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Integration of leaky-integrate-and-fire neurons in standard machine learning architectures to generate hybrid networks: a surrogate gradient approach. (English) Zbl 07480287

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Summary: Up to now, modern machine learning (ML) has been based on approximating big data sets with high-dimensional functions, taking advantage of huge computational resources. We show that biologically inspired neuron models such as the leaky-integrate-and-fire (LIF) neuron provide novel and efficient ways of information processing. They can be integrated in machine learning models and are a potential target to improve ML performance. Thus, we have derived simple update rules for LIF units to numerically integrate the differential equations. We apply a surrogate gradient approach to train the LIF units via backpropagation. We demonstrate that tuning the leak term of the LIF neurons can be used to run the neurons in different operating modes, such as simple signal integrators or coincidence detectors. Furthermore, we show that the constant surrogate gradient, in combination with tuning the leak term of the LIF units, can be used to achieve the learning dynamics of more complex surrogate gradients.

To prove the validity of our method, we applied it to established image data sets (the Oxford 102 flower data set, MNIST), implemented various network architectures, used several input data encodings and demonstrated that the method is suitable to achieve state-of-the-art classification performance.

We provide our method as well as further surrogate gradient methods to train spiking neural networks via backpropagation as an open-source KERAS package to make it available to the neuroscience and machine learning community. To increase the interpretability of the underlying effects and thus make a small step toward opening the black box of machine learning, we provide interactive illustrations, with the possibility of systematically monitoring the effects of parameter changes on the learning characteristics.

MSC:

68-XX Computer science

Software:

Matplotlib; S4NN; TensorFlow; Keras

Full Text: DOI

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