بسمه تعالی

دانشگاه شهید بهشتی

دانشکده علوم ریاضی

گزارش پروژه

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گردآورنده :

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هدف ساخت تعدادی نرون هست که در کنار یک دیگر یک جمعیت نرونی را تشکیل دهند و برای ساخت آنها از مدل های تمرین قبل استفاده میکنیم . ابتدا پارامترهای مختلف را به آنها میدهیم و مقایسه میکنیم . این مجموعه نرون ها تشکیل شده اند ازنرون های تحریکی و نرون ها مهاری . تعداد نرون ها به ترتیب 800 و 200 و در مجموع 1000 تاست (برای اجرای بهتر از 80 و 20 استفاده شده)

تعریف توابع و نمودار ها

```
def plot_mv_ms(mv, time_list, name="", top=None, bottom=None,
save=False, max_x=0):
    plt.plot(time_list, mv)
    plt.xlim(max_x, len(time_list)*0.03125)
    plt.ylim(top=top, bottom=bottom)
    plt.ylabel('Membrane Potential (mV)')
    plt.xlabel('Time (ms)')
    if name!="": name=" for "+name
    name="Voltage-Current"+name
    plt.title(name)
    if save: plt.savefig(name)
    plt.show()


def plot_current(current, time_list, name="", save=False,
max_x=0):
    from matplotlib.pyplot import figure
    figure(figsize=(10, 5), dpi=80)
    plt.plot(time_list, current)
    plt.xlim(max_x, len(time_list)*0.03125)
    plt.ylabel('Input current (pA)')
    plt.xlabel('Time (ms)')
    if name!="": name=" for "+name
    name="Time-Current"+name
    plt.title(name)
    plt.xlim(max_x)
    if save: plt.savefig(name)
    plt.show()


def plot_internal_current(current, time_list, name=1,top=None,
bottom=None):
    plt.plot(time_list, current)
    plt.ylabel('Adaption current (pA)')
    plt.xlabel('Time (ms)')
    plt.ylim(top=top, bottom=bottom)
    if name!=1: name=" for "+name
    name="Time-Adaption Current"+str(name)
    plt.title(name)
    # plt.savefig(name)
```

```
    plt.show()


def plot_raster(spike_history, idx_neuron, neuron_type,
activity, runtime, dt, min_t=0):
    fig = plt.figure(figsize=(8, 6))
    gs = fig.add_gridspec(2, 1)
    raster = fig.add_subplot(gs[0, 0])
    raster.set_title("Raster plot")
    raster.set(ylabel="Neuron", xlabel="time(S)")
    sns.scatterplot(ax=raster, y=idx_neuron, x=spike_history,
hue=neuron_type, marker='.')
    raster.set(xlim=(min_t, runtime))

    pop_activity = fig.add_subplot(gs[1, 0])
    pop_activity.set_title("Population activity")
    pop_activity.set(ylabel="A(t)", xlabel="time(S)")
    sns.lineplot(ax=pop_activity, x=np.arange(0, runtime, dt),
y=activity)
    pop_activity.set(ylim=(0, 0.015))
    pop_activity.set(xlim=(min_t, runtime))

    fig.show()
```

در این بخش روابط نرون ها به هم را نشان میدهیم مثلا اینکه اتصالات بین آنها کامل یا به صورت رندوم با درصد خاصی باشد :

```
class FullyConnectedPopulation:
    def __init__(self, J=0.5, stdp_eng=None, *args, **kwargs):
        self.J=J
        self.neurons = []
        self.conection_count=0
        self.stdp_eng=stdp_eng

        delay_range=(1,5); self.delay_seg=4
        self.delay_period=(delay_range[1]-
delay_range[0])/self.delay_seg
        self.delay_timer=0

        self.populate_neurons(*args, **kwargs)
        self.create_network()

    def populate_neurons(self, n_type=None, n_config=None,
excitatory=None, inhibitory=None, *args, **kwargs):
        for i in range(excitatory):
            self.neurons.append(n_type(is_exc=True, **n_config))
        for i in range(inhibitory):
            self.neurons.append(n_type(is_exc=False,
```

```
**n_config))

    def create_network(self):
        for pre_neuron in self.neurons:
            for post_neuron in self.neurons:
                self.connect_neurons(pre_neuron, post_neuron)

    def connect_neurons(self, pre_neuron, post_neuron):
        if self.decide_to_connect() and post_neuron !=
pre_neuron:
            self.conection_count += 1
            pre_neuron.post_syn.append([post_neuron,
[self.decide_weight() for i in range(self.delay_seg)]])
            post_neuron.pre_syn.append([len(pre_neuron.post_syn)
- 1, pre_neuron])
            post_neuron.pre_syn_input_delayed = [0 for i in
range(self.delay_seg)]

    def decide_to_connect(self):
        return True

    def decide_weight(self):
        return self.J / self.conection_count + np_normal(0.0,
0.001)

    def fix_neurons(self, input_spike_list, output_spike_list):
        for neuron, to_spike in zip(
                self.input_neurons+self.output_neurons,
input_spike_list+output_spike_list):
            neuron.syn_input=0;neuron.pre_syn_input=0
            if to_spike: neuron.U=neuron.U_spike+10
            elif neuron.U>neuron.U_reset:
neuron.U=neuron.U_reset

    def simulate_network_one_step(self, I_t):
        u_history=[]
        i_history=[]
        for neuron in self.neurons:
            inter_U, curr = neuron.simulate_one_step(I_t)
            u_history.append(inter_U)
            i_history.append(curr)

        if self.delay_timer<=0:
            self.delay_timer=self.delay_period
            for neuron in self.neurons:
                neuron.syn_input +=
neuron.pre_syn_input_delayed[0]
                for _, post_w in neuron.post_syn:
```

```
                    neuron.pre_syn_input_delayed = [psi +
w*neuron.pre_syn_input
                         for w, psi in
zip(post_w,neuron.pre_syn_input_delayed[1:]+[0])]
                neuron.pre_syn_input = 0
        else: self.delay_timer -= neuron.dt

        for neuron in self.neurons:
            if self.stdp_eng!=None and neuron.last_fired:
self.stdp_eng.train(neuron)

        return u_history, i_history


class FixedCouplingPopulation(FullyConnectedPopulation):
    def __init__(self, prob, *args, **kwargs):
        self.prob = prob
        super().__init__(*args, **kwargs)

    def decide_to_connect(self):
        return np_random() < self.prob

    def decide_weight(self):
        return self.J/self.conection_count/self.prob +
np_normal(0.0, 0.01)


class GaussianFullyConnected(FullyConnectedPopulation):
    def __init__(self, sigma, *args, **kwargs):
        self.sigma = sigma
        super().__init__(*args, **kwargs)


    def decide_weight(self):
        return np_normal(self.J/self.conection_count,
self.sigma/self.conection_count)


class FullyConnected2Populations(FullyConnectedPopulation):
    def populate_neurons(self, pre_pop=None, post_pop=None,
*args, **kwargs):
        self.pre_pop = pre_pop
        self.post_pop = post_pop
        self.neurons = pre_pop.neurons+post_pop.neurons

    def create_network(self):
        for pre_neuron in self.pre_pop.neurons:
            for post_neuron in self.post_pop.neurons:
```

```
                self.connect_neurons(pre_neuron, post_neuron)


class FixedCoupling2Populations(FullyConnected2Populations):
    def __init__(self, prob, *args, **kwargs):
        self.prob = prob
        super().__init__(*args, **kwargs)

    def decide_to_connect(self):
        return np_random() < self.prob

    def decide_weight(self):
        return self.J/self.conection_count/self.prob +
np_normal(0.0, 0.01)


class
GaussianFullyConnected2Populations(FullyConnected2Populations):
    def __init__(self, sigma, *args, **kwargs):
        self.sigma = sigma
        super().__init__(*args, **kwargs)

    def decide_weight(self):
        return np_normal(self.J/self.conection_count,
self.sigma/self.conection_count)
```

این قسمت نحوه ی تقسیم اسپایک هارا خواهیم داشت

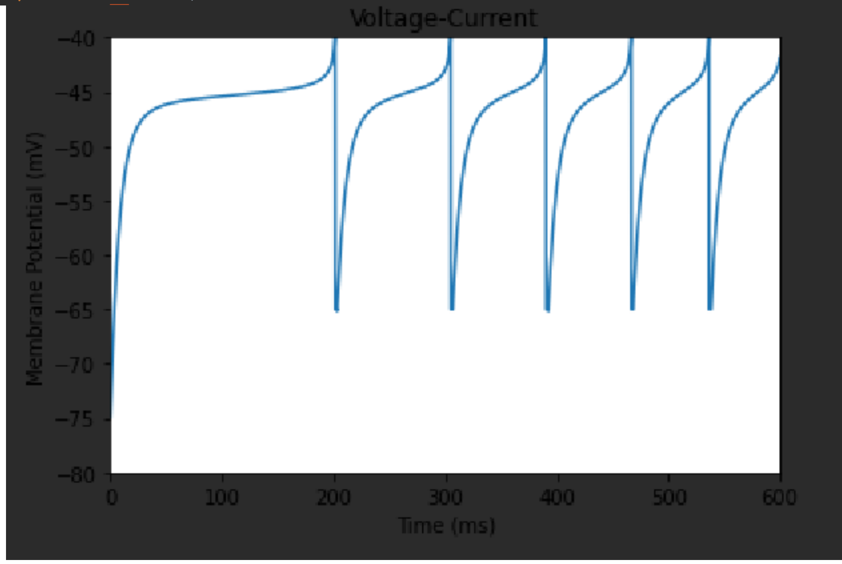
```
def generate_spike_data(pop, runtime, dt, conv_size = 10):
    spike_history = []
    idx_neuron = []
    neuron_type=[]
    for idx, neuron in enumerate(pop.neurons):
        idx_neuron += [idx for i in neuron.t_fired]

        type=('exc' if neuron.is_exc == 1 else 'inh')
        try:
            if neuron in pop.output_neurons: type="output"
            elif neuron in pop.input_neurons: type="input"
        except: pass
        neuron_type += [type for i in neuron.t_fired]

        spike_history+=neuron.t_fired

    activity = np.bincount(np.array(np.array(spike_history)//dt,
dtype = int))
    activity = np.pad(activity, (0, int(runtime//dt-
```

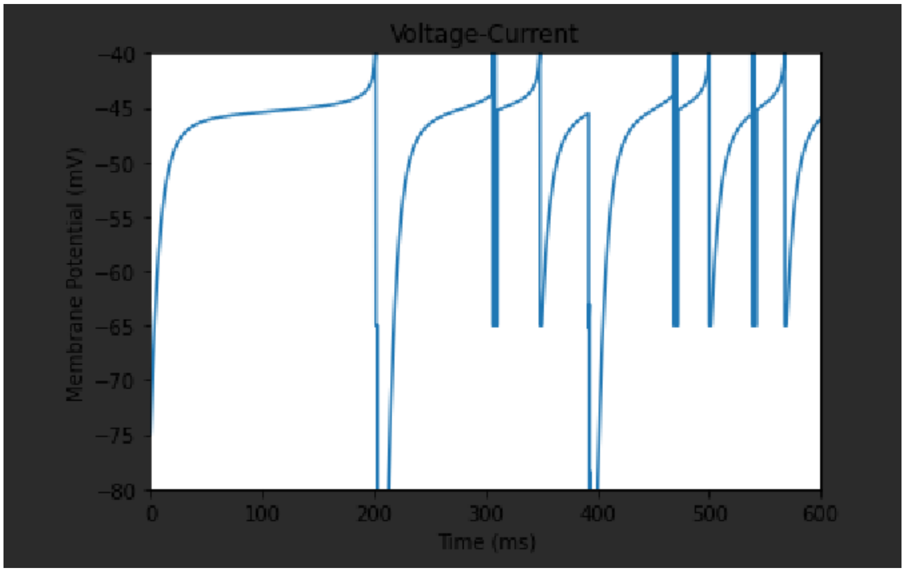
```
len(activity)+1)), 'constant')[:int(runtime//dt)]
    conv=int(conv_size * (.1 / dt))
    activity = np.convolve(activity, conv*[1/conv],
"same")/len(pop.neurons)

    return spike_history, idx_neuron, neuron_type, activity
```

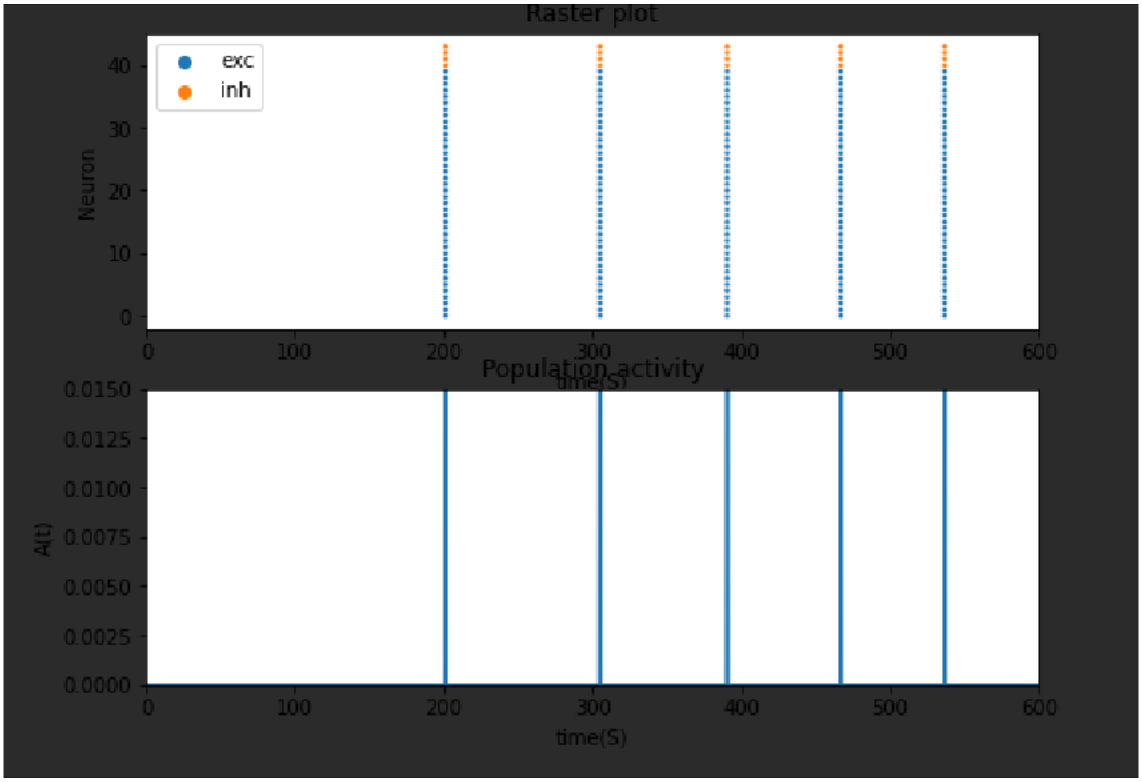
جمع بندی و کشیدن نهایی نمودار :

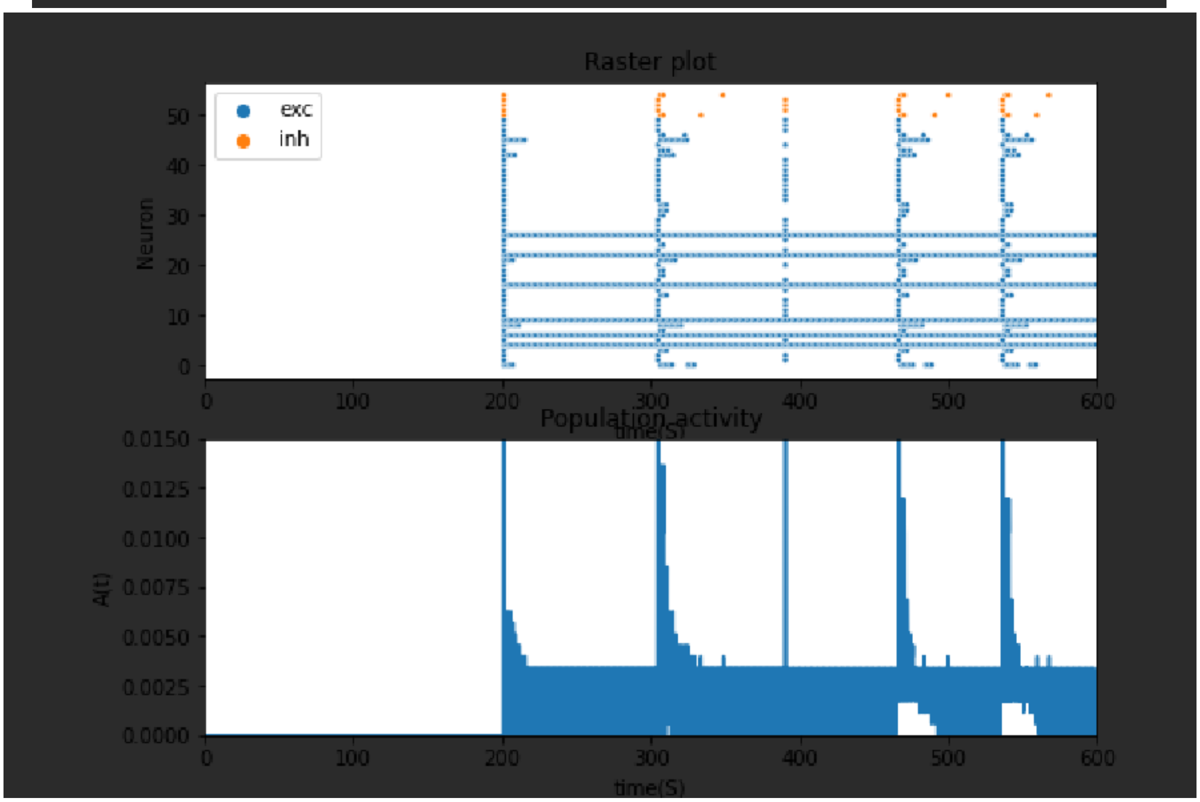
```
dt = 0.03125
n_config={'R': 10, 'tau': 8, 'theta': -40, 'U_rest': -75,
'U_reset': -65,
          'U_spike': 5, 'weight_sens': 1, 'ref_period': 2,
'ref_time': 0,
          'theta_rh': -45, 'delta_t': 2, 'a': 0.01, 'b': 500,
'tau_k': 100}

model = GaussianFullyConnected2Populations(
    J=6, sigma=1,
    post_pop=FixedCouplingPopulation(
        n_type=AELIF, excitatory=50, inhibitory=5, J=6.5,
prob=0.01, n_config=n_config),
    pre_pop=FullyConnectedPopulation(
        n_type=AELIF, excitatory=40, inhibitory=4, J=2.5,
n_config=n_config)
    )

runtime=600
time_steps=int(runtime//dt)
curr_func = lambda x: 1515*(sin(x/time_steps*3.3+1)+1) #
limited_sin(time_steps)
u_history=[]
i_history=[]
plot_current([curr_func(t) for t in range(time_steps)],
arange(0,runtime, dt))
for t in range(time_steps):
    u, cur = model.simulate_network_one_step(curr_func(t*dt))
    u_history.append(u)
    i_history.append(cur)

plot_mv_ms(array(u_history)[:,1], arange(0,runtime, dt), top=-
40, bottom=-80)
plot_mv_ms(array(u_history)[:,-1], arange(0,runtime, dt), top=-
40, bottom=-80)

plot_raster(*generate_spike_data(model.pre_pop, runtime, dt),
runtime, dt, min_t=0)
```

```
plot_raster(*generate_spike_data(model.post_pop, runtime, dt),
runtime, dt, min_t=0)
```






Raster plot
exc
inh
Neuron
time(S)
Population activity
A(t)
time(S)


Raster plot
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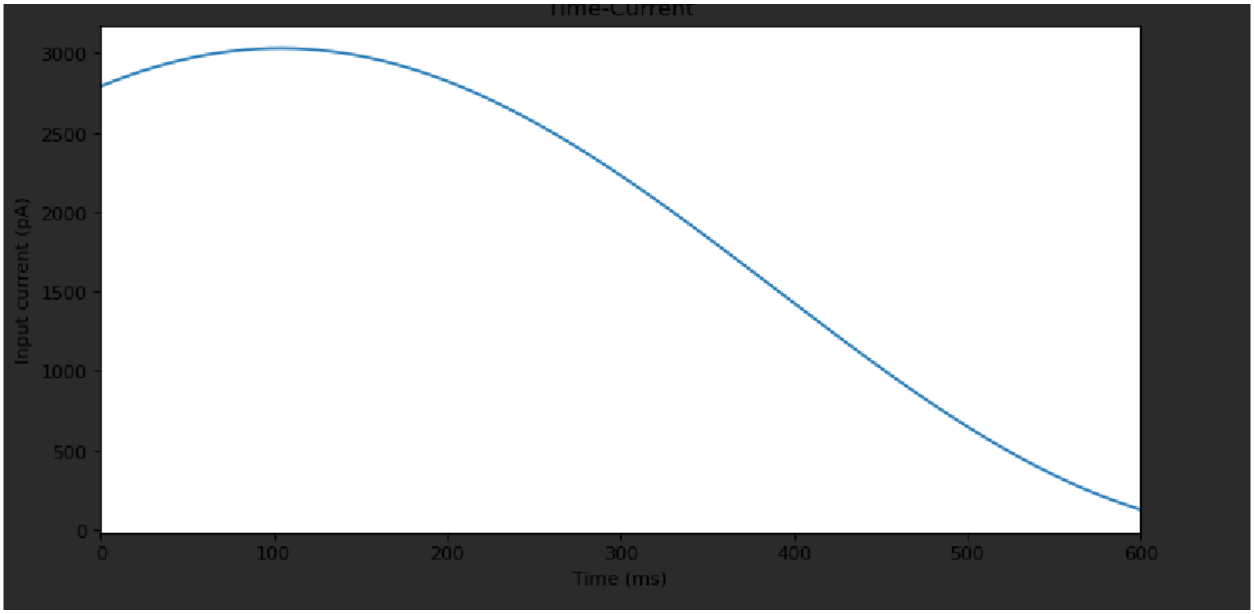


```
dt = 0.03125
n_config={'R': 10, 'tau': 8, 'theta': -40, 'U_rest': -75,
'U_reset': -65,
          'U_spike': 5, 'weight_sens': 1, 'ref_period': 2,
'ref_time': 0,
          'theta_rh': -45, 'delta_t': 2, 'a': 0.01, 'b': 500,
'tau_k': 100}

model = FixedCouplingPopulation(
        n_type=AELIF, excitatory=100, inhibitory=20, J=6.5,
prob=0.1, n_config=n_config)

runtime=600
time_steps=int(runtime//dt)
curr_func = lambda x: 1515*(sin(x/time_steps*3.3+1)+1) #
limited_sin(time_steps)
u_history=[]
i_history=[]
plot_current([curr_func(t) for t in range(time_steps)],
arange(0,runtime, dt))
for t in range(time_steps):
    u, cur = model.simulate_network_one_step(curr_func(t*dt))
    u_history.append(u)
    i_history.append(cur)

plot_mv_ms(array(u_history)[:,1], arange(0,runtime, dt), top=-
40, bottom=-80)
plot_mv_ms(array(u_history)[:,-1], arange(0,runtime, dt), top=-
40, bottom=-80)
```

```
plot_raster(*generate_spike_data(model, runtime, dt), runtime,
dt, min_t=0)
```

(عکس ها مشابه بالا)

```
dt = 0.03125
n_config={'R': 10, 'tau': 8, 'theta': -40, 'U_rest': -75,
'U_reset': -65,
          'U_spike': 5, 'weight_sens': 1, 'ref_period': 2,
'ref_time': 0,
          'theta_rh': -45, 'delta_t': 2, 'a': 0.01, 'b': 500,
'tau_k': 100}

model = GaussianFullyConnected(
        n_type=AELIF, excitatory=100, inhibitory=20, J=6.5,
prob=0.01, n_config=n_config, sigma=1)

runtime=600
time_steps=int(runtime//dt)
curr_func = lambda x: 1515*(sin(x/time_steps*3.3+1)+1)  #
limited_sin(time_steps)
u_history=[]
i_history=[]
plot_current([curr_func(t) for t in range(time_steps)],
arange(0,runtime, dt))
for t in range(time_steps):
    u, cur = model.simulate_network_one_step(curr_func(t*dt))
    u_history.append(u)
    i_history.append(cur)

plot_mv_ms(array(u_history)[:,1], arange(0,runtime, dt), top=-
40, bottom=-80)
plot_mv_ms(array(u_history)[:,-1], arange(0,runtime, dt), top=-
40, bottom=-80)

plot_raster(*generate_spike_data(model, runtime, dt), runtime,
dt, min_t=0)
n_config={'R': 10, 'tau': 8, 'theta': -40, 'U_rest': -75,
'U_reset': -65,
          'U_spike': 5, 'weight_sens': 1, 'ref_period': 2,
'ref_time': 0,
          'theta_rh': -45, 'delta_t': 2, 'a': 0.01, 'b': 500,
'tau_k': 100}

model = FullyConnectedPopulation(
        n_type=AELIF, excitatory=100, inhibitory=20, J=6.5,
```

```
prob=0.01, n_config=n_config)

runtime=600
time_steps=int(runtime//dt)
curr_func = lambda x: 1515*(sin(x/time_steps*3.3+1)+1) #
limited_sin(time_steps)
u_history=[]
i_history=[]
plot_current([curr_func(t) for t in range(time_steps)],
arange(0,runtime, dt))
for t in range(time_steps):
    u, cur = model.simulate_network_one_step(curr_func(t*dt))
    u_history.append(u)
    i_history.append(cur)

plot_mv_ms(array(u_history)[:,1], arange(0,runtime, dt), top=-
40, bottom=-80)
plot_mv_ms(array(u_history)[:,-1], arange(0,runtime, dt), top=-
40, bottom=-80)

plot_raster(*generate_spike_data(model, runtime, dt), runtime,
dt, min_t=0)
```