

Spiking-EEG2TEXT: A Brain-to-Text System

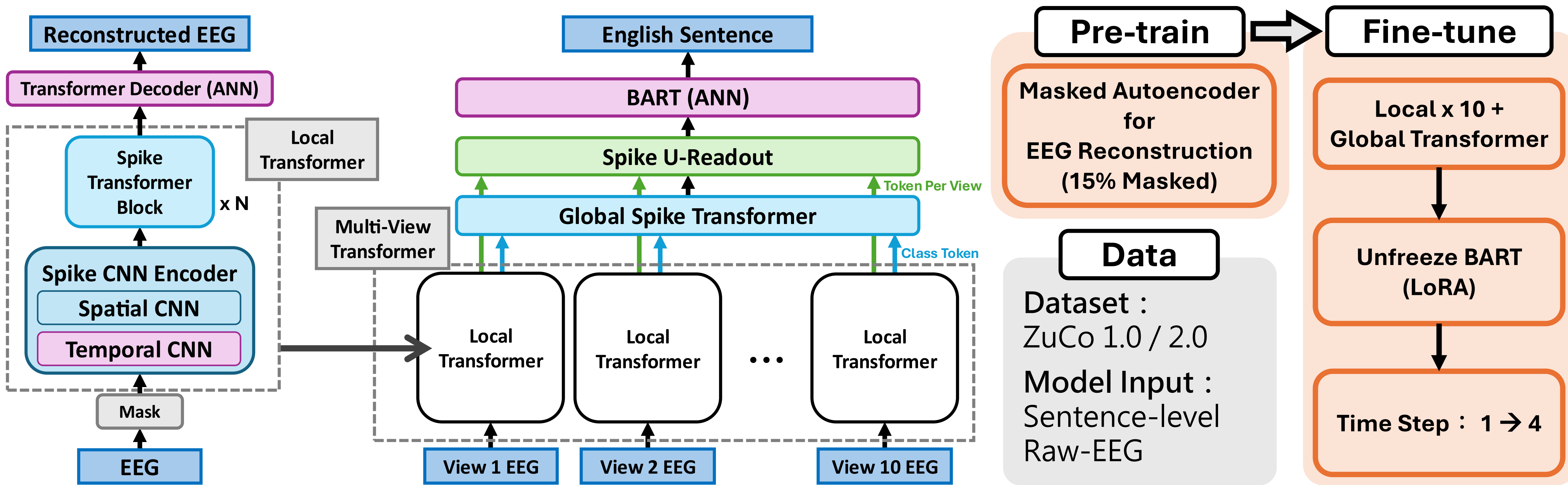
Combining Multi-View Spatio Temporal Features and Spiking Transformers

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Introduction

- 現況與挑戰：主流 EEG-to-Text 依賴 Artificial Neural Networks (ANNs) 架構，推理成本高昂
- 技術新契機：Spiking Neural Networks (SNNs) 具備抗噪與低功耗優勢，適合 EEG 邊緣運算
- 研究切入點：當前缺乏結合 SNN 的 EEG-to-Text 研究
- 本研究目標：以 SOTA 架構 (Multi-view EEG2TEXT) 為 Baseline，評估 SNN 應用於 EEG-to-Text 的可行性與效能邊界

Spiking-EEG2TEXT Design



Result

Table 1. Comparison of the Noise Resistance of ANN and SNN

	ANN w/TF		SNN w/TF	
	w/o noise	w/noise	w/o noise	w/noise
BLEU - 1	35.03	35.04	29.93	27.30
BLEU - 2	20.22	20.13	15.39	13.36
BLEU - 3	11.89	11.81	8.10	6.43
BLEU - 4	6.89	6.92	4.36	2.77

TF: Teacher Forcing

Table 2. Comparison of the Energy Consumption of ANN and SNN

	Architectural Layers	ANN		SNN	
		Operations	Energy (mJ)	Operations	Energy (mJ)
Spike Encoding	Temporal Convolution	MAC	38.640	MAC	38.640
Spiking Core	Spatial Convolution Transformer U-Readout	MAC	10.158	AC	0.177
Language Model	BART	MAC	307.428	MAC	307.428
Total Energy			356.227		346.246

MAC: Multiply-Accumulate / AC: Accumulate

Table 3. Comparison of Output Sentences

Best	Ground Truth	Kennedy's other decorations of the Second World War include the Purple Heart, Asiatic-Pacific Campaign Medal, and the World War II Victory Medal.
	ANN (45.56)	edy was portrayal notable include the year World War include the Purple Heart, theiatic-Pacific Medal Medal, and the Presidential War II Victory Medal.
	SNN (10.84)	edy's performance half are the year World War are the Medal Heart, thepenatic-American ,,and the Medal War II Medal Medal.
Near BLEU-4	Ground Truth	After World War II, Kennedy entered politics (partly to fill the void of his popular brother, Joseph P. Kennedy, Jr., on whom his family had pinned many of their hopes but who was killed in the war).
	ANN (6.92)	a War II, he became the asasly as run the vacancy left the father father, President Kennedy. Kennedy, who.) who the he father had been their hopes their hopes) who had now in World Battle)
	SNN (7.73)	a War II, he was the andasly as serve a gap left a father father, who). Kennedy), who.), who the he father had been their hopes their hopes). who had not in the war.
Worst	Ground Truth	In 1946 McNamara joined Ford Motor Company, which he later said had been the result of a Life magazine article which reported how few college-educated managers there were at the then unprofitable company.
	ANN (1.92)	the,amara was the's Company as where was served became was a a largest of his " Time article that had that the people studentseducated men were were in Ford time-incitable Ford.
	SNN (3.31)	a,amara was the's Company as where was left became was been a biggest of his desireboat article. had on the people studentseducated men were were. the time-incitable company.

Conclusion

Performance Gaps :

- 在對抗雜訊的表現上，SNN 現階段仍不如 ANN
- 受限於脈衝與 surrogate function，SNN 的 BLEU 分數仍低於 ANN

Energy Trade-offs :

- 單看 Spiking Core，其高度稀疏性確實帶來了極低的局部能耗
- 由於 Spike Encoding 與 Language Model 占比較大，導致整體能耗並未顯著降低

Future Work

Performance Optimization :

- 引入 $\{-1, 0, 1\}$ 的三元編碼機制取代目前的二元脈衝，大幅提升時序編碼的資訊承載量
- 棄用目前 CNN 編碼，改採將腦波的序列維度與 SNN 的時間維度直接對齊的編碼方式

Energy Reduction :

- 訓練 Spike 版本的 BART