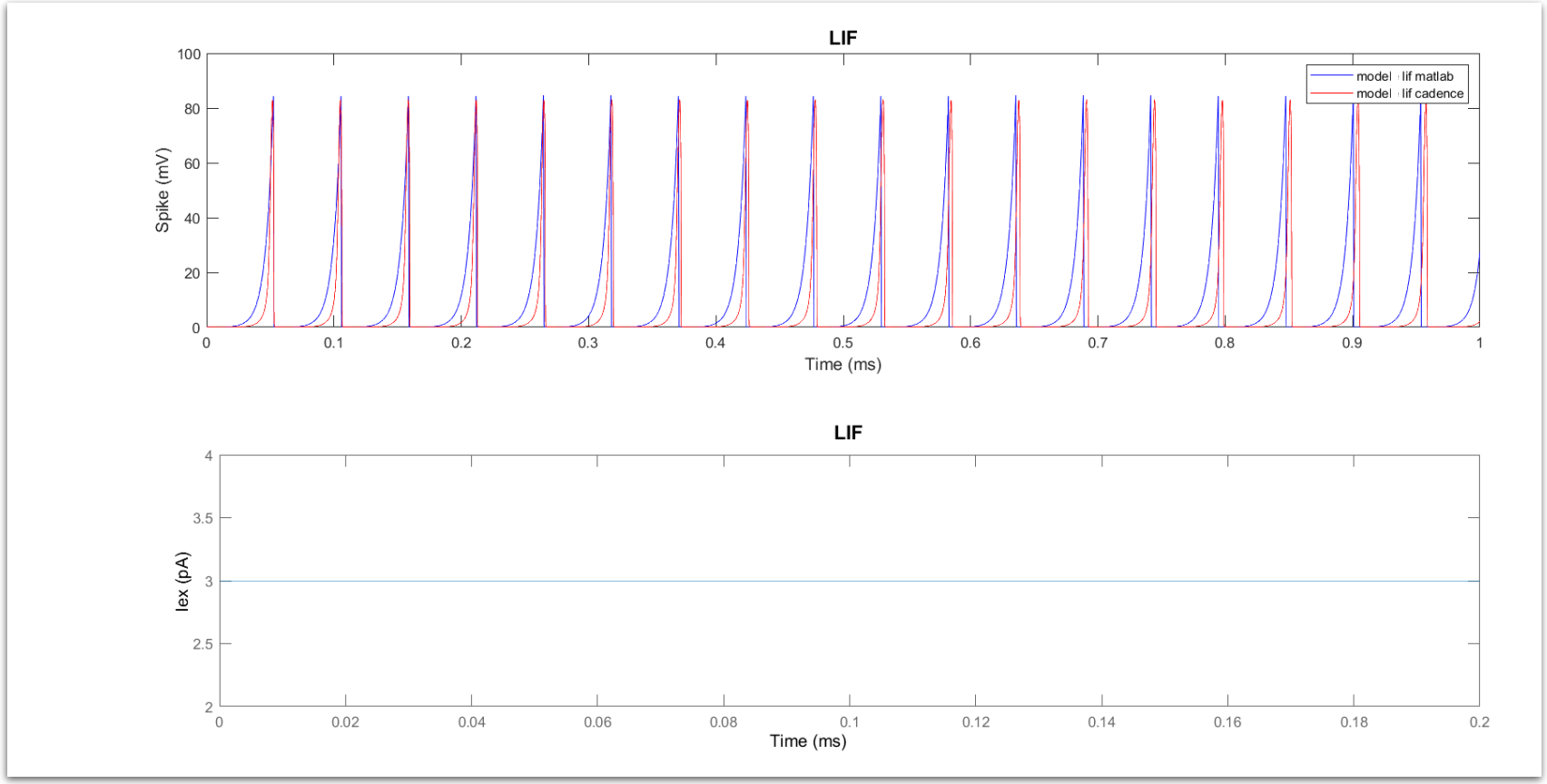
Weakness: Greedy in computation time

MODELING IN MATLAB

- Step 1: Development of the algorithm that approximates the results provided by cadence
- Step 2: Interpolate the curves of **Prms** (Power consumed by a neuron) and **Fspike** (Frequency of the action potential of a neuron) to reduce the error between Cadence and Matlab
- Step 3: Check the relations **Fspike = f(Iex)** and **Prms = g (Iex)**

➢ Objective : Modeling of the LIF model in Matlab

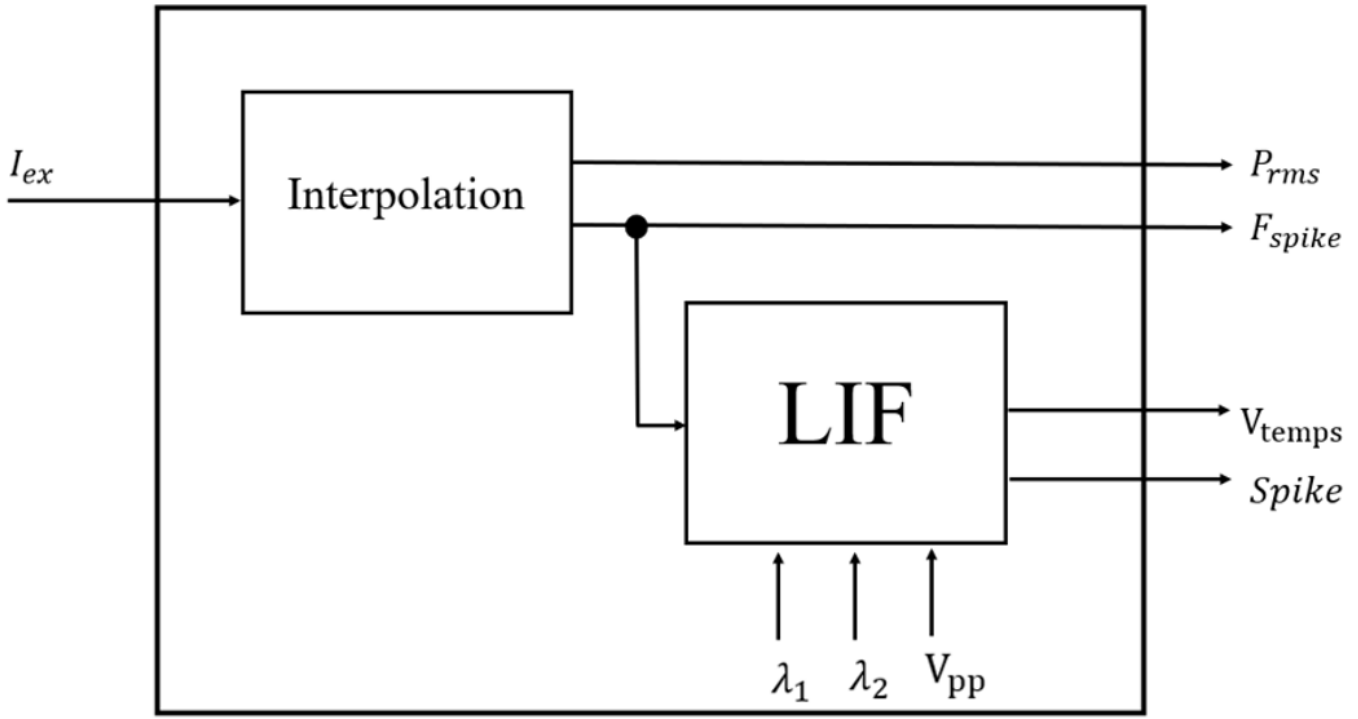
Targeted objective



Step 1: Development of the algoritme that approximates the results provided by Cadence

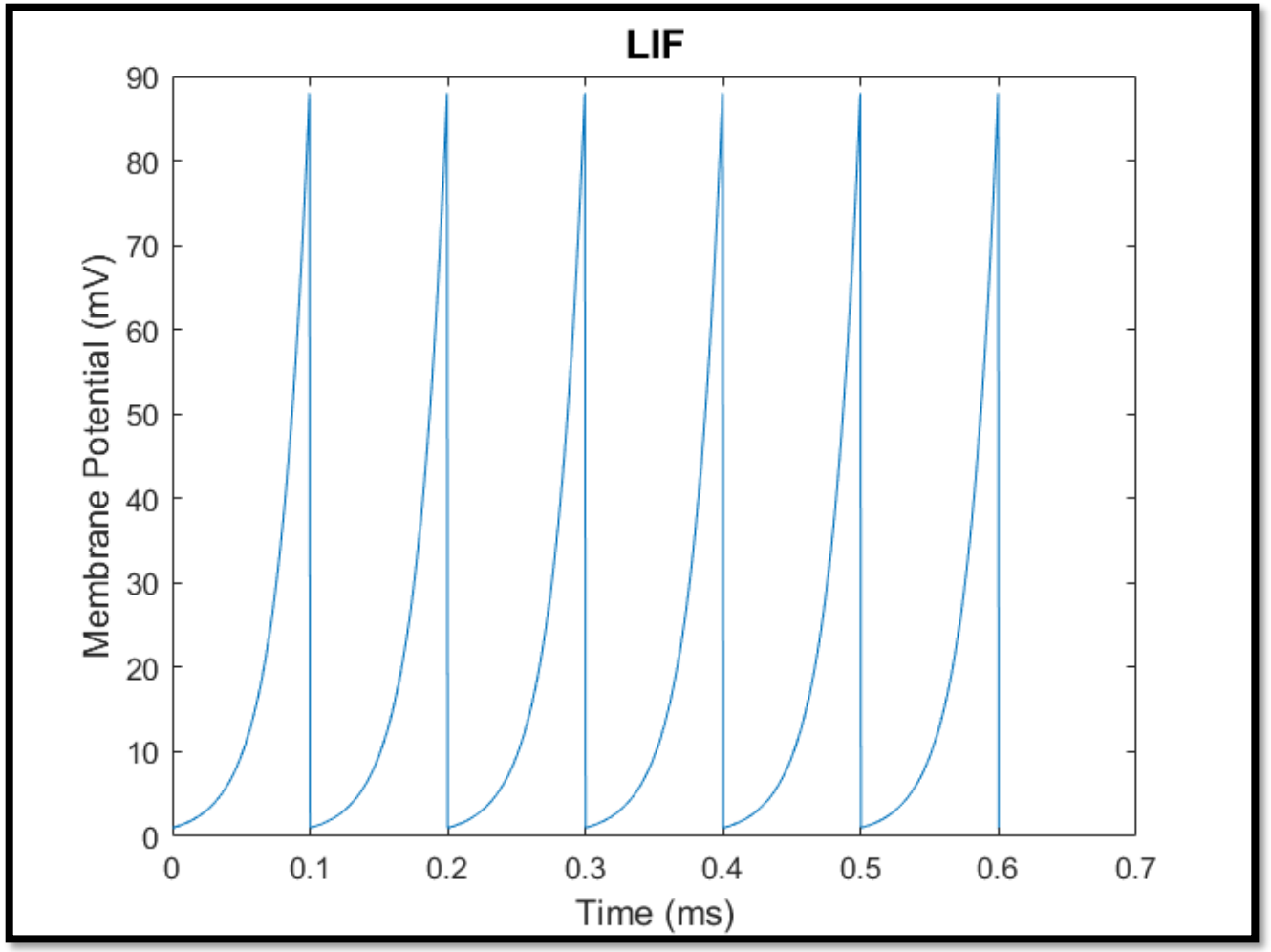
Step 1: Development of the algoritme that approximates the results provided by Cadence

Black box provided by the researchers



Step 1: Development of the algoritme that approximates the results provided by Cadence

The modeled LIF function:

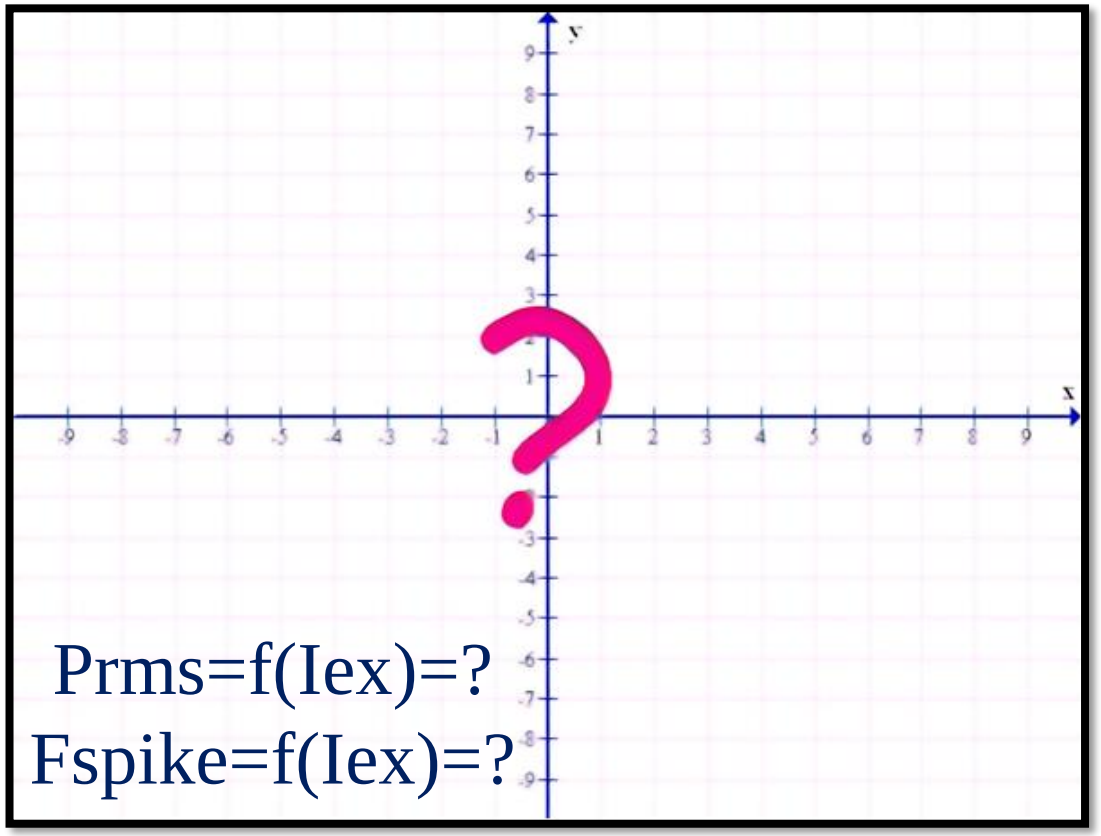


Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

Iex	Prms	fspike
17.58e-12	75.42e-12	1,00E+03
17.99e-12	75.72e-12	1,00E+03
18.41e-12	75.7e-12	1,00E+03
18.83e-12	76.05e-12	1,00E+03
19.26e-12	76.5e-12	1,00E+03
19.71e-12	76.7e-12	1,00E+03
20.16e-12	81.99e-12	2,00E+03
20.63e-12	86.94e-12	3,00E+03
21.1e-12	103.3e-12	5,00E+03
21.59e-12	110.4e-12	5,00E+03
22.09e-12	114.0e-12	6,00E+03
22.6e-12	124.1e-12	7,00E+03
23.12e-12	130.6e-12	8,00E+03
23.65e-12	144.3e-12	1,00E+04
24.2e-12	154.9e-12	1,20E+04
24.75e-12	162.0e-12	1,30E+04
25.33e-12	166.6e-12	1,40E+04

Cadence data



What is the expression of the function? [6]

Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

2 Matlab commands

P = polyfit(X,Y,N)

Example :

- f(X)=Y for X∈ I,

If we put N “The order” equals to 2, P returns a vector containing the coefficients of a 2nd degree polynomial : [a , b , c]

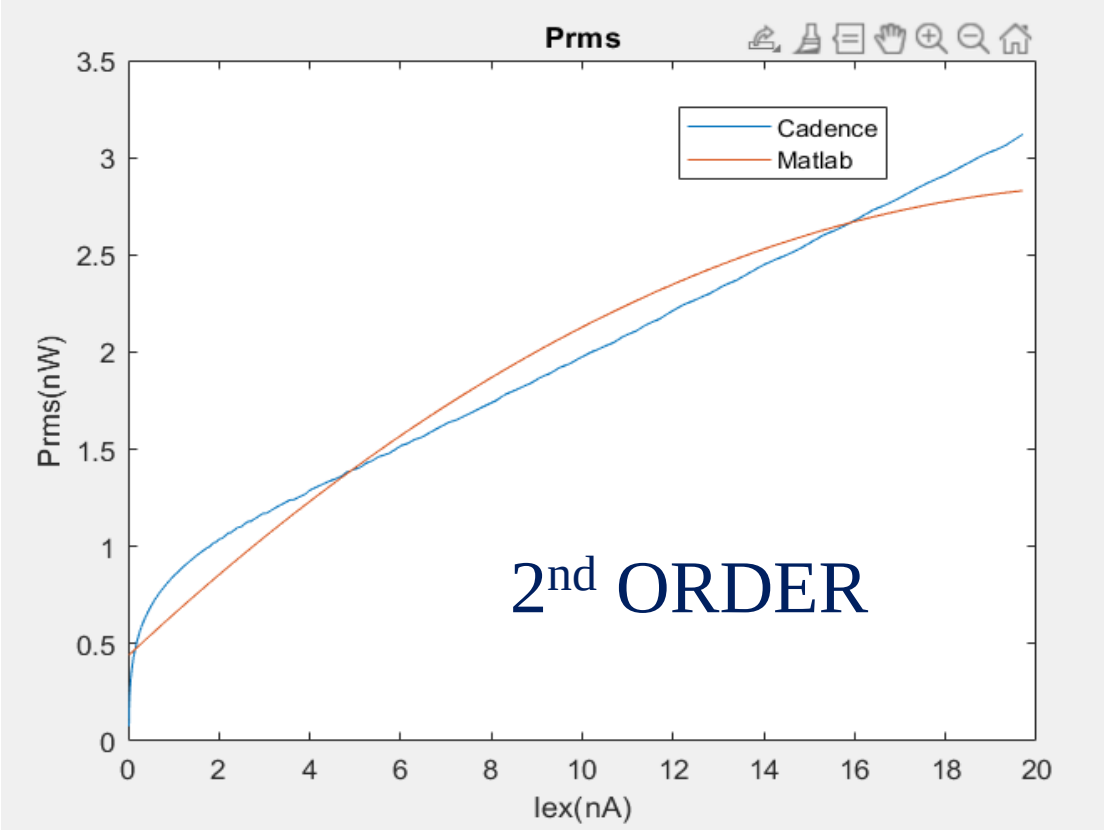
Y2 = polyval(P,X)

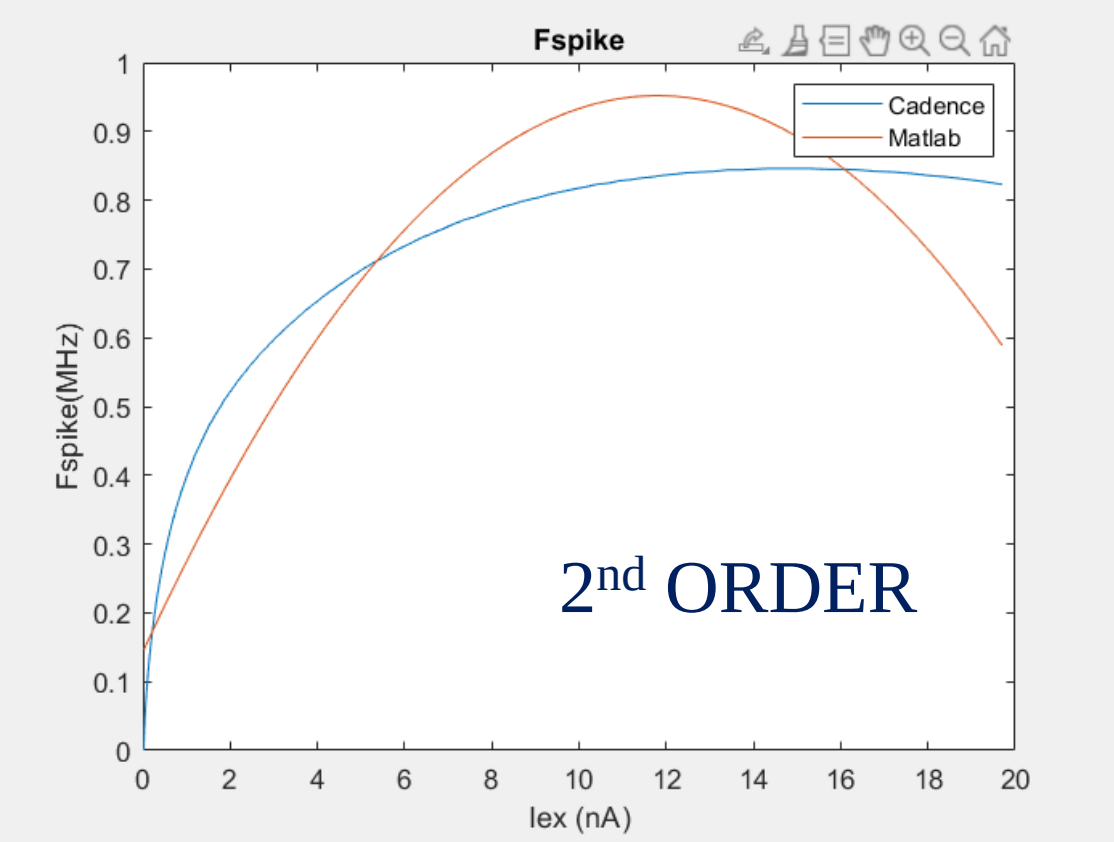
Example :

- P = [a, b, c] for N=2;

Y2 = a. X^2 + b. X + c

Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab





Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

RMSE (root mean square error) [8]

$$\mathrm{RMSE} = \sqrt{\sum \frac{(y_{pred} - y_{ref})^2}{N}}$$

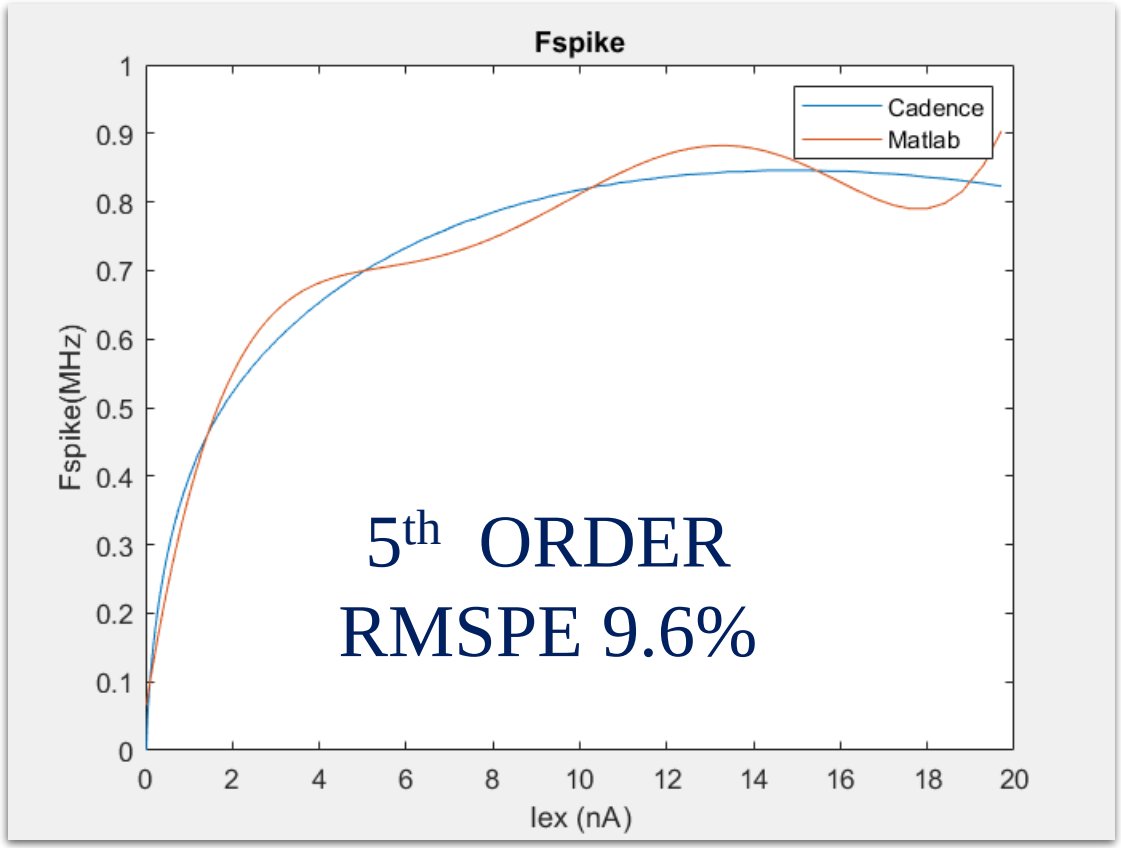
RMSPE (root mean square percentage error) [9]

$$\mathrm{RMSPE} = \sqrt{\frac{100\%}{n} \cdot \sum_{i=1}^{n} \Delta X_{\mathrm{rel},i}^2}$$

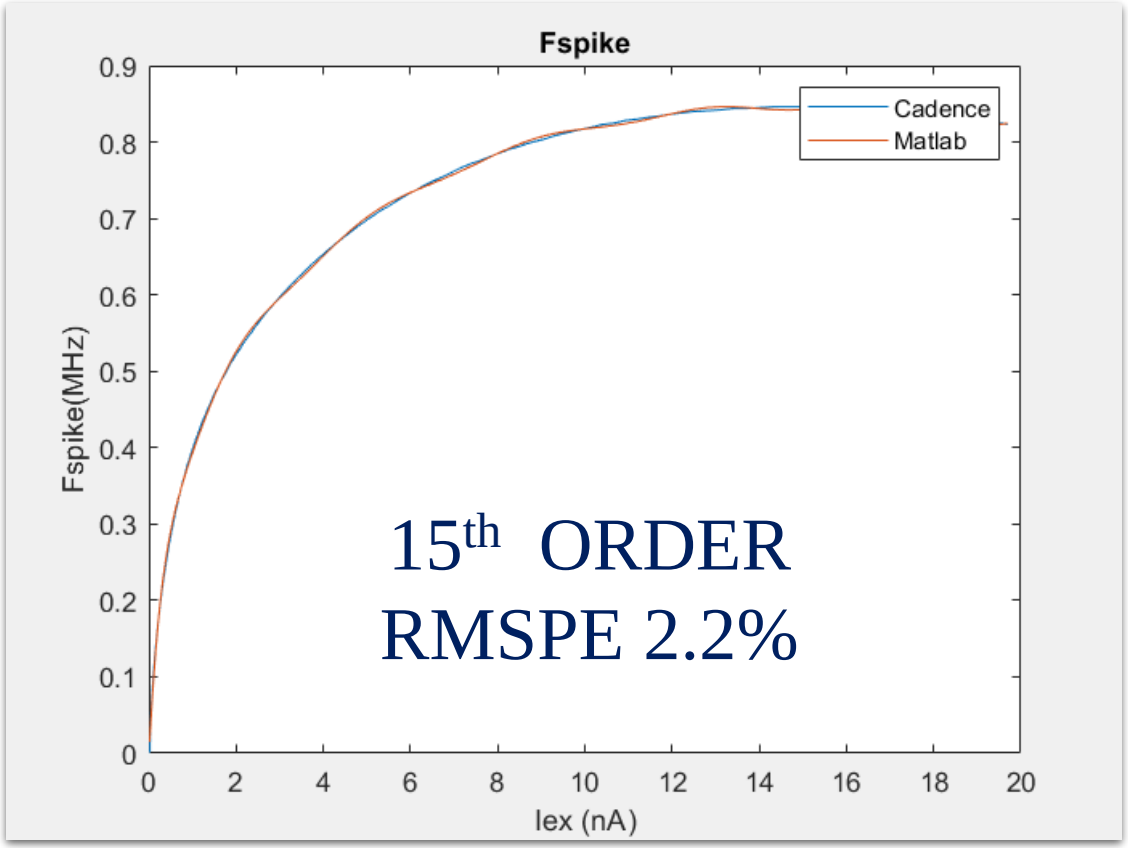
$$\Delta X_{\mathrm{rel},i} = \frac{X_i}{T_i} - 1,$$

Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

Fspike :



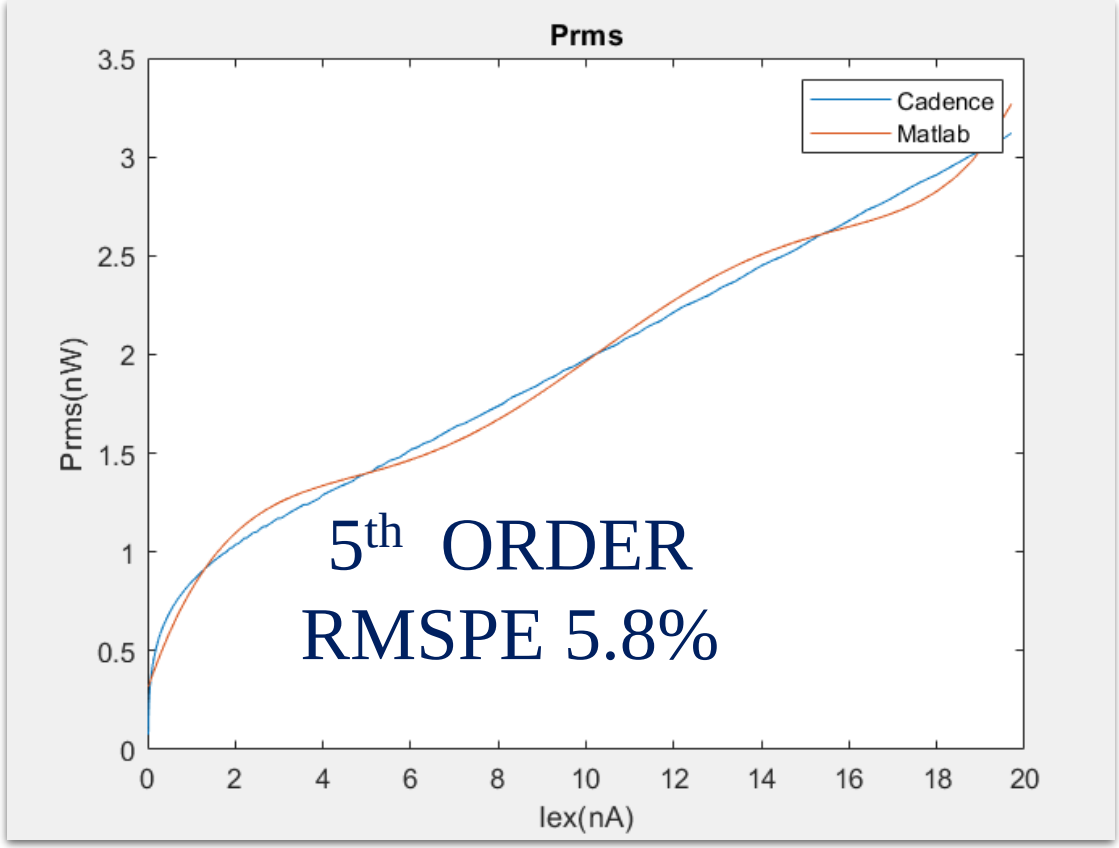
5th ORDER
RMSPE 9.6%

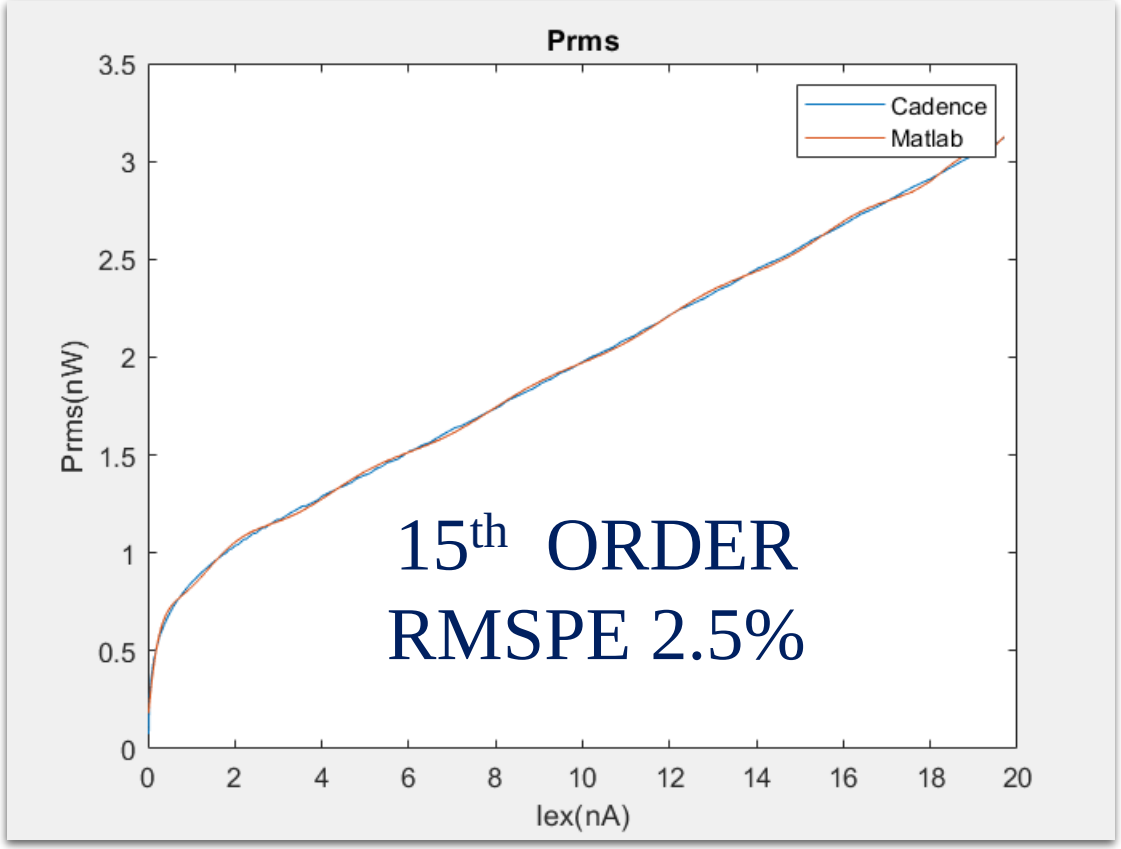


15th ORDER
RMSPE 2.2%

Step 2: Interpolate the curves of **Prms** and **Fspike** to reduce the error between Cadence and Matlab

Prms :





Step 3: Check the relations **Fspike = f(Iex)** and **Prms = g (Iex)**

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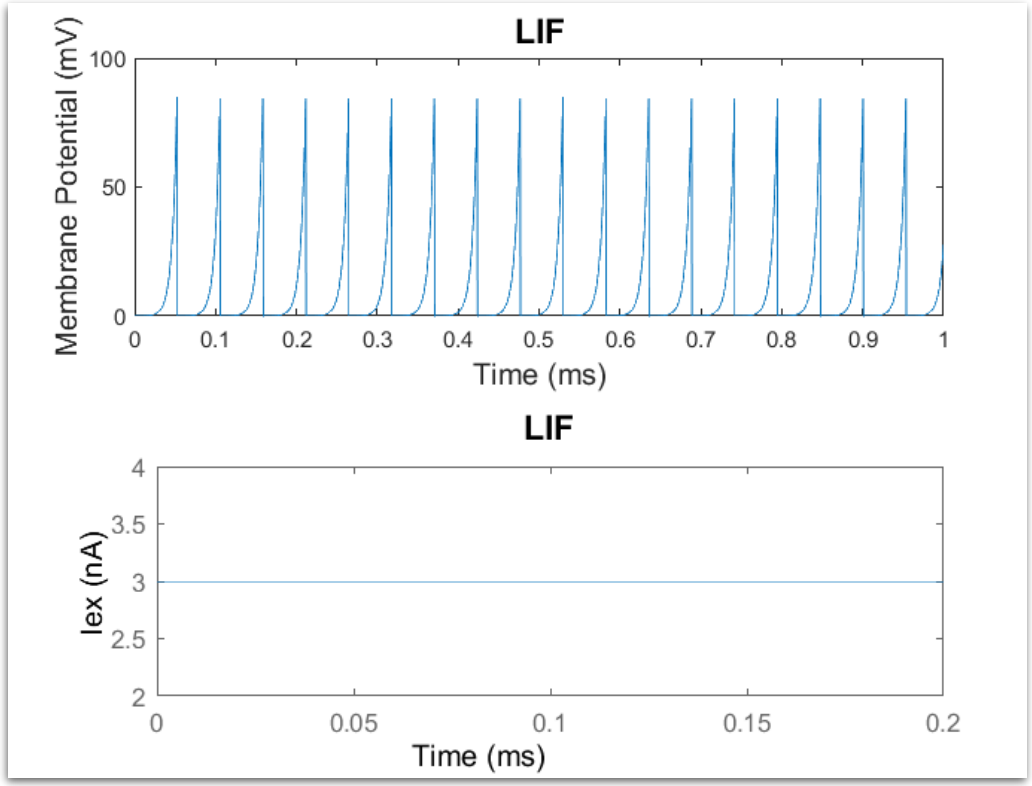
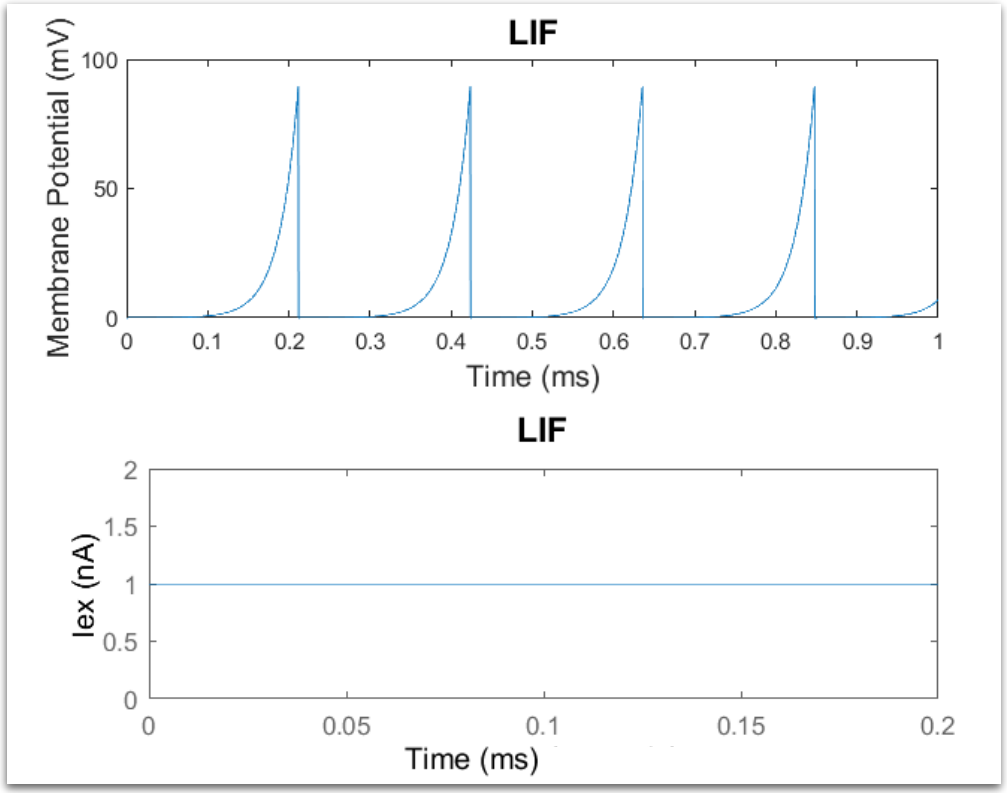
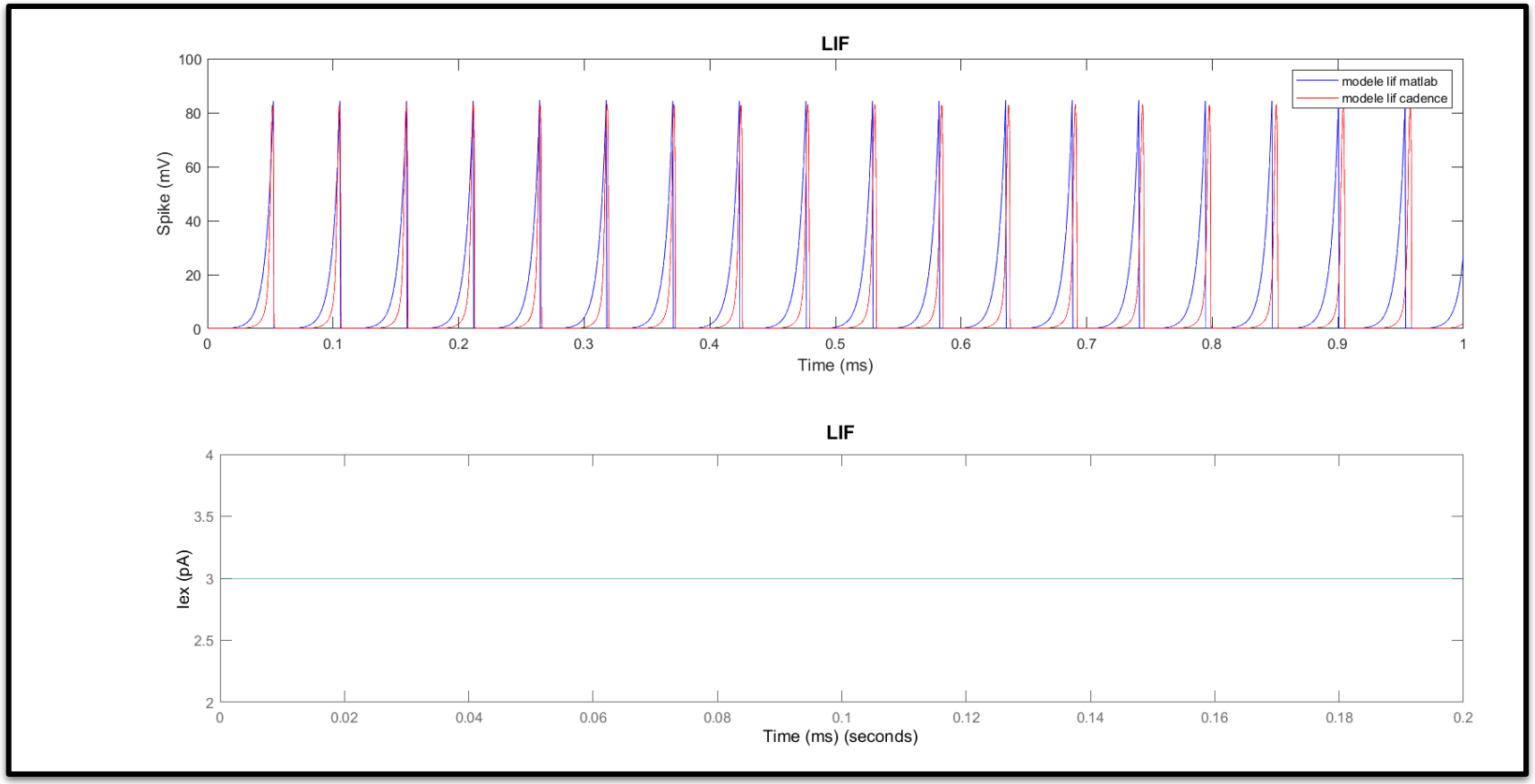


Iex = 3 nA
Fspike = 27.8 kHz



Iex = 1 nA
Fspike = 6.9 kHz

Step 3: Check the relations **Fspike = f(Iex)** and **Prms = g (Iex)**



15th ORDER
RMSPE 9.2 %*

* Percentage imposed by the researchers

Conclusion

-Contemporary issues

- Humongous Data Exchange
- Humongous energy consumption

-Neuromorphic solution

- Inspired by the brain
- Good compromise betwen complexity of realization and the degree of bio-inspiration

-Modeling in Matlab

- With Fspike and Prms being modelled as functions of Iex
- Cadence/Matlab Comparison

Thank you for listening

Questions ?

List of works quoted

- [1] « Qu'est ce que l'internet des objets (IoT) ». TIBCO Software, https://www.tibco.com/fr/reference-center/what-is-the-internet-of-things-iot. Consulté le 2 décembre 2021.
- [2] Futura, Janlou Chaput. « Votre cerveau en 15 chiffres clés ». *Futura*, https://www.futura-sciences.com/sante/actualites/biologie-votre-cerveau-15-chiffres-cles-51904/. Consulté le 21 décembre 2021.
- [3] Xiang, Zuoxian, et al. « A New Viewpoint and Model of Neural Signal Generation and Transmission: Signal Transmission on Unmyelinated Neurons ». Nano Research, vol. 14, no 3, mars 2021, p. 590-600. Springer Link, https://doi.org/10.1007/s12274-020-3016-1.
- [4] Schuman, Catherine D., et al. « A Survey of Neuromorphic Computing and Neural Networks in Hardware ». arXiv:1705.06963 [cs], mai 2017. arXiv.org, http://arxiv.org/abs/1705.06963.
- [5] Chowdhury, Sayeed & Lee, Chankyu & Roy, Kaushik. (2020). Towards Understanding the Effect of Leak in Spiking Neural Networks, p.2.

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- [6] Stéphane. "math et info à pásztó: Équations-méthode graphique". math et info à pásztó, mercredi juin 2011, http://math-info-paszto.blogspot.com/2011/06/equations-methode-graphique.html

- [7] 《Intégration du message nerveux par le motoneurone》. MAXICOURS, https://www.maxicours.com/se/cours/integration-du-message-nerveux-par-le-motoneurone/.

- [8] Zell, Jürgen et al. "Estimation de la biomasse aérienne des arbres : comparaison de l'étalonnage bayésien avec la technique de régression". European Journal of Forest Research, volume 133, numéro 4, juillet 2014, pages 649 à 60. Springer Link, https : / /doi.org/10.1007/s10342-014-0793-7.

- [9] rms-Quelle est la définition correcte de l'erreur quadratique moyenne en pourcentage (RMSPE) ?-Cross Validated. https://stats.stackexchange.com/questions/413249/what-is-the-correct-definition-of-the- root-mean-square-percentage-error-rmspe. Vue le 2 décembre 2021.

- [10] File:Philosophy Hydraulic Analogy 1000.Jpg - Wikibooks, Open Books for an Open World. https://commons.wikimedia.org/wiki/File:Philosophy_hydraulic_analogy_1000.jpg. Consulté le 27 septembre 2022.