ENERGY ESTIMATION OF DEEP LEARNING

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Problems

Advanced building

- Damage detection
- Floor monitoring
- Intrusion detection
- Fault detection

Smart mobility & Connected vehicle

- Self-driving vehicle
- Intelligent surveillance
- Traffic flow monitoring
- Malicious node detection

Smart Grid and RE

- Electric load prediction
- RE forecasting
- False data attack detection
- Electricity theft detection

Deep Learning (DL) is increasingly used extensively in various domains

- DL training takes a lot of computation time
- Energy consumption is a critical resource

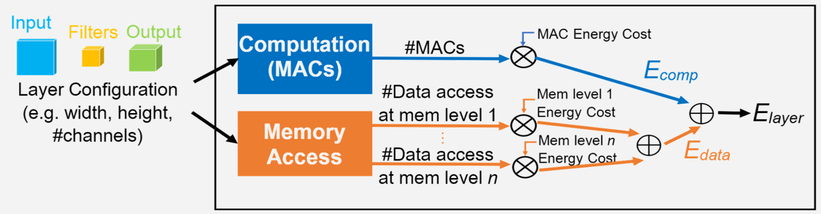
How much energy does DL consumed?

Existing Work

- use simulation-based methods which require knowledge of the systems
- use tool-based methods are system-specific and not always available or replicable
- focus only on inference phase.

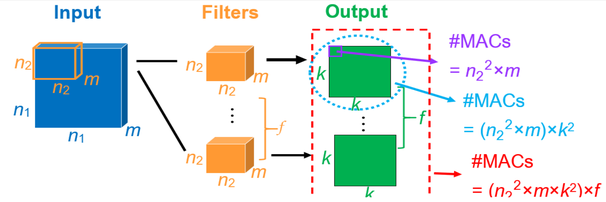
Our Approach

- Analytical model to estimating energy consumption of deep learning training.
- For each layer, our model quantifies number of MAC (multiply-and-accumulate) operations and the corresponding data access from a memory hierarchy.
- Considering two types of deep learning: Convolutional Neural Network (CNN) and Artificial Neural Network (ANN)



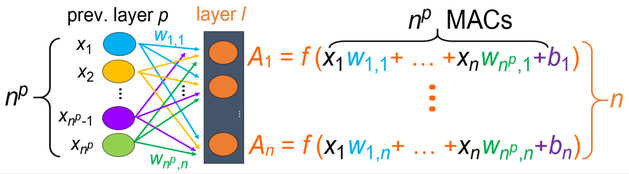
CONV layer

$$a_{input} = n_2^2 m + \sum_{i=2}^{n_2^2 mf} r_i i$$
$$a_{weight} = n_2^2\, m\, f\, k^2$$
$$a_{bias} = fk^2$$
$$a_{output} = k^2 f (2n_2^2\, m)$$



FC layer

$$a_{input} = n^p(n)$$
$$a_{weight} = nn^p$$
$$a_{bias} = n$$
$$a_{output} = n^p(2n)$$



Illustration

- In smart city [1] e.g. smart drainage, smart transportation and smart parking
- For smart parking, CNN is adopted in spot detection which takes image of a parking lot and determines if a spot is vacant.
  - Input: CNN model configuration
  - Output: energy consumption

TABLE I. COMPARISON BETWEEN CNN MODELS

Metrics	CNN Architecture	
	Alexnet	*miniAlexnet*
Normalized energy (MACs)	5237.13 G	76.42 G
Power (Watt; J/s)	2618.56	56.44

- Take away:
  - More number of parameters does not always mean more energy consumption
  - System managers can effectively plan energy consumption at the planning level and determine tradeoff with energy and model architecture and configuration, execution frequency.

[1] Puangpontip, S. and R. Hewett, 2020. Energy Usage of Deep Learning in Smart Cities. Proceedings of the 7th Computational Science & Computational Intelligence (CSCI'20).