Application of Transfer Learning Tuning to a Convolutional Neural Network for Image classification to the analysis of collisions in High Energy Physics

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ABSTRACT

The program of **LHC and CMS records the collision of high energy physics** and shares the data in the worldwide LHC Computing Grid, which gives a platform for physicists in 42 countries.

With CMS open data, this research applied **convolutional neural networks to classify ($t\bar{t}$+ jets), (W + jets) and Drell-Yan processes**. We compare the performance of five well-known convolutional neural network and test transfer learning in particle classification.

BACKGROUND

Convolutional Neural Networks (CNN)

CNNs are commonly utilized in the computer vision field for complex image classification problems as it can identify particle interactions in high energy physics. CNNs stem from a feed-forward neural network and contain several layers of convolution. The CNNs we have chosen were made with image recognition problems in mind, thus the models typically perform excellently in visual classification tasks.

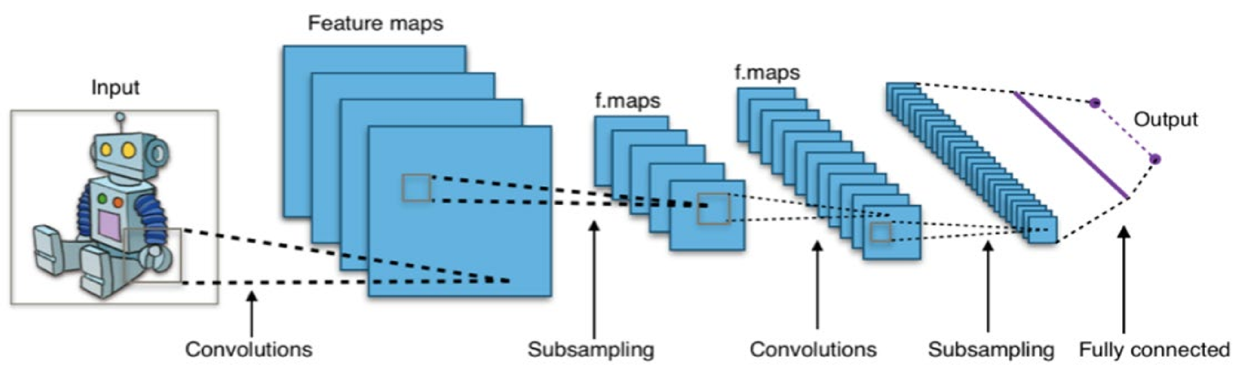


Figure 1. CNN model

The Large Hadron Collider (LHC)

It is the world's largest particle collider and is used to accelerate particles beams and guide particle's collision. It allows the physicists to test the predictions of various theories of particle physics where it collides with charged particles which are then broken into new particles.

Compact Muon Solenoid (CMS)

It is the particle detector, which uses to detect the new particles produced in high energy collisions in LHC. It uses the key data to create a picture of events at the heart of the collision.

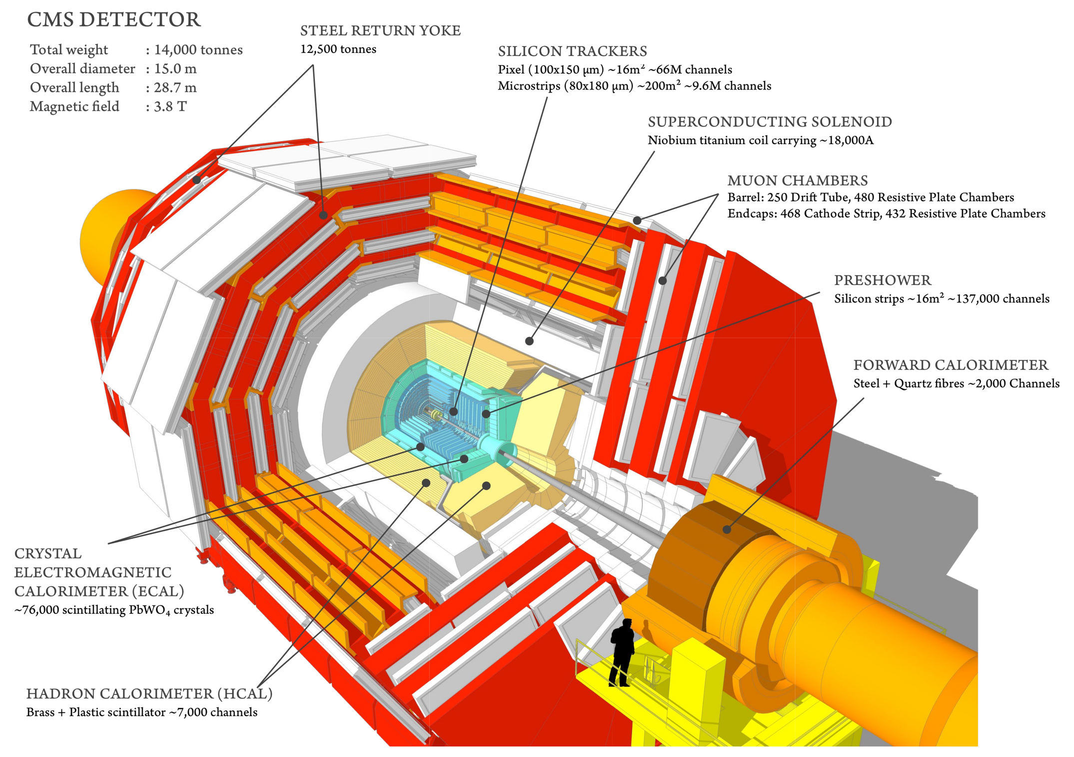


Figure 2. Compact Muon Solenoid (CMS)

Collision Model :

We focus on the classification of top quark pair ($t\bar{t}$) events with additional jets ($t\bar{t}$+ jets), W boson produced in association with additional jets (*W + jets*) events and *Drell-Yan* processes.

Each top quark decays into a W boson and a bottom quark.

- One of W bosons decays leptonically into a charged lepton, electron or muon, with an associated neutrino.

METHODOLOGY

Open Data Monte Carlo samples of collisions at LHC from CMS Open Data portal is being used to create images containing information of different physics observables. Then we train the convolutional neural network on these images to distinguish the different physics process.

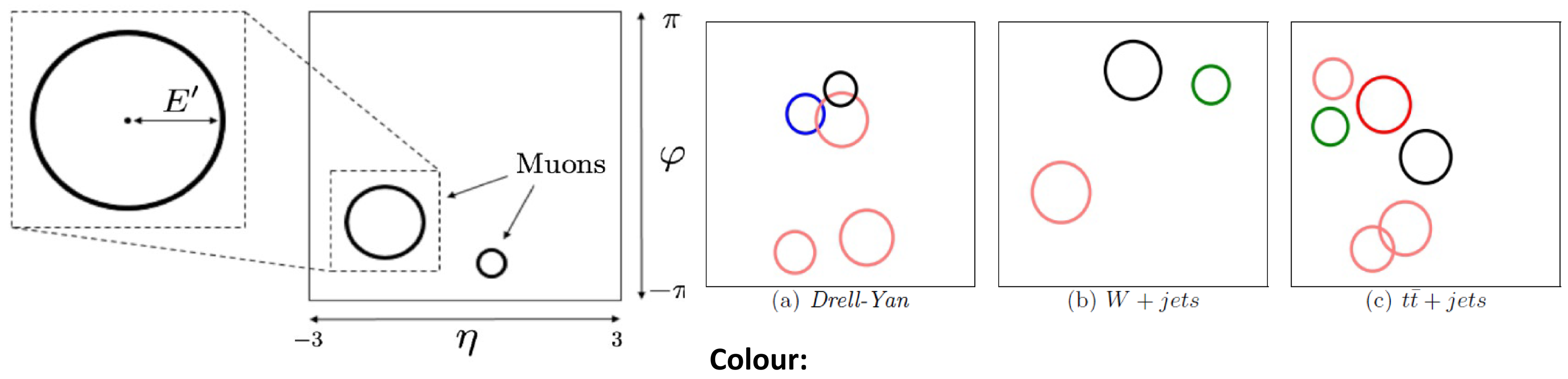
Getting data & Creating JSON → Images Creation → Classifying images by Transfer Learning techniques

1. Getting data & Creating JSON

- **Data Type:** AODSIM root files is recorded in a HEP experiment by a detector like CMS. Collisions, also known as events are described by a set of variables: the momentum of muons, electrons, photons and hadrons.
- **Flow:** Create a link to condition database and download the target index respectively. Generate JSON using a C++ framework based on a template provided by the Open Data group.

2. Images Creation

- All the observables are to be represented using a canvas of dimension 200x200 pixels.
- Each particle or physics object is represented as a **circumference with a radius proportional to its energy**.
- **The momentum direction** coordinates the pseudo rapidity η and the azimuthal angle ϕ
- **Color**: different type of particles and physics objects



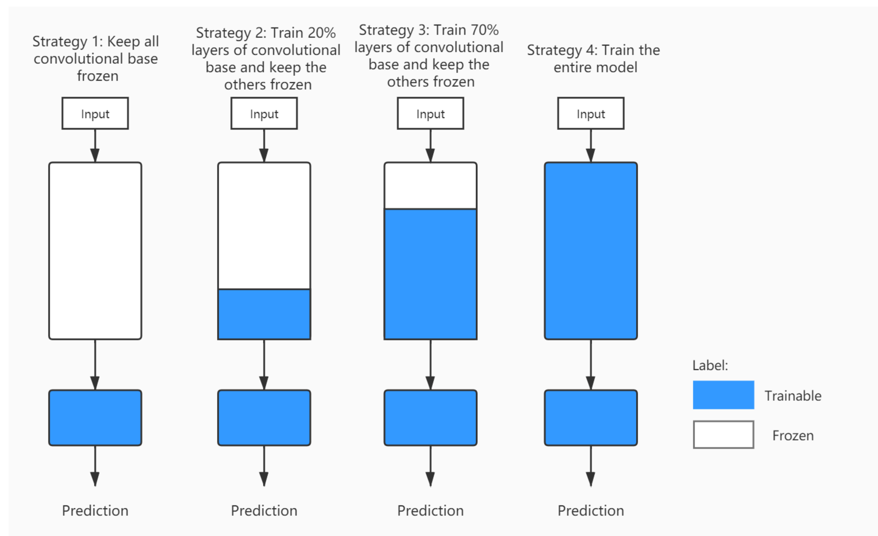
Circumferences: Leptons and Jets
Radius: proportional to transverse momentum
Scale: Pt' = C * ln (pt) (C ~ 10.5)

Colour:

- **Blue - electrons**
- **Green - muons**
- **Pink - non-B-tagged jets**
- **Red - B-tagged jets**
- **Black - missing transverse energy**

3. Classifying images utilizing Transfer Learning Tuning:

Each model is tested with two different optimizers. 4 frozen-unfrozen layer proportions are tested with each model and optimizer combination.



RESULTS

RESULTS	InceptionV3		Inception-ResNetV2		VGG16		VGG19		ResNet50	
	Adam	RMSprop	Adam	RMSprop	Adam	Rmsprop	Adam	RMSprop	Adam	RMSprop
% Layers unfrozen	0	0	0	0	0	0	0	0	0	0
Test Accuracy (%)	30.6	33.3	33.9	34.4	75.6	78.1	74.9	76.9	59.4	34.4
% Layers unfrozen	20.3	20.3	20	20	21.1	21.1	22.7	22.7	20.0	20.0
Test Accuracy (%)	34.4	30.3	33.3	34.2	32.5	76.1	35.3	72.5	34.1	32.0
% Layers unfrozen	70.1	70.1	70	70	73.7	73.7	72.7	72.7	70.2	70.2
Test Accuracy (%)	29.2	33.6	33.9	34.4	32.5	28.3	30.8	72.8	56.3	31.7
% Layers unfrozen	100	100	100	100	100	100	100	100	100	100
Test Accuracy (%)	80.6	70.6	71.9	72.8	31.7	76.7	30.8	71.9	54.4	76.1
Best Accuracy	80.6		72.8		78.1		76.9		76.1	

CONCLUSION

From the result, the performing best model is InceptionV3 (80.6% accuracy). In conclusion, state of the art models such as inceptionV3 and VGG16 are viable options for out of the box transfer learning. The weights loaded from image net reduce the amount of time that a deep learning network would have to otherwise take if learning from scratch.

CONTACT & REFERENCE

Scan the QR code to find the reference.
Website: https://github.com/jzyee/cms_image_classification

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