Math INDUSTRY

Analyzing deforestation in the Amazon Basin with Machine Learning

MULTIVERSE

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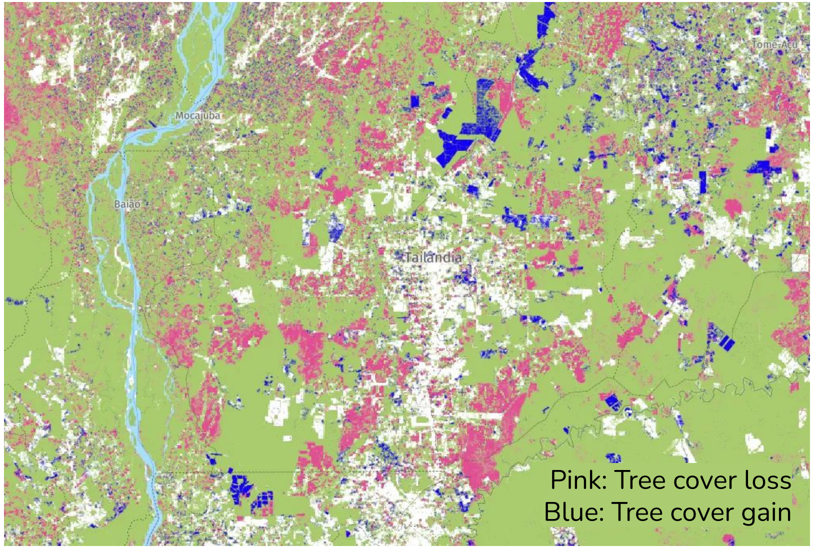
The Forest Degradation Problem

- ➢ Every minute, the world loses an area of forest the size of 48 football fields

How to reduce forest degradation?

- ➢ Early detection of forest destruction
- ➢ Identification of lands where trees can be replanted
- ➢ Detection and monitoring of patterns



Changes in tree cover in Tailândia municipality in the Amazon rainforest — Global Forest Watch.

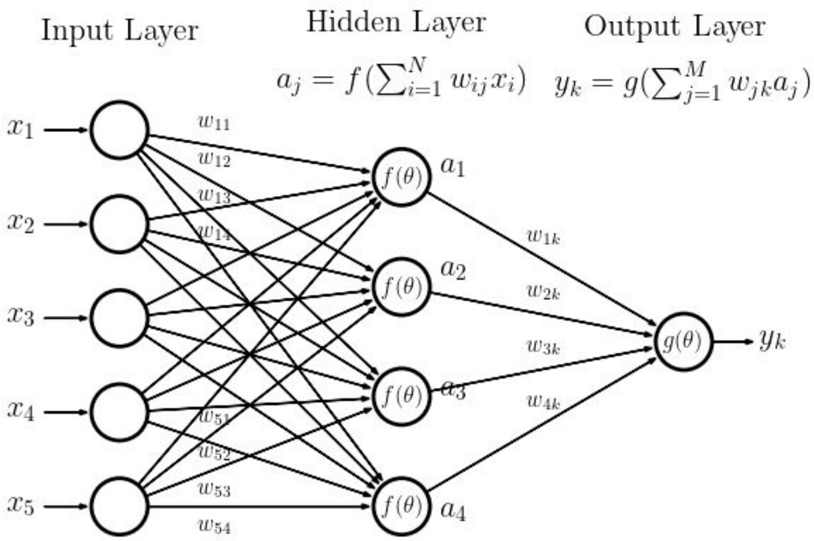
Kaggle's Multi-label Classification Competition *Planet: Understanding the Amazon from Space*

- **4 Atmospheric conditions:** clear, partly cloudy, cloudy, haze
- **7 Common land cover and land use types:** rainforest, agriculture, rivers, towns/cities, roads, cultivation, bare ground
- **6 Rare land cover and land use types:** slash and burn, selective logging, blooming, conventional mining, artisanal mining, blow down

Neural Networks 101

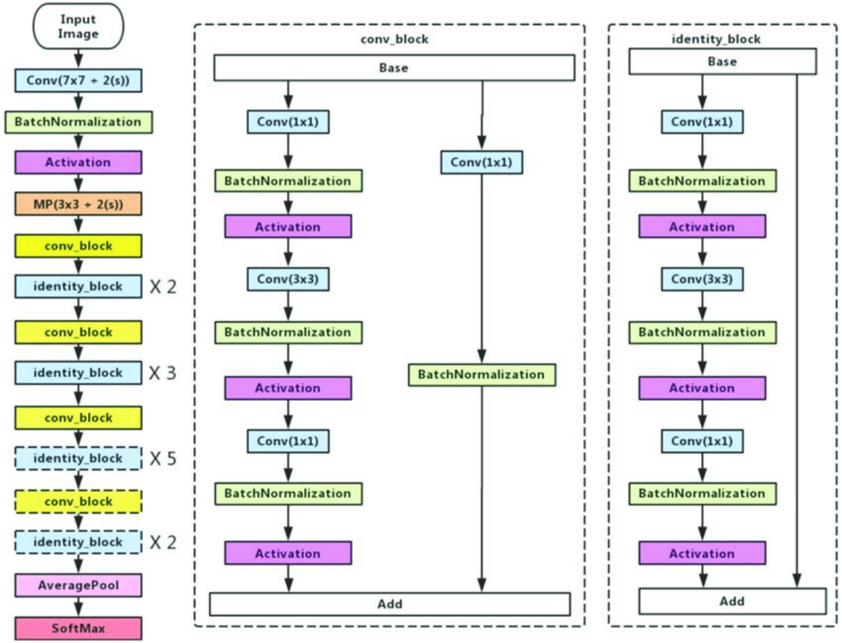
- **Input Layer:** Receives and passes data to hidden layers.
- **Hidden Layer(s):** Performs computations and feature extractions.
    - Uses matrix-vector multiplication
- **Output Layer:** Produces the final prediction or output.
    - In our case, there will be 17

Training a neural network means minimizing the loss (cost) function and involves calculus techniques like gradient descent.



A hidden layer is any layer between the input layer and output layer. There can be multiple hidden layers!

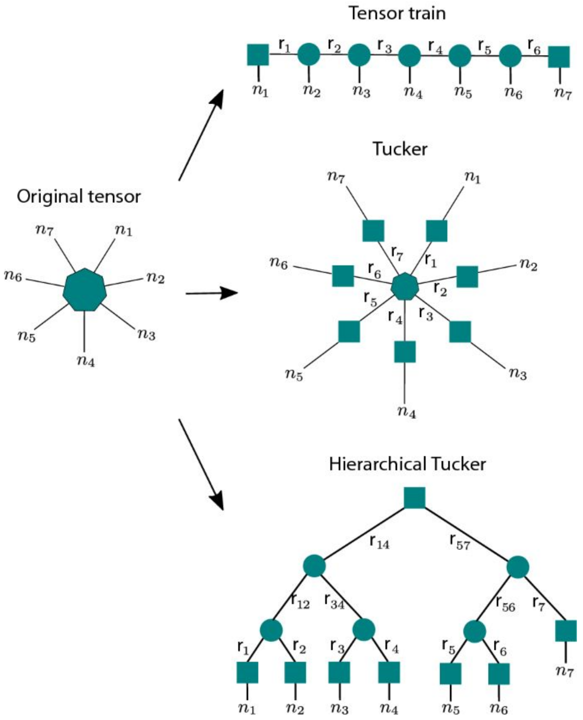
ResNet



The ResNet50 Architecture

- ## ResNet-50:
  - A deep CNN architecture, 50 layers.
  - Combining depth and scale for performance.
- ## The Significance of Depth:
  - Deeper Networks enable capturing complex features.
  - Avoids the vanishing gradient problem.
- ## Unveiling the Scale:
  - Multiple scales of features through skip connections.
  - Empowering hierarchical representation learning.
- ## The Challenge of Size:
  - Over 25 million parameters.
  - Long training times and large computations.
- ## Environmental Impact:
  - Massive computational resources needed.
  - Contributes to increased carbon footprint.

Tensor Decomposition



Tensor Decompositions

➢ Tensor Decomposition:

- A powerful technique to represent and analyze high-dimensional tensors.
- Breaking multi-dimensional arrays into simpler components (rank).

➢ TT Decomposition:

- Representing a tensor as a sequence of smaller, interconnected tensors.
- Compressing large tensors into a compact format.
- Memory efficiency: Reducing storage requirements for big data tensors.

➢ Tensor Train in Deep Learning:

- Accelerating computation in neural networks.
- Efficiently handling large model parameters.

Compression of a CNN model

- By replacing the output layer of ResNet50 with *17* neurons, we obtain *32,768*17* new weight matrix parameters and *17* bias vector parameters, totaling *557,073* new parameters.
- Just to retrain the final layer of our model (i.e. training the *557,073* parameters) for *20* epochs with GPU on Google Colab it takes around *40* minutes.
- Using TT decomposition on the weight matrix on the output layer of the ResNet50 architecture we are able to reduce the number of parameters to only *17,425*.
- Retraining the new model with the same setup takes less time and gives comparable accuracy.
- Tensorizing the entire model using TT decomposition gives significant advantages in terms of speeding up training time and also utilization of resources.
- Complete tensorization using TT decomposition will further reduce training time and model size, enabling implementation on previously inaccessible devices.

Setup

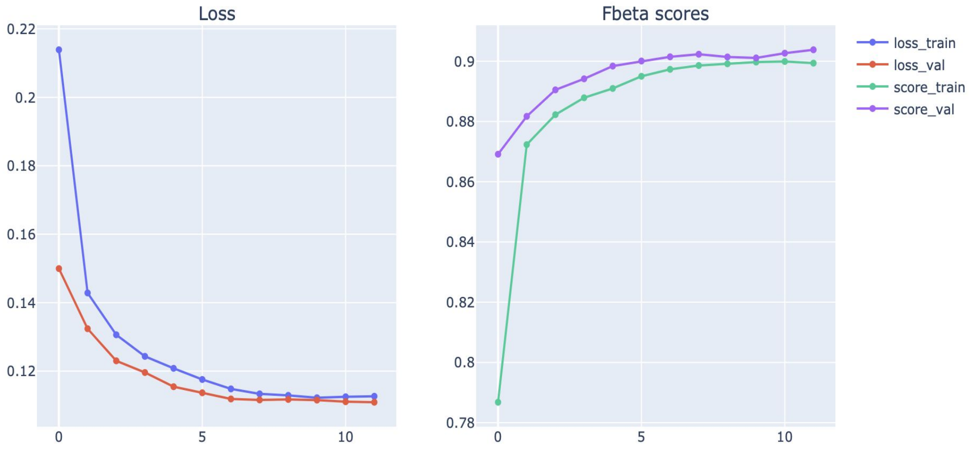
➢ **Baseline:**

ResNet50 + FC1(2048,512) + FC2(512,17)

➢ **Number of parameters of FC1:** 1048576

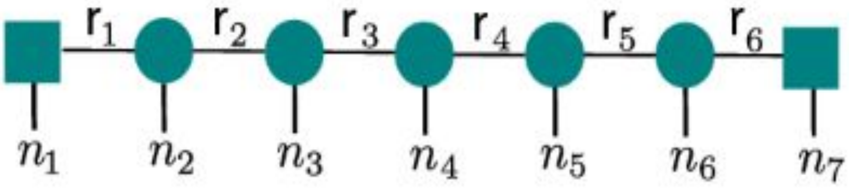
➢ **Number of epochs:** 12

FC1 layer --- number of parameters: 1048576

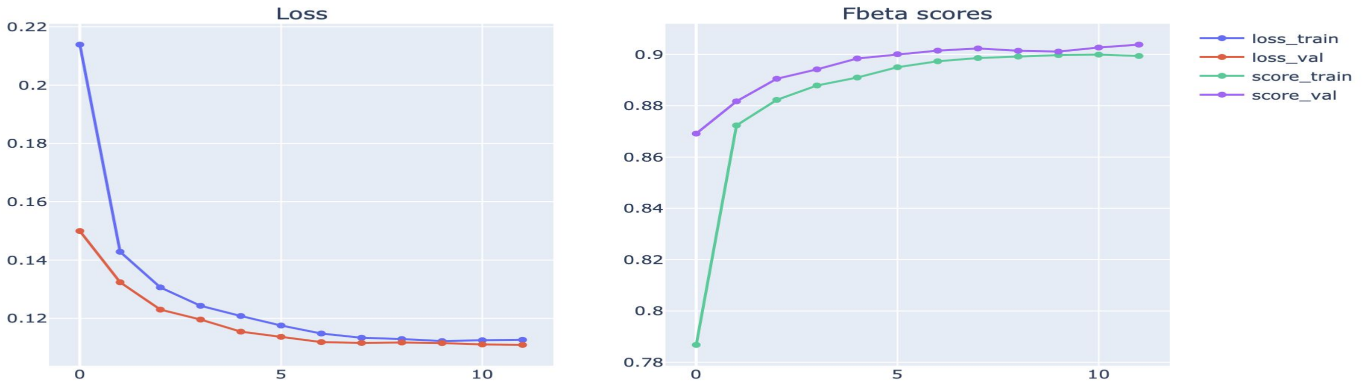


Tensorizing the fully connected layer FC1(2048,512)

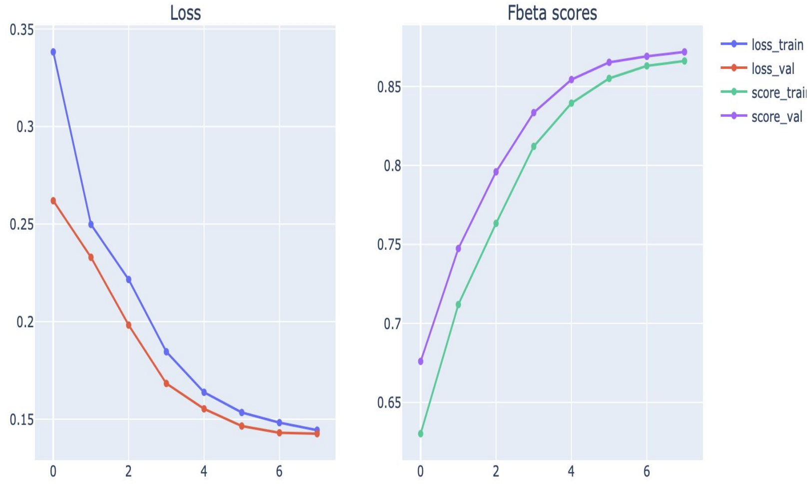
- Reshape the weight matrix 2048x512
- TT decomposition of the weight matrix
- Train the network with various tt-ranks=(r1,...,r6).



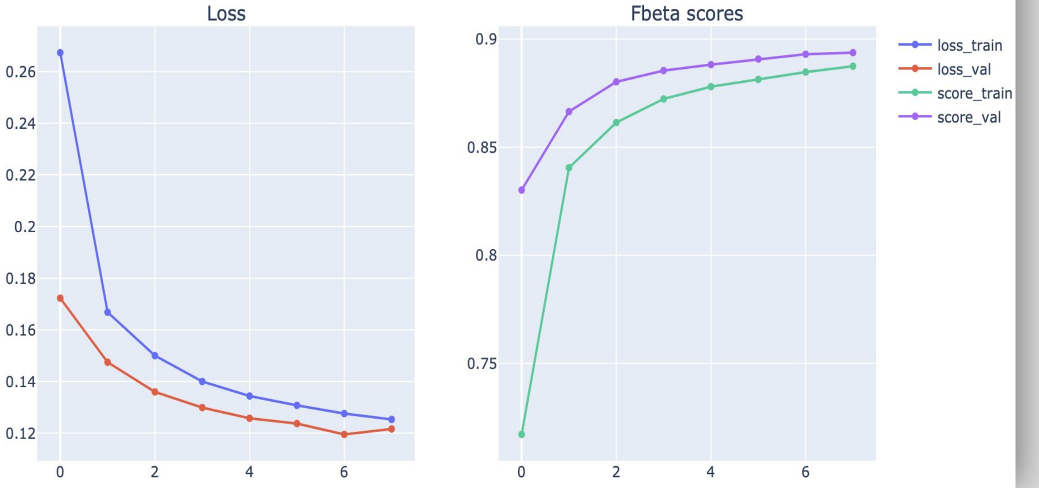
FC1 layer --- number of parameters: 1048576



Shape: (16,8,16,512) --- tt-rank=(24,24,24,24) --- number of parameters: 345024



Shape: (32,64,512) --- tt-rank=(64,64,64) --- number of parameters: 301056



Experimental results

Model	Comp. ratio	Accuracy	Inference time/epoch(s)
Baseline ResNet18+FC	1:1	89.00%	847
(8x8x8), tt-rank=(8,8,8,8)	1:12	71.00%	859
(8x8x8), tt-rank=(16,16,16,16)	1:1	83.12%	851
Baseline ResNet50+FC	1:1	**90.30%**	929
(16x8x16), tt-rank=(24,24,24,24)	**1:3**	87.20%	935
(16x8x16), tt-rank=(32,32,32,32)	1:1	**89.09%**	939
(32x64), tt-rank=(64,64,64)	**1:3.5**	**89.37%**	929

Why tensorize

- State-of-the-art deep neural networks are too big to fit into the memory of mobile devices.
- There is lot of redundancy in big neural networks
- Tensorization allows the reduction of the size of FC with a small drop in accuracy.
- The ultimate goal is to increase accuracy while decreasing memory and complexity.

Thank you!