

Key	Value	Year	Title	Author	Publisher	DOI	URL	RQ1a_Encoding_Type	RQ1a_Inversible_encoding_parameters	RQ1a_Training_mechanism	RQ1d_Hybrid_Integration_Type	RQ2a_Spike_wise_efficiency	RQ2b_Resource_efficiency	RQ2c_Training_Behavior	RQ2d_Model_Performance	RQ2e_Dataset_modality	RQ2f_Input_Representation	RQ2g_Datasets_Used	RQ2h_Task_or_Domain	RQ2i_Evaluation_Metrics	RQ2j_Limitation_Categories	RQ2k_Reported_Limitations	RQ2l_Research_Gaps	Hardware_or_simulator	paper_type	Architecture_Type	Code_availability	training_config_sheet
rayyan-308588274	PG2	2024	Accurate and Efficient Spiking Encoding	Zhang, Xu	Optics Express	10.48820/http://invenia	Inversible and adaptive encoding	Synaptic weights Temporal decay parameters	Surrogate gradient	Pure SNN architecture		Spikes activity Reduced firing rate Stable spiking behavior Efficient Timings	Reduced computational operations Multiplication-free Energy efficiency computation Memory-efficient	Robustness Smoothness	Generalization Performance	Vision Event streams Grayscale images RGB Images	OOD17 DSEC-Semantic task	Semantic Segmentation # Timings # Add # Mult Energy	# Timings # Params # Add # Mult Energy	Architectural Limitations Hardware Limitations Theoretical Limitations Algorithmic Limitations Numerical Limitations Only	SpikeTrain Sparcity/Architecture Lacks Deep Theoretical Algorithmic Numerical Energy Estimation Limitations Optimization Limitations	Neuromorphic Hardware Deployment Real-World Application Algorithmic Numerical Energy Estimates Only	Architectural proposal	Spiking Encoder-Decoder Network	Promised	Neuron: LF Method: Direct SNN Training (Spiking-Temporal BP + Decay) Optimizer: Adam (lr = 0.001) Loss: Per-pixel Cross-Entropy Epochs: Search 20, Retraining: 100-1000 Input: SBT (44 x 50m, n = 5)		
rayyan-308589102	PG2	2024	Brain-Inspired AI Tang, Fen IEEE Access	10.2390/I	https://w...	Inversible and adaptive encoding	Synaptic weights	Surrogate gradient	Pure SNN architecture	Efficient Timings Reduced Firing rate		Reduced computational operations Energy efficiency computation Memory-efficient	Stable Convergence Randomness reduced	Robustness Generalization Performance	Vision Grayscale Images RGB Images	MNIST Fashion-MNIST CIFAR-10	Classification task Accuracy # Timings	Accuracy # Timings	Biological Limitations Generalizability / limitations Hardware Limitations	Limited exploitation of temporal interactions Absence of lateral interactions and recurrent connectivity Evaluation of single-classification tasks No Neuromorphic Hardware Deployment	Extension to more biologically realistic learning rules Inclusion of more complex connections Application to speech and time-series tasks	GPU / CPU	Architecture proposal	Convolutional Spiking Neural Network (Conv-SNN)	Not Available	Neuron: LF Optimizer: Adam weight initialization Dropout = 40% in fully connected layers Batch normalization (BN) Loss: Loss function + L2 norm (MSE) Method: Surrogate gradient comparison Optimizer: Adam (signed vs unsigned) Recommendation: a = 4.0 30 epochs Model: LR = 0.0002, Batch size = 128, Loss function: cross-entropy gradient = Adam Fashion-MNIST: a = 0.0002, Batch size = 128, Epochs = 100 Surrogate gradient = Adam CIFAR-10: a = 0.0001, Batch size = 128, Epochs = 100, Surrogate gradient = Adam		
rayyan-378478369	PG2	2024	Brain-Inspired Spiking Tandem, I	Neurocomputing	10.1007/s00360-023-05616-0	learnable and adaptive encoding	Synaptic weights Temporal decay parameters Membrane thresholds	Surrogate gradient	Hybrid ANN-SNN architecture	Spikes activity Reduced firing rate		Energy efficiency computation Memory-efficient Faster inference	Convergence Higher simulation speed Smoothness	Robustness Generalization Performance	Real Numbers Real Numbers	Custom	Regression task	Root Mean Squared Error (RMSE) Energy Simulation speed	Accuracy Limitations Energy Estimation Limitations Generalizability Limitations Hardware Limitations Numerical Limitations	No on-chip training for Xyla-Av2 Keras/tensorflow Keras/tf2 Keras/tf3 Keras/tf4 Keras/tf5 Keras/tf6 Keras/tf7 Keras/tf8 Keras/tf9 Keras/tf10 Keras/tf11 Keras/tf12 Keras/tf13 Keras/tf14 Keras/tf15 Keras/tf16 Keras/tf17 Keras/tf18 Keras/tf19 Keras/tf20 Keras/tf21 Keras/tf22 Keras/tf23 Keras/tf24 Keras/tf25 Keras/tf26 Keras/tf27 Keras/tf28 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royyan-208589111	PoR	2024 Diagnostic Bioms Saeednia, Samaneh-Alatbar, Jz 10-2038() https://w Adaptive encoding	Adaptive (data-driven) parameters	Local learning rule	Pure SNN architecture	Sparse spike activity Efficient Timings	Reduced computational operations Energy efficiency computation Memory-efficient Faster inference	Convergence	Robustness Performance	Biosignals	Electroencephalogram (EEG) Custom	Classification task Biomarker discovery	Accuracy Neuron firing patterns Execution time	Accuracy Limitations Computational Constraints Generalizability Limitations Hardware Limitations	Small and imbalanced dataset Overfitting with large reservoirs Lack of large-scale validation for neuromorphic hardware deployment	Validation on larger Multi-center datasets Early prediction of biomarkers Deployment on neuromorphic hardware Longitudinal EEG analysis	MATLAB simulation GPU /CPU	Architecture proposal Novel Encoding Mechanism	Resource-based SNN	Available	Neuron: Unbiased spiking neurons (70% excitatory / 30% inhibitory) Algorithm: LIF + adaptive Online Spike Encoding + partially observed reservoir SNN → Firing rate threshold Learning: Hybrid local learning (supervised/training for observed neurons + unsupervised STDP for hidden neurons) Classifier calibration: firing rate threshold trained on 70% of data (backprop trained leave-one-out cross-validation)	
royyan-378477363	PoD	2022 DTS-SNN: Spiking Yoo, Donghyung; Jeong, Daesik 10-1139/ACCESS.20 learnable and adaptive encoding	Trainable DTS aggregation weights ai	Surrogate gradient	Pure SNN architecture	Activity-driven suppression Activity-driven responsiveness Efficient Timings	Reduced computational operations Energy efficiency computation Memory-efficient	Stable	Performance Robustness	Vision Audio	Event streams	DVS128 Gesture Spiking Heidelberg Dataset (SHD) N-Cars	Classification task Action/Gesture Recognition	Accuracy # Params # Ops # Timings	Generalizability Limitations Hardware Limitations Accuracy Limitations	Kernel time constants selected manually Evaluation limited to simple FC NNs No systematic study of kernel behavior across tasks No significant comparison with neuromorphic hardware Slight accuracy drop compared to top convolutional-based SNNs despite major efficiency gains.	Fast (non-learnable) temporal kernels, memory efficient or adaptive learning or adaptive kernel design Extension to deeper SNN architectures and more complex tasks beyond classification.	GPU /CPU	Novel Encoding Mechanism	DTS-SNN (Dynamic Time-Surfaces Spiking Neural Network)	Available	Neuron: LF Optimizer: Adam (no weight decay or LR schedule) Train: 300 (Gesture), 500 (SHD), 100 (N-Cars) Batch sizes: 16, 64, or 256 depending on dataset
royyan-308580278	PoE	2025 Efficient (ANN)-I Liu, Chang; Shen, Jiangrong; He 10-48550, http://in learnable encoding	Learnable clipping threshold Dual-threshold neuron parameters Membrane potential initialization value	ANN-to-SNN Conversion Method	ANN-to-SNN conversion	Reduced firing rate Efficient Timings	Energy efficiency computation Reduced computational operations	Stable	Performance Inference Robustness	Vision	Grayscale images RGB Images	CIFAR-10 CIFAR-100 ImageNet	Classification task	Accuracy # Timings Energy	Energy Estimation Limitations Generalizability Limitations	No neuromorphic hardware deployment (simulation-based methods) No significant use of analytical SDF-VLOC extraction Method validated only on image classification	Extension to non-vision modalities Variational autoencoder for neuromorphic validation Exploration beyond rate-based conversion	GPU /CPU	Conversion framework	Converted deep CNN-based SNN	Not Available	Neuron: IF ANN trained with quantized clip-threshold activation (Invertible, I _t =4-8) Inference at T = 3-16 time steps
royyan-378478131	PoT	2022 Encoding Event-4 Stewart, I Nature Commun 10-11457 https://w learnable encoding	Synaptic weights Latent parameters	Surrogate gradient	Hybrid ANN-SNN architecture	Sparse spike activity Activity-driven suppression	Energy efficiency computation	Hardware-induced performance degradation	Performance Robustness	Vision	Event streams	NABIGT IBM Signature Custom	Classification task Quantitative latent-space evaluation (T-SNE)	Hardware Limitations Accuracy Limitations Generalizability Limitations	Hardware performance degradation Precision-sensitive latent disentanglement Partial hardware deployment Class confusion	Evaluation on higher-precision neuromorphic hardware Extension to more complex datasets and larger class counts Missing adaptive encoders and decoders Limited scalability analysis No backpropagation benchmarks Improved on-chip learning algorithms	GPU /CPU LoRa	Novel Algorithmic Framework	Hybrid Guided Variational Autoencoder with SNN encoder	Not Available	Neuron: LF (I _t = 1 ms) Surrogate gradients (fast sigmoid) Truncated EPTT (320 ms) VAE loss + execution/embodiment losses GPU training with PyTorch Loss function: VAE + SLAYER with quantized spiking a, z	

rayyan-37847679	P08	2022 Enhancing spiking Liu, Fajja Nature Commun. 10:3389/ https://w/ learnable and adaptive encoding	Synaptic weights Membrane thresholds Temporal decay parameters	Surrogate gradient	Hybrid ANN-DNN architecture	Activity-driven suppression Reduced firing rate Sparse spike activity	Reduced computational operations Energy efficiency computation MAC operations reduction	Stable Efficiency	Vision	Grayscale images RGB images Event streams	CIFAR-10 CIFAR-100 MNIST ImageNet	Classification task	Accuracy Robustness Inference Generalization	Architectural Limitations Methodological Limitations	Additional ANN introduces extra parameters and computation Attention applied mainly to inference (not training) Exploration of deeper feedback No direct deployment or benchmarking on neuromorphic hardware	End-to-end deployment on neuromorphic chips Extension to non-vision tasks More complex or multi-level attention mechanisms	GPU CPU	Architecture proposal	Hybrid ANN-DNN (Convolutional DNN with ANN-based top-down attention)	Available	Neuron: LF SGD with momentum 0.9 Batch size 200 Initial learning rate warm-up Time step T=1 ms K = 6 (static) / 10 (neuromorphic) Attention period T= 210 Temperature scheduled sigmoid (max T= 4) Loss weight $\alpha = [0.01, 0.1]$ Sparsity coefficients $\beta = 0.40$; $\gamma = 0.51$	
rayyan-308580261	P09	2022 Event-(Enhanced) Wang, Ya npj Unconventional 10:1145/ https://w/ learnable and adaptive encoding	Synaptic weights Latent parameters Membrane thresholds	Surrogate gradient	Hybrid ANN-DNN architecture	Sparse spike activity	Reduced computational operations Energy efficiency computation Memory-efficient	Stable Convergence Faster training	Performance Robustness Inference Generalization	Multimodal	Event streams Laser scans	Custom	Reinforcement learning task	Success rate # Add # Mult	Hardware Limitations Generalizability Limitations	Evaluated only in simulation No real-world deployment Need more real challenging stories	Lack of real-world neuromorphic benchmarks No UAV or submarine robot validation Absence of energy benchmarks on hardware	Gaoro simulator+KAIS GRU CPU	Architecture proposal	Spiking Actor-Critic	Not Available	Neuron: LF DDPG (Deep Deterministic Policy Gradient) + Actor-Critic Batch size 256 Learning rate 1e-4 Memory size 1e6 Lever 20 Hz, DNN 100 ms Current decay 5%, voltage decay 0.75 Population size = 10
rayyan-308580203	P10	2022 Feasibility study i Sun, Anto Nature Commun. 10:3389/ https://w/ Adaptive encoding	Adaptive (data-driven) parameters	Surrogate gradient	Pure SNN architecture	Sparse spike activity Activity-driven suppression	Reduced computational operations Low latency AC-dominant computation Energy efficiency computation	Stable Faster training	Inference Robustness	BiSignals	Event streams	Custom	Classification task Action/Genre Recognition	Accuracy Energy # Add # Mult Latency Spike release rate (SRR) Statistical significance (ANOVA)	Methodological Limitations Generalizability Limitations Hardware Limitations Architectural Limitations Accuracy Limitations	Single encoding method and neuron model Only steady-state EMG used Evaluated on limited datasets Leveraging existing advanced DNN approaches over/alternating with algorithmic methods only No neuromorphic hardware deployment	Evaluation of alternative encoding schemes Evaluation on public datasets Inclusion of transition phase EMG integration with advanced learning strategies On-chip neuromorphic deployment	GPU CPU	Feasibility study	SNN	Not Available	Neuron: LF Optimizer: Adam Learning rate: 3.1, 0.01 Batch size: 1/6 of training set Loss cross-entropy Integration window: T=1000 Br=0.6 Vth=2.5
rayyan-37847670	P11	2022 Hybrid photonic i Zhang, Ya Neuromorphic Comp. 10:1364/ https://w/ learnable encoding	Synaptic weights	Surrogate gradient	Hybrid ANN-DNN architecture ANN-to-DNN conversion	Efficient Timetaps	Energy efficiency computation Performance sensitive to time-step	Convergence Performance sensitive to time-step	Inference	Texts	Word embeddings	ME AG News IMDb Yelp review polarity	Classification task	Accuracy # Timetaps	Generalizability Limitations Hardware Limitations Energy Estimation Limitations	Energy efficiency discussed conceptually without measured neuromorphic power metrics Photonic SNN limited to classification tasks Evaluation limited to test classification benchmarks No direct deployment or benchmarking on neuromorphic hardware	End-to-end photonic Data training Deeper photonic integration beyond SNN Broader NLP tasks and multilingual datasets	GPU CPU	Architecture proposal	Deep convolutional residual networing (DCRNN)	Not Available	Neuron: LF Surrogate gradient (rectified/reLU/gamma) Adam optimizer ($\eta = 0.01$) Batch size: 256 Time window T = 1-16 ms 50 epochs
rayyan-37847669	P12	2022 Hybrid Spiking Fu, Zhang, Ta Frontiers in Neurosci. 10:3390/ https://w/ learnable encoding	Synaptic weights	Surrogate gradient	Hybrid ANN-DNN architecture	AC-dominant computation Energy efficiency computation	Stable Performance sensitive to time-step	Performance	Vision	RGB Images	VOC2012 COCO2017 DRIVE Cityscapes	Semantic Segmentation task	MIoU Pixel Acc # Params Inference Recall F1 Energy	Training scalability Limitations Accuracy Limitations Hardware Limitations Energy Estimation Limitations	Performance inferior to CNN Sensitive to time-step selection Long training time Large memory usage Energy based on theoretical estimation No direct deployment or benchmarking on neuromorphic hardware	Lack of pretrained SNN baselines Limited exploration of spiking encoding No real neuromorphic hardware deployment	GPU CPU CMOS energy model	Architecture proposal	Hybrid spiking fully convolutional neural network (SFCNN)	Not Available	Neuron: LF Time window Simulation time step 1 ms Adam optimizer $\eta=0.0005$ Batch size: Convolutional submodules Softsign surrogate Cross-entropy loss	

paperID	P13	2025	Neurobridge: bridging Yuchen Liu, Jingcheng Yu 10.1089/cb.https://www.learnable-and-adaptive-encoding.com	Synaptic weights	ANN-to-SNN Conversion Method	ANN-to-SNN conversion	Reduced spike count	Low latency	Stable	Inference Performance	Vision	Grayscale images RGB images	CIFAR-10 Imagenet	Classification task	Accuracy	Hardware Limitations	No physical neuromorphic chip deployment	GPU (CPU)	Novel Algorithmic Framework	Converted spiking neural network (SNN-based)	Available	Neuron: LF Quantization-aware ANN training		
paperID	P14	2023	Single (I)Channel Rate, Abl. Complexity	10.48550/artsiv.230 learnable encoding	Synaptic weights Temporal decay parameters Membrane thresholds	Surrogate gradient	Hybrid ANN-SNN architecture	Sparsify activity Activity-driven suppression	Energy efficiency computation MC operations reduction	Stable	Inference Performance Robustness	Audio	Time-frequency representation	Voice Bank Corpus (VCTK + DEMAND noise dataset)	Regression task Speech enhancement	Perceived Evaluation of Speech Quality (PESQ) Short-Time Objective Intelligibility (STOI) DeepSpeech2 WER Mean Opinion Score (DMS/MOS: S4M, QMUL)	Generalizability Limitations Hardware Limitations Methodological Limitations	No physical neuromorphic chip deployment	Lack of real neuromorphic hardware	GRU (CPU)	Architecture proposal	U-Net based Spiking Neural Network	Not Available	Neuron: LF Adam (beta=0.9, beta2=0.99, epsilon=1e-08) Batch size 32 60 epochs Gradient descent (Adam) Convolution weight = (0.2,2) Decay strength & thresholds initialized from normal ^R distributions.
paperID	P15	2022	SIT ([A,Basic]) + In, Cheng Biometrics	10.48550/artsiv.220 learnable encoding	Synaptic weights	Surrogate gradient	Hybrid ANN-SNN architecture	Faster training	Vision	Grayscale images RGB images Event streams	MNIST Fashion-MNIST CIFAR-10 CIFAR-100 DVS DVSG128 Gesture	Classification task Action/Gesture Recognition	Accuracy	Methodological Limitations Interpretability Limitations Energy Estimation Limitations Hardware Limitations	RPA-based standardization quantitatively resolves only parameter values. All learned parameters rely on empirical or neuroscience heuristics. Neuromorphic hardware deployment or energy evaluation.	Fully learnable or adaptive neuron parameterization	GPU (CPU)	Architecture proposal	Hybrid CNN-SNN	Not Available	Neuron: (bio)hWk Surrogate-gradient training Adam (beta = 0.9) with cosine learning rate. Batch size 16 17 epochs Gradient step T = 8-20 depending on dataset SIT neurons inserted into selected convolutional layers.			
paperID	P16	2025	Spike (Encoding) Lazarus, IEEE Access	10.48550/http://arxiv.org/abs/2503.04850 Adaptive encoding	Adaptive (data-driven) parameters	Surrogate gradient	Pure SNN architecture	Reduced firing rate Reduced spike count	Energy efficiency computation	Stable	Audio	128-band Mel-spectrograms (20–20 kHz)	ESC-10 UrbanSound8K TAU Urban Acoustic Scenes (TAU-30Class)	Classification task Regression task Signal reconstruction	Error (in decibels (dB)) Signal-to-noise ratio (SNR)	Methodological Limitations Architectural Limitations Accuracy Limitations Hardware Limitations	All SNN results remain in below ANN baselines. No encoder-architecture co-optimization. Pure SNN architecture not optimized for audio. No neuromorphic hardware deployment.	Lack of learnable or gradient-trained spike encoders for neuromorphic audio	GRU (CPU)	Comparative Benchmark Study	Pure SNN classifier with external spike encoder	Not Available	Neuron: LF Mel-spectrogram > spike encoding (MW / 2 / TAU) > FC-MLP (100 units) > SIT. Batch = 32 LR = 0.01, 300 epochs Macro-accuracy evaluation	

rayyan-37847837	P17	2024 Spiking Neural Net Staffel, Marcus; Tandale, Sauri 10.1038/s43355-024-00000-0 learnable and adaptive encoding	Synaptic weights Temporal decay parameters Membrane thresholds	Surrogate gradient	Hybrid ANN-DNN architecture	Sparse spike activity	Energy efficiency computation	Slower Stable	Robustness	Real Numbers	Real Numbers	Custom	Regression task	Root Mean Squared Error (RMSE) Energy	Training scalability Limitations Hardware Limitations Energy Estimation Limitations	Energy values are estimated using backpropagation (not direct hardware measurement). Hardware costs are higher than ANN counterparts. Full deployment on neuromorphic hardware is constrained by dense layers.	Limited prior work on nonlinear regression with SNNs. Hardware costs are higher than ANN counterparts. Full deployment on neuromorphic hardware is constrained by dense layers.	LoHi GPU /CPU	Novel Algorithmic framework	Recurrent Spiking Neural Network (RSNN)	Not Available	Neuron: LF Adam optimizer ($\eta = 0.001$, $\beta_1 = 0.9$, $\beta_2 = 0.999$) Stochastic gradient learning Hyperparameter search RMSE loss
rayyan-38858275	P18	2024 STAL: Spike Train Hierarchical, Freek; Dehghani, Mohsen 10.48550/http://arxiv.org/abs/2401.08550 learnable and adaptive encoding	Synaptic weights Membrane thresholds	Surrogate gradient	Hybrid ANN-DNN architecture	Sparse spike activity	Energy efficiency computation	Stable	Robustness Performance	Multimodal	Electromyography (EMG) inertial measurement unit (IMU)	EmoPain dataset	Classification task	Accuracy 21 AUC Matthews Correlation Coefficient (MCC) Spike density	Hardware Limitations Energy Estimation Limitations Generalizability Limitations	Small dataset size and class imbalance. Spike density for best-performing STAL-trained variant. No deployment on neuromorphic hardware. Performance lower than deep learning models in AUC.	Neuromorphic hardware implementation and memory constraints. Extension to multi-level gain intensity and latency minimization. Broader biological domains. Real-world wearable deployment.	GPU /CPU	Architecture proposal	Ensemble of Spiking Recurrent Neural Network (SRNN)	Available	Neuron: LF AdamW optimizer LR = 1e-05, weight decay = 0.0001, 7.5e-4 (SRNN) Angle (3D) 0 + 1e-05 step dropout = 0.5 3D encoder epochs 20 5000 steps early stopping LOOCV (Leave One Subject Out) cross-validation
rayyan-38858277	P19	2024 Ternary (Spike)-T Wang, Shuai; Zhang, Dehai; Bi, Bo 10.48550/http://arxiv.org/abs/2401.08550 Adaptive encoding	Adaptive (data-driven) parameters	Surrogate gradient	Pure SNN architecture	Sparse spike activity Reduced firing rate	Energy efficiency computation Memory-efficient Multiplication-free inference (MF)	Stable	Robustness Performance	Signals Audio	Electroencephalogram (EEG) raw audio waveform [time-domain signal]	Google Speech Commands (CSC) KUS, EEG dataset DTU EEG dataset	Classification task Speech recognition	Accuracy Precision/recalls / F-measures # Epochs # Add # Mult Energy	Hardware Limitations Energy Estimation Limitations Generalizability Limitations	Energy evaluation based on theoretical analysis only. No real neuromorphic hardware deployment. Evaluation limited to speech and EEG tasks.	Designing neural neuromorphic chips. Extension to additional signal modalities. On-chip learning validation.	GPU /CPU	Architecture proposal	Quantized Ternary Spiking neural Network (QT-SNN)	Not Available	Neuron: LF Learnable VtinyV1++ inside the QT-SNN neuron model (not in the modulator). a_0/a_1 constrained to powers of two. 4 reference timesteps. Raw signal \rightarrow TAU \rightarrow ternary spikes \rightarrow QT-SNN. STDP training. Learning rule: weight \propto spike amplitude; quantized inference with bit-shift operations.