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INVESTIGATION OF LOW-ENERGY SPIKING NEURAL NETWORKS BASED ON TEMPORAL CODING FOR SCENE CLASSIFICATION

Abstract

Spiking Neural Networks (SNN) are becoming increasingly interesting to the space domain due to their energy efficiency. Indeed, small satellites use devices with low computational power and have a low system power budget in general. For this reason, SNNs represent a promising candidate for the on-board implementation of neural-based algorithms: among those, the scene classification task is of primary importance for the space community and constitutes a valuable test case given the abundance of competitive methods available to establish a benchmark. SNNs are also commonly referred to as the third generation of Artificial Neural Networks (ANNs), where each neuron in the network uses discrete electrical pulses (spikes) communicating in an event-based manner. SNNs have the potential advantage of achieving higher energy efficiency than their ANN counterparts. While generally a loss of accuracy on SNN models is reported, new algorithms and training techniques can help close the gap in terms of accuracy while maintaining a low energy consumption profile. To evaluate the feasibility of applying SNNs onboard spacecraft, this research paper focuses on a theoretical analysis and comparison of different SNN techniques applied to the task of scene classification for the EuroSAT database. A particular focus is put on information encoding and learning representations for sparse spiking architectures. A widely adopted encoding method is rate-based coding, where information is encoded by the average number of spikes fired by a neuron. Several drawbacks, in particular in the context of low energy applications, have been identified for this method. Instead, temporal coding, where the time signal between spikes drive the encoding, is here investigated due to its inherent sparsity nature and higher efficiency of the resulting spiking network, i.e. lower number of spikes for a given information content. Considerable effort is also dedicated to the evaluation of several competing models, developed following the state-of-the-art in SNN coding (rate and temporal coding) and training techniques, as well as the study of the impact of different neuron and synapse models on the output performance. In addition, this research aims at developing and validating reliable metrics and proxies that can be used to compare different architectures and to establish a clear theoretical dependence between architecture parameters (e.g. number of neurons and spikes) and the expected energy consumption one could expect on-board the spacecraft.