Spodbujevano učenje na impulznih nevronskih mrežah

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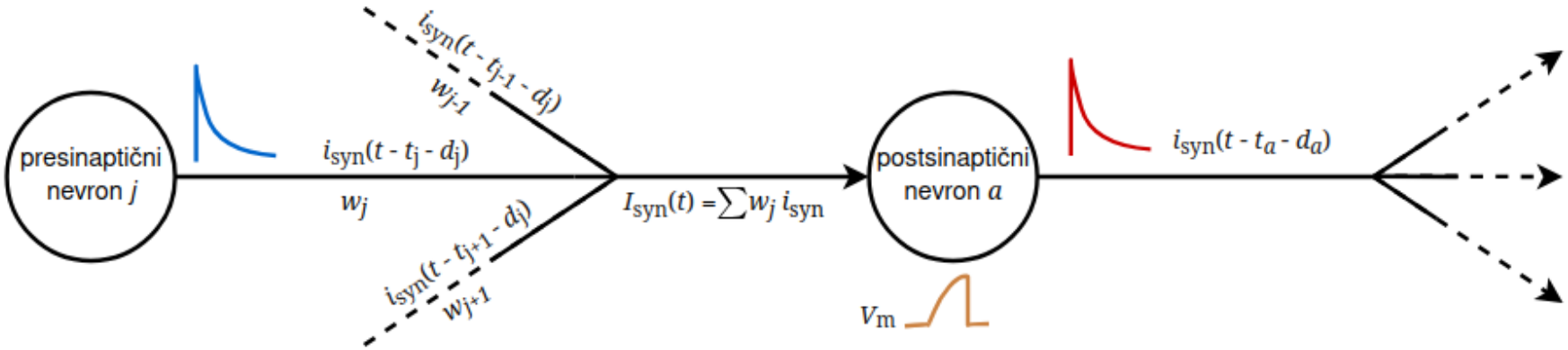
Overview

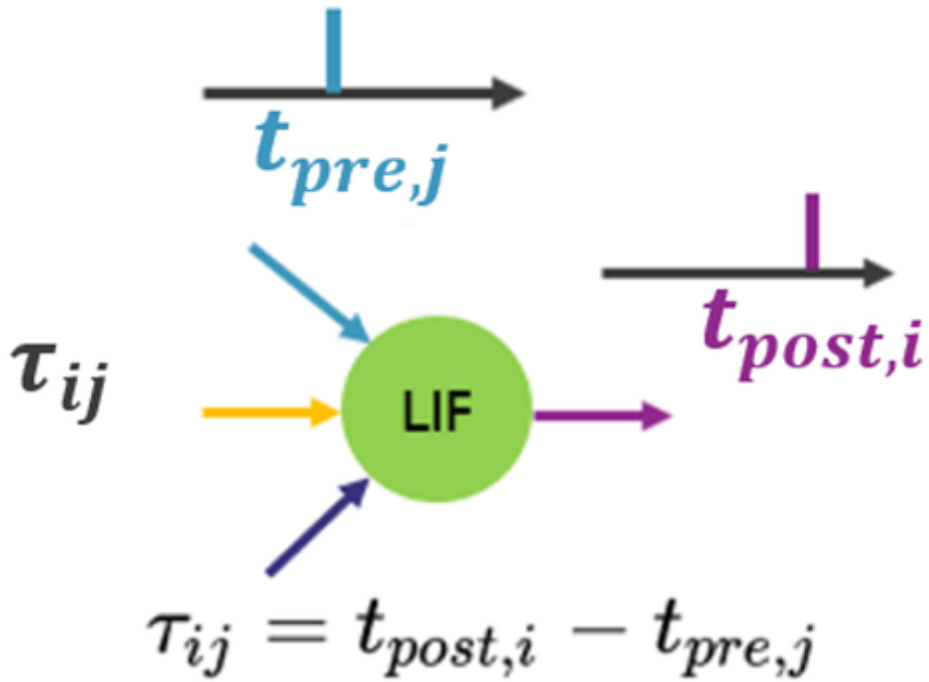
Impulzne nevronske mreže

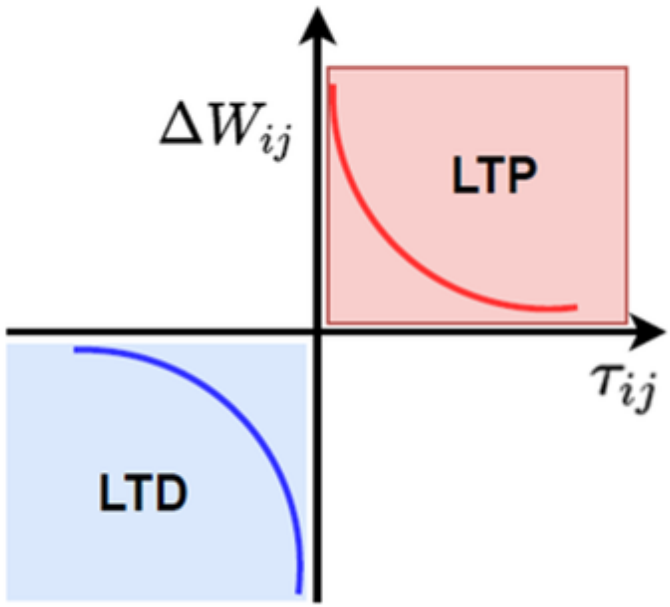
- SNN združujejo čas, energijsko učinkovitost in biološko realnost.
- Informacija je kodirana v zaporedju in času impulzov.
- Pri ANN čas zanemarjen ali obravnavan v diskretnih korakih.
- Učenje preko lokalnih pravil namesto gradientov.



Lokalno pravilo za učenje

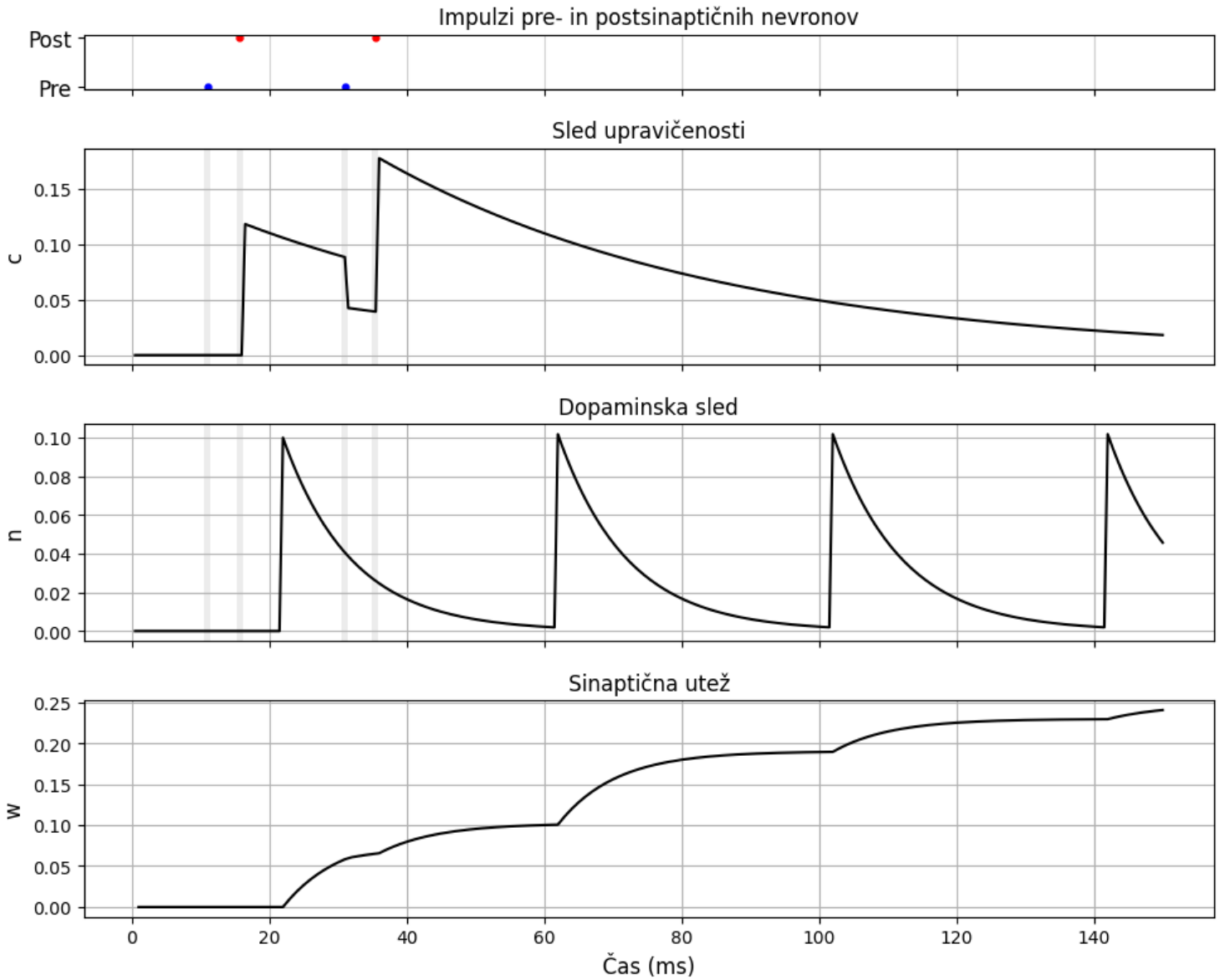
- Sinaptična plastičnost odvisna od časovne razporeditve impulzov (STDP).
- Hebbov princip: "Nevroni, ki se skupaj prožijo, se povežejo".





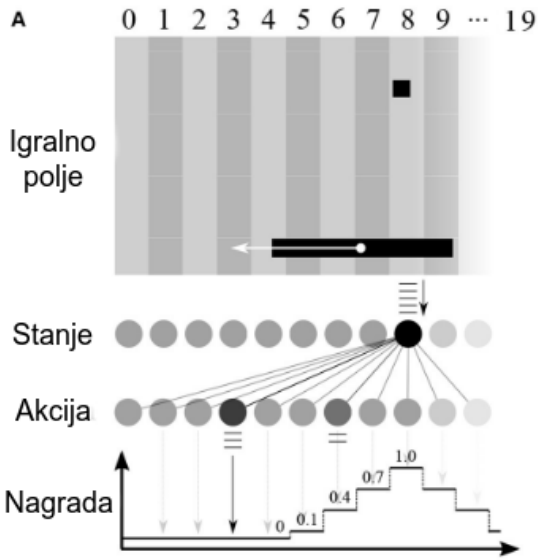
Source: [Safa, 2024]

Nevromodulirana STDP

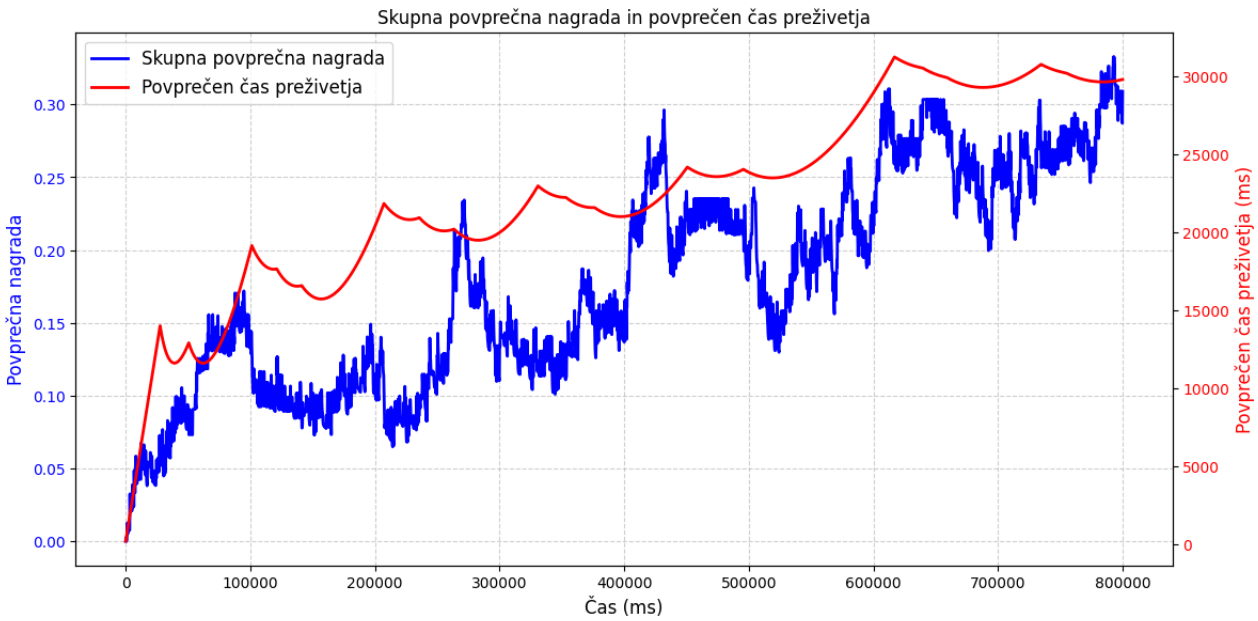


Igra Pong

- Stanje - presinaptični nevron
- Akcija - postsinaptični nevron
- Nagrada - koncentracija dopamina
- Gradient aproksimiramo preko sinaps z visoko sledjo upravičenosti.

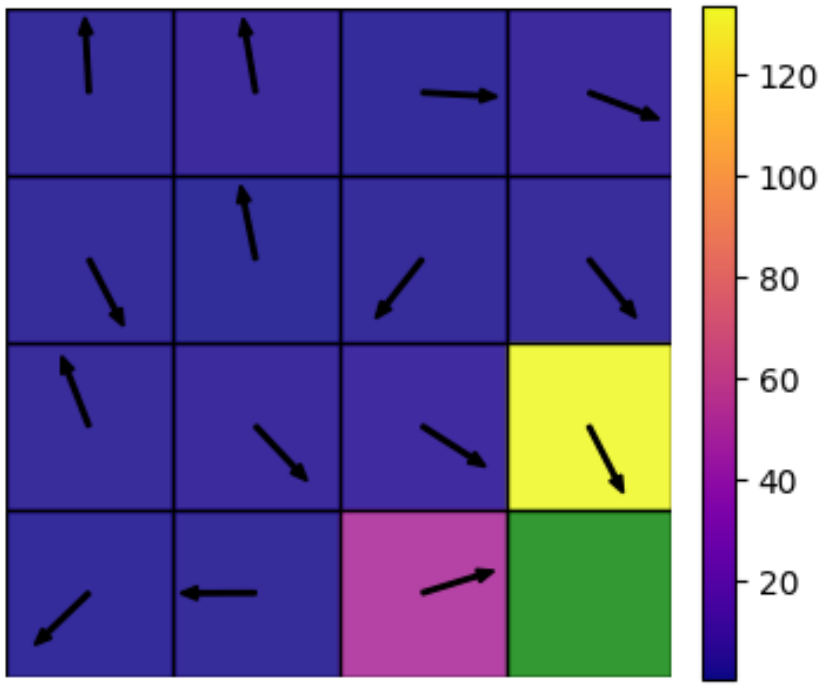


Source: [Wunderlich et al., 2019]



Mrežni svet

- Verjetnost izbire akcije a v stanju i $\pi(a|i)$ - utež med vhodnim nevronom (stanje) in izhodnim (akcija)
- Rezultat učenja je zvišana sinaptična utež za pravilno akcijo.

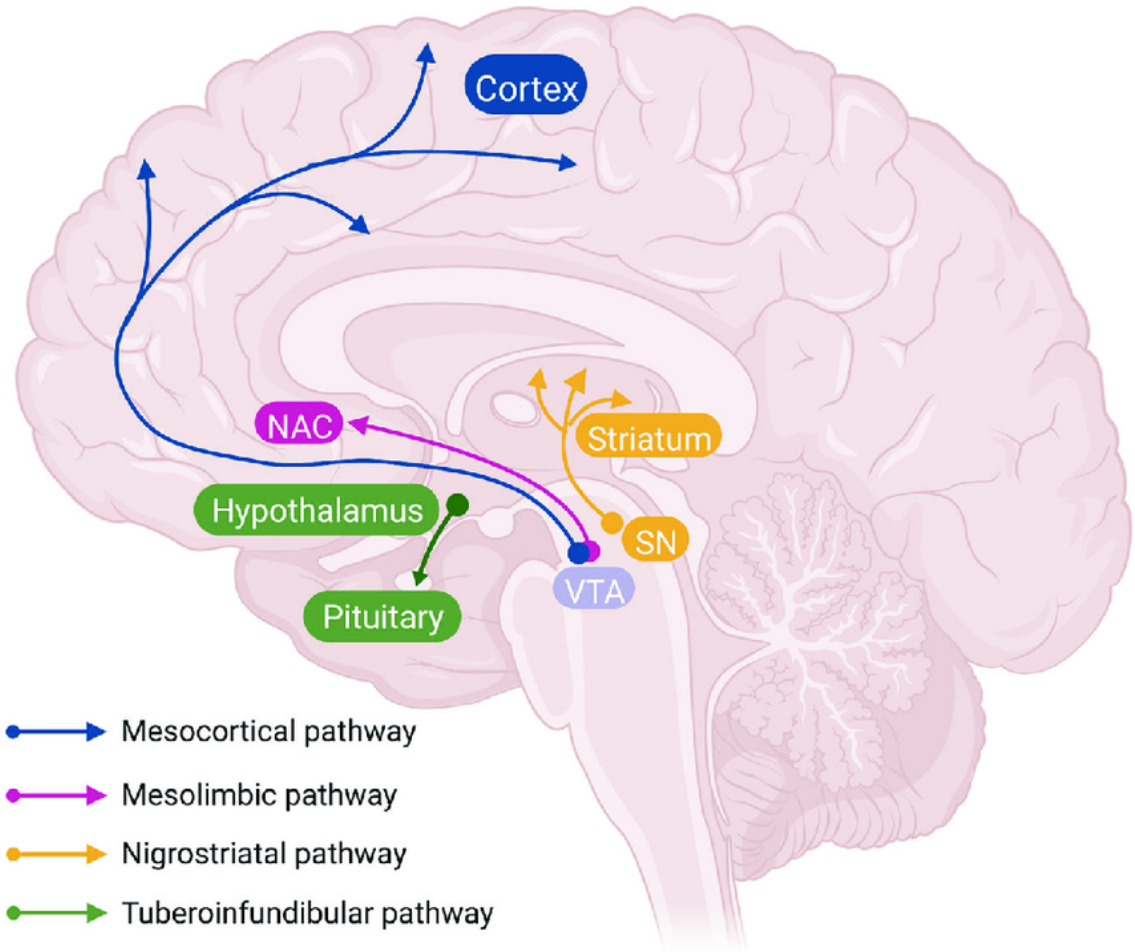


TD učenje (angl. *Temporal difference learning*)

figs/td.png

Source: [BotPenguin, 2024]

Človeški dopaminski sistem



Source: [Xu Yang, 2022]

Simulacija dopaminskega sistema

figs/shift.png

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Source: [Wunderlich et al., 2019]

Zaključek

Predstavitev in komentar rezultatov

Reference (1/2)

Gökssel Gündüz (2021).

Spiking Neural Networks (SNN).

https://medium.com/@goksselgunduz/spiking-neural-networks-snn-40ef3fd369b4

IBM Think Blog (2023).

Reinforcement Learning.

https://www.ibm.com/think/topics/reinforcement-learning

Nengo Forum (2020).

How should I use STDP after training in Nengo?

https://forum.nengo.ai/t/how-should-i-use-stdp-after-training-in-nengo/1931

Straker.

Simple Pong game in JavaScript using canvas.

https://gist.github.com/straker/81b59eecf70da93af396f963596dfdc5

Reference (2/2)

T. Wunderlich et al. (2019).
Demonstrating Advantages of Neuromorphic Computation: A Pilot Study.
Frontiers in Neuroscience, 13:260.
https://doi.org/10.3389/fnins.2019.00260

A. Safa (2024).
Continual Learning in Bio-plausible Spiking Neural Networks with Hebbian and Spike Timing Dependent Plasticity: A Survey and Perspective.
arXiv preprint.
https://doi.org/10.48550/arXiv.2407.17305

E. M. Izhikevich (2007).
Solving the distal reward problem through linkage of STDP and dopamine signaling.
Cerebral Cortex, 17(10).
https://doi.org/10.1093/cercor/bhl152

Haiyun Xu, Fan Yang (2022).
The interplay of dopamine metabolism abnormalities and mitochondrial defects in the pathogenesis of schizophrenia.
Translational Psychiatry, 12.

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