Autonomy for Hypersonics

Neural-Inspired Approaches and Implementations for Automatic Target Recognition

Craig M. Vineyard, 1421
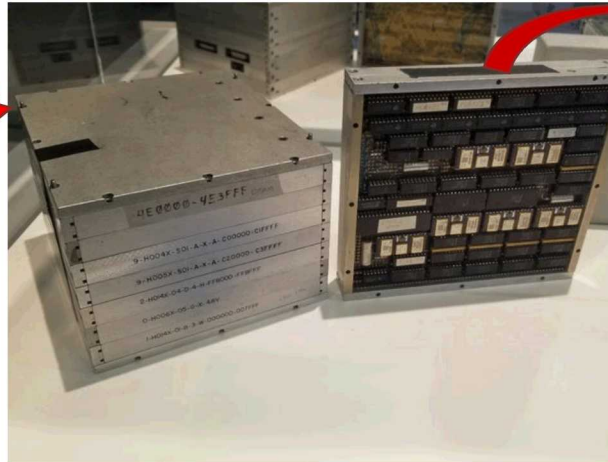
Sandia National Laboratories

Neural-Inspired Approaches for ATR

CRAY-1

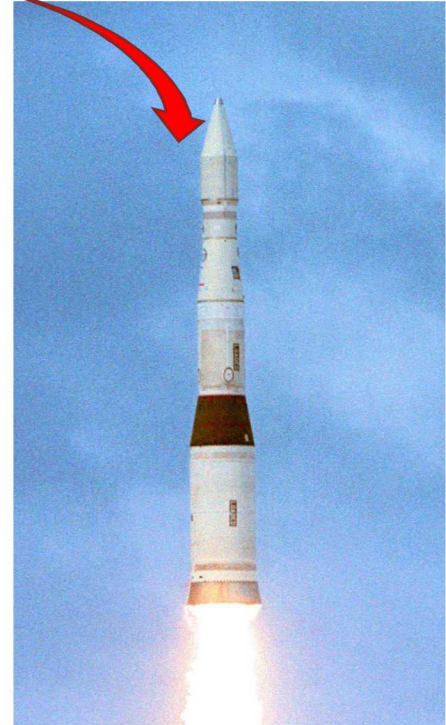https://shop.minimuseum.com/products/first-super-computer

Sandia National Labs
Airborne Computer
(SANDAC)

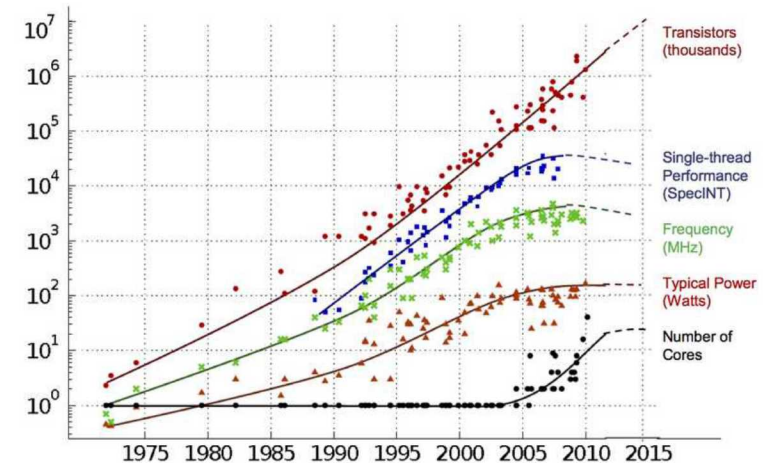https://www.tomshardware.com/picturestory/866-supercomputer-department-of-energy-amd-intel-nvidia.html#s5

Dennard scaling

- As transistors get smaller, their power density remains constant

Unfortunately ended 10-15 years ago

- Cannot run CPUs at faster speeds

- Emphasis on multi-core

Original data collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond and C. Batten
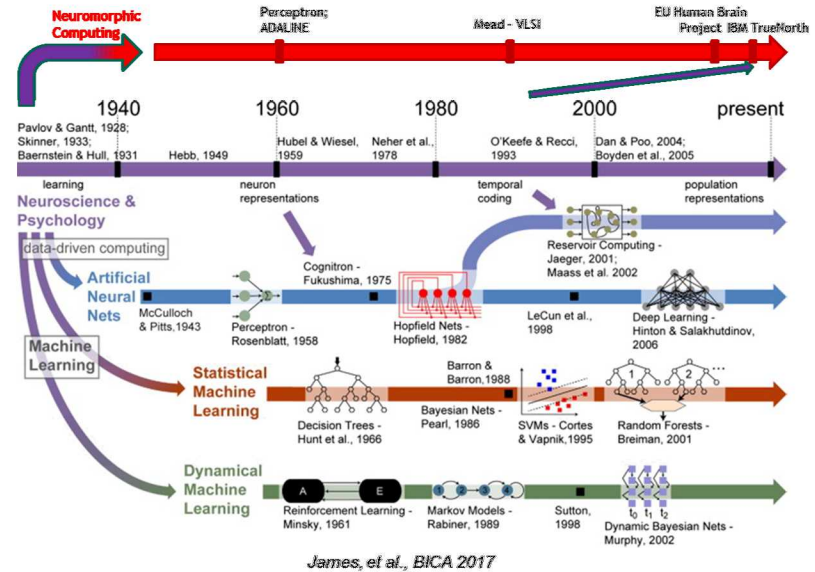Dotted line extrapolations by C. Moore
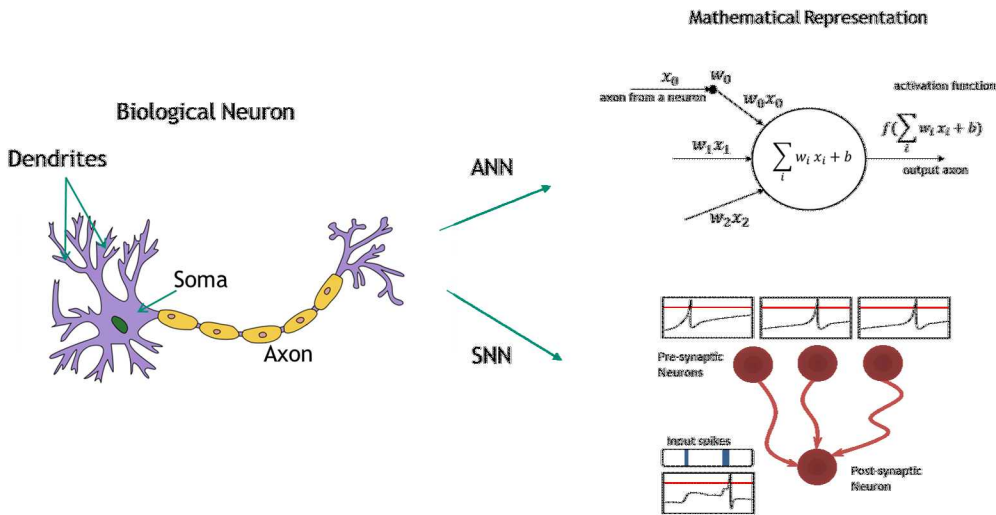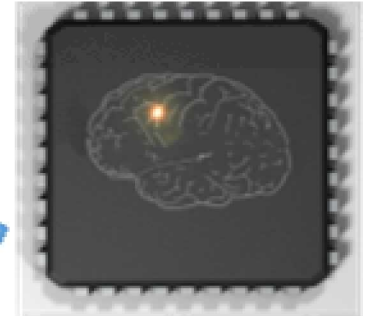
Need for new paradigm of computing

Neural-Inspired Approaches for ATR

What is neural-inspired, neuromorphic, brain-inspired computing?

- Many terms
- Fundamental notion of taking inspiration from how the brain performs computation
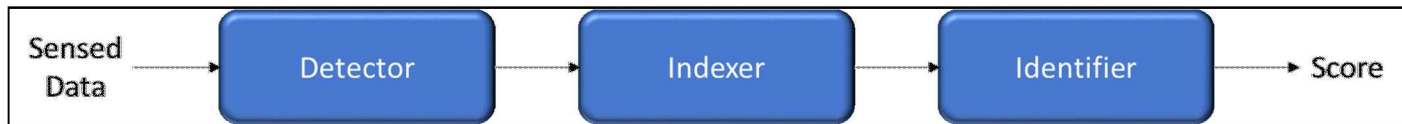

James, et al., BICA 2017

Neural-Inspired Approaches for ATR

Neural-Inspired Approaches for ATR

Automatic Target Recognition (ATR) - an exploitation algorithm for the detection or classification of items of interest via a remote sensor


Three-stage ATR block diagram

- Detector - first operates upon the raw sensed data to extract regions which express features or expressions that there may be a target of interest in the smaller identified sub-region

- Indexer - operates upon this reduced data to compare against the representations of known targets of interest

- Identifier - receives regions of interest (ROIs) as well as cues/hypotheses regarding the salient features (whether template or model based) which are used to determine a quantified score
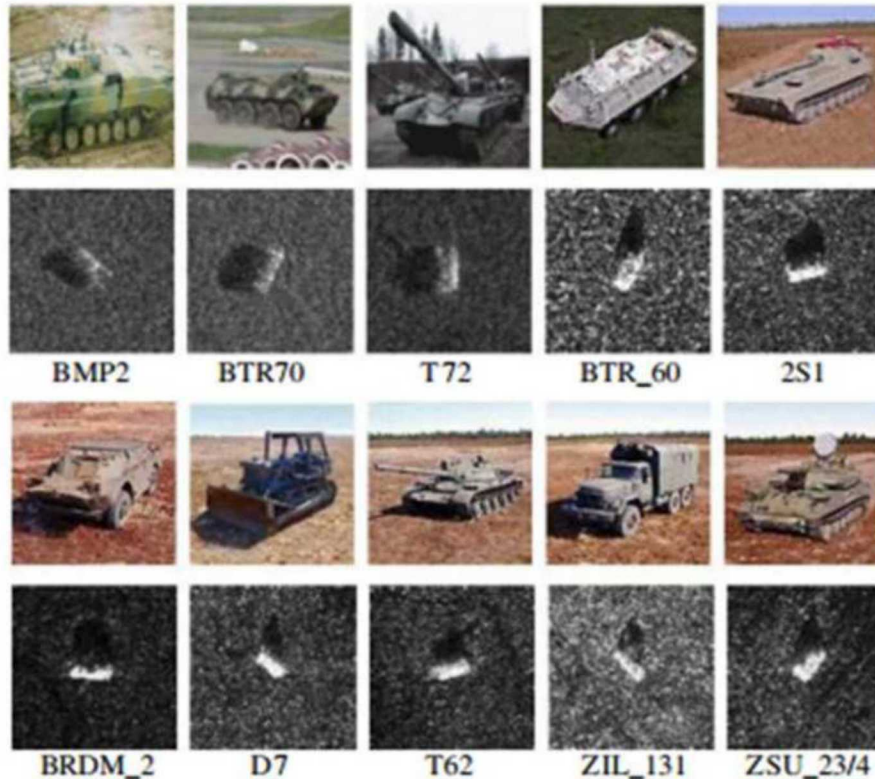
Neural-Inspired Approaches for ATR
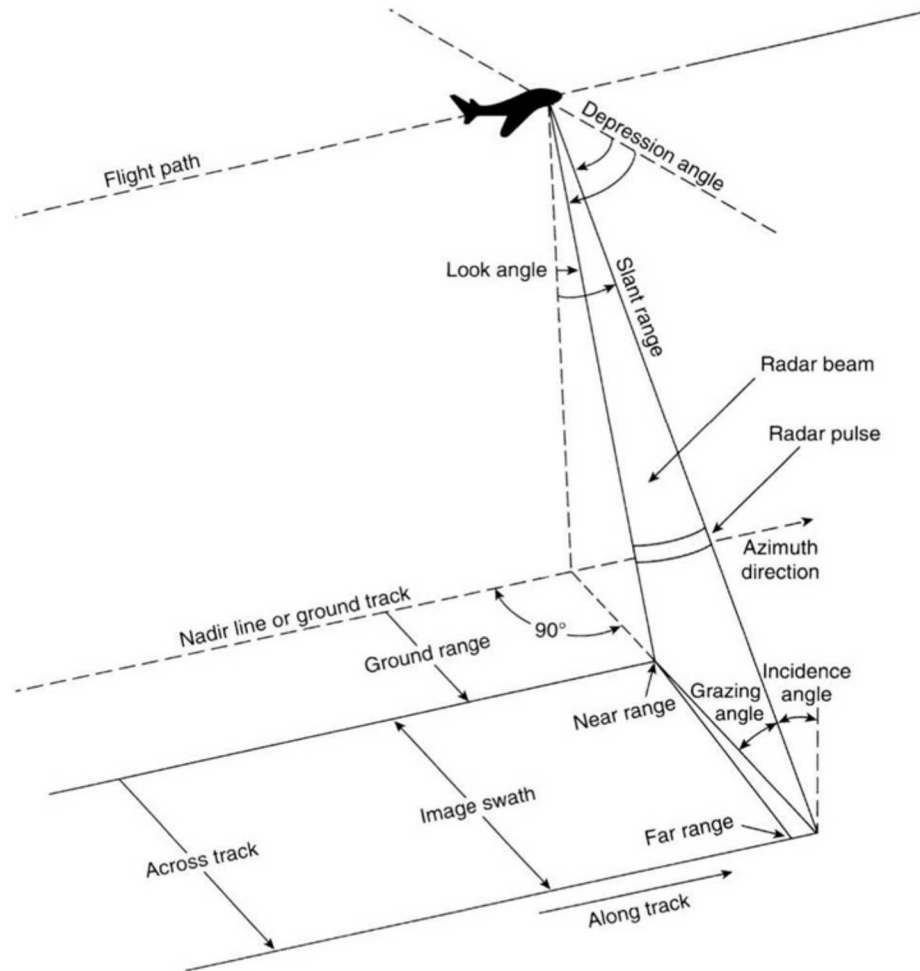
Neural-Inspired Approaches for ATR

Targets	BMP2	BTR70	T72	BTR60	2S1	BRDM2	D7	T62	ZIL131	ZSU234
17	233	233	232	256	299	298	299	299	299	299
15	587	196	582	195	274	274	274	273	274	274

BMP2   BTR70   T72   BTR_60   2S1

BRDM_2   D7   T62   ZIL_131   ZSU_23/4

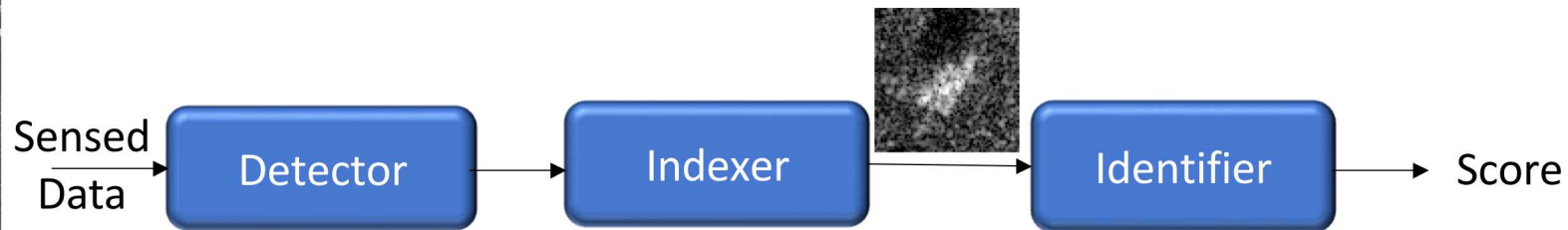# Neural-Inspired Approaches for ATR
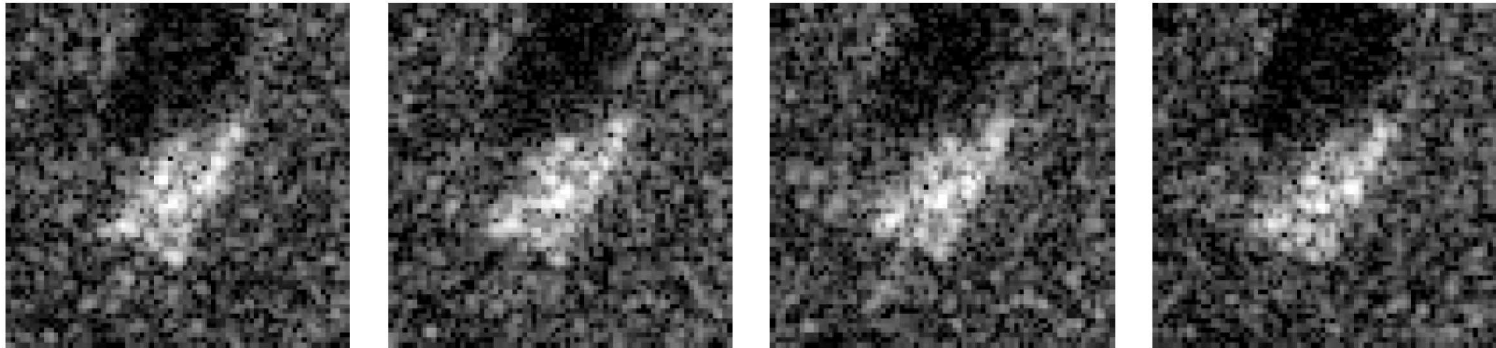
Sensor induced challenges –

- Unknown sensor types
  - Synthetic Aperture Radar (SAR) or High-range Resolution (HRR)

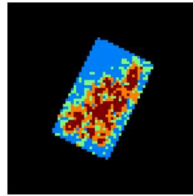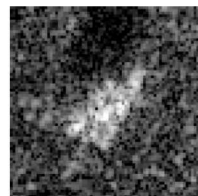- Signal variability due to coherence, specularity, and speckle
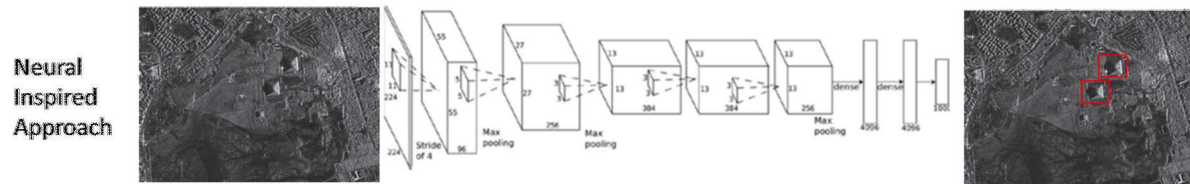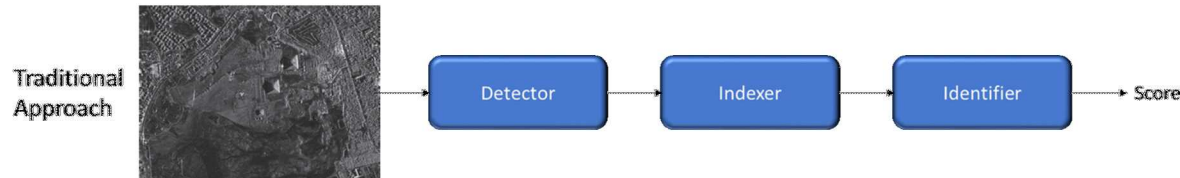
Neural-Inspired Approaches for ATR

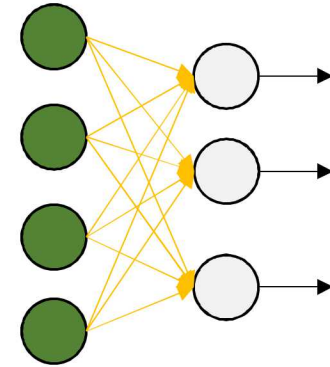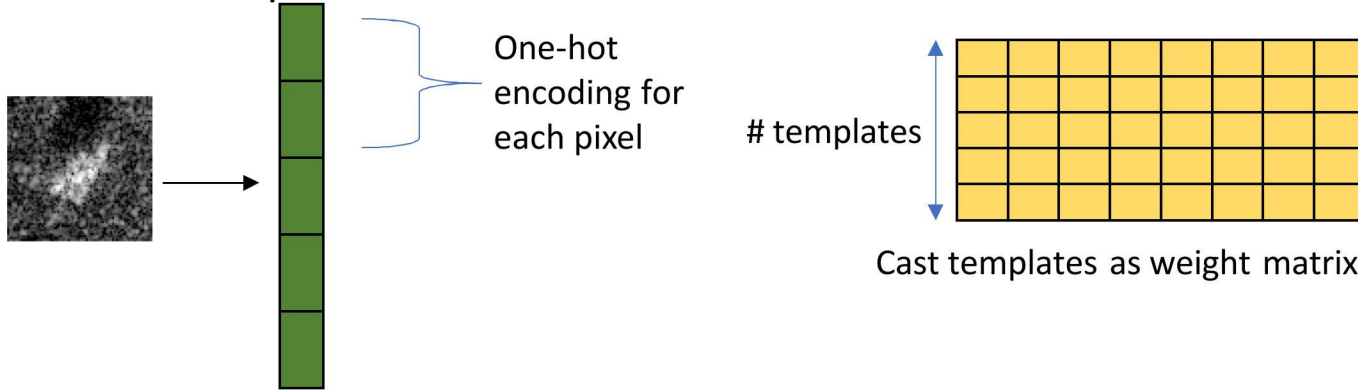Sensed Data → **Detector** → **Indexer** → **Identifier** → Score

MPM

Signature-to-template match score Z

$$Z = \frac{1}{C} \sum_{k=1}^{K} t_{k,q_k}$$

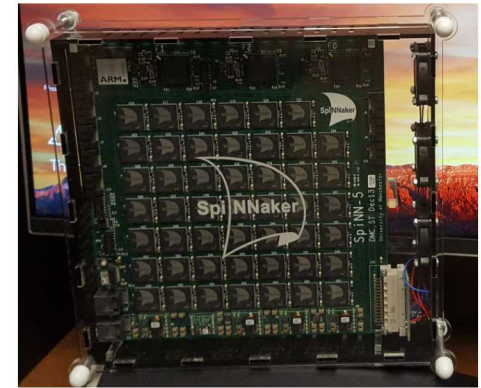# Neural-Inspired Approaches for ATR

Neural Circuit Equivalent

One-hot encoding for each pixel

templates

Cast templates as weight matrix

Traditional Approach

Detector → Indexer → Identifier → Score

Neural Inspired Approach

Max pooling   Max pooling   Max pooling   dense   dense

Stride of 4

End-to-end Approach

Neural-Inspired Approaches for ATR

Exploring suite of hardware platforms
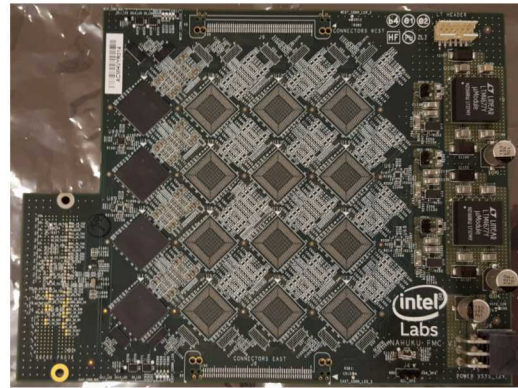
Neural-Inspired Approaches for ATR

Initial results from Intel Neural Compute Stick 2 -

Architecture	DNN accelerator	
Power	~1 W	
Throughput	307.4 fps	
Batched throughput (batch size)	1156.397 fps	(10)
	1536.95 fps	(50)
	1614.5227 fps	(100)
	1648.32 fps	(250)

50x50 input tile
100 templates

Neural-Inspired Approaches for ATR
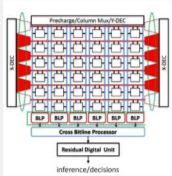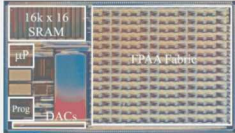
Initial results from IBM TrueNorth -

Architecture	Spiking Neuromorphic
Power	123 mw (3 W system)
Throughput	1000 fps
CNN Accuracy	~94.36%

32x32 input tile
~10 templates

Neural-Inspired Approaches for ATR

University Collaborations

UIUC	Georgia Tech	Purdue
Naresh Shanbhag	Jennifer Hasler	Kaushik Roy
Deep In-memory Architecture (DIMA) • Co-located memory & compute	Field Programmable Analog Array (FPAA) • Ultra-low power device coupling computational speed of analog computing & digital communication	Programmable Ultra-efficient Memristor-based Accelerator for Machine Learning Inference (PUMA) • Optimization of energy

Neural-Inspired Approaches for ATR

Thank you