Mid-term project

Project description: This project aims to implement a spiking neuron layer (32×32) that encode an input image and to evaluate the spike-count rate for the spiking neurons.

Project goals:

- Implementation of Poisson spike encoder for an input image
- Implementation of convolution of Poisson spike maps using a Gabor function
- Implementation of the synapse and LIF models (Chapters 3 and 6)
- Evaluation of spike-count rate for each spiking neuron

Approaches: The simulated period T is 1 s with a timestep width Δt of 1 ms (i.e., 1,001 timesteps).

Step 1: Encoding a given input image as spikes
Take an 8-bit gray-scaled Lena image (512×512) as in input image. Each gray-scale pixel value ($0 - 255$) is first scaled and used as a spike-firing rate a. The maximum firing rate a_{max} is set to 100 Hz, so that each pixel value should be scaled in the range $0 - 100$ Hz. Then, encode the image as a Poisson spike map using the spiking probability $p = a\Delta t$. This encoding should be executed over the whole 1,001 timesteps.

Step 2: Convolution of the spike map at each timestep using the Gabor kernel
At each timestep, convolve the 512×512 spike map using the following 16×16 kernel (Gabor filter).
Kernel specification: 16×16, $\sigma_x = \sigma_y = 2$, $k = 1$, $\phi = \pi/2$. This is used as an input to the 32×32 spiking neuron layer.

Step 3: Evaluation of synaptic current over time
Evaluate the synaptic current to each spiking neuron using the synapse models addressed in Chapter 5 (without the upper limit of channel-opening probability). Note that the weight w in the synapse model corresponds to each kernel value in the Gabor kernel. Use a synaptic current decay time-constant τ_s of 20 ms ($\tau_s = 20$ ms).

Step 4: Evaluation of membrane potential over time
Evaluate membrane potential for each neuron in the 32×32 spiking neuron layer. The synaptic current evaluated in the previous step is used as the input current to each neuron. To this end, use the LIF model in Chapter 3. Evaluate the membrane potential over the 32×32 layer over the whole timesteps and the generated spike map. Use the following neuronal parameters.

- Membrane potential time-constant τ_m: 40 ms
- Resistance of the leakage channel R: 1 ohm
- Resting potential u_{rest}: 0 V
- Spiking threshold u_{th}: 50 mV

Step 5: Evaluation of spike-count rate over the layer
Evaluate the spike-count rate for all neurons in the 512×512 layer. Visualize the rate over the layer using a color map.