Using Deep Learning to Detect Galaxy Mergers

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Contents:

Objectives

- Detect galaxy mergers using Deep Learning techniques
- Investigate 3 Convolutional Neural Networks (CNNs) architectures
- Compare learning from scratch and transfer learning
- Outperform previous automatic detection methods

Background

Astronomy

- What is a galaxy merger?

- How astronomers get imaging data?

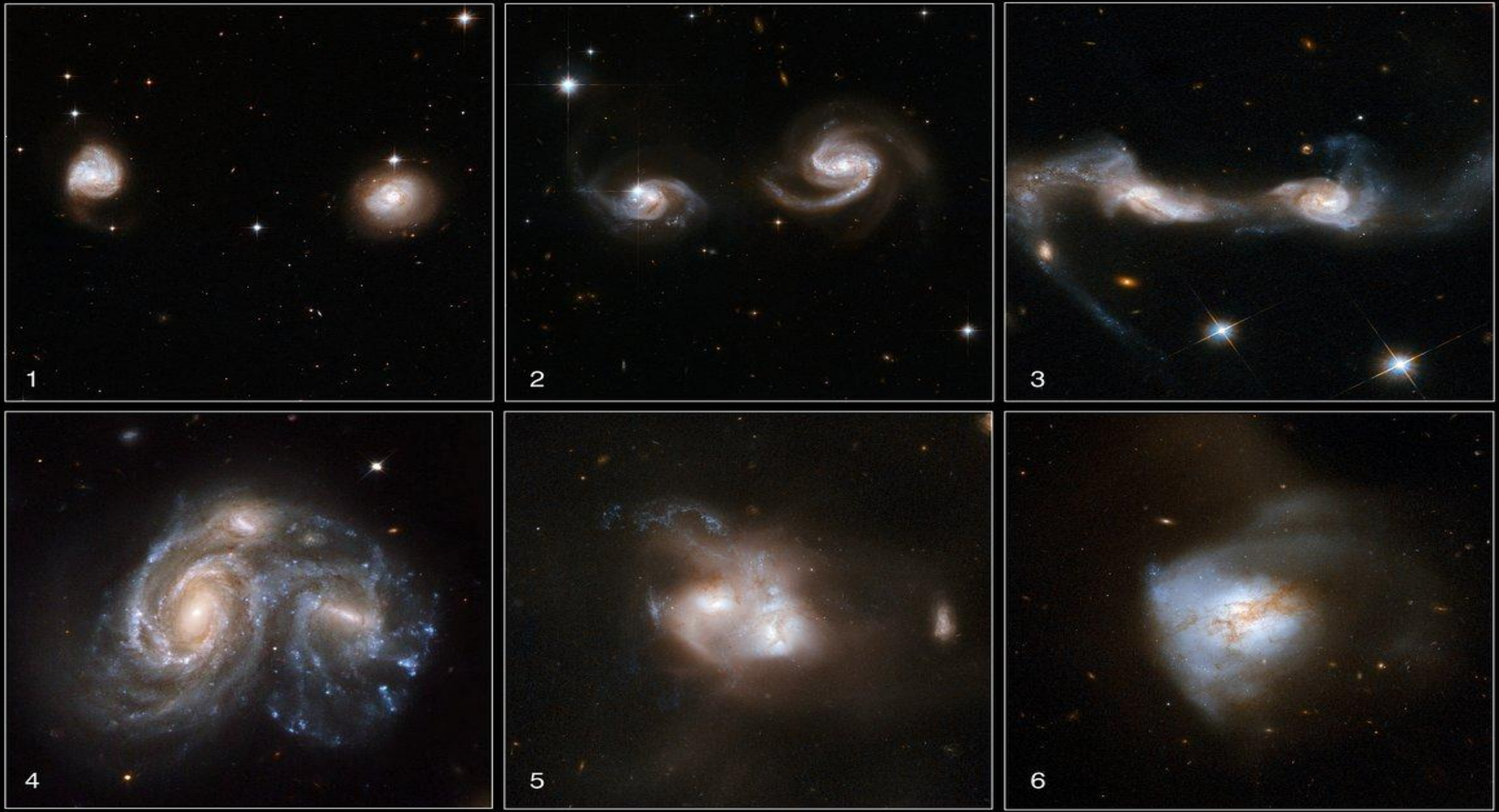


Image by ESA/Hubble available at https://www.spacetelescope.org/images/heic0810ac/

Deep Learning

- Neural Networks

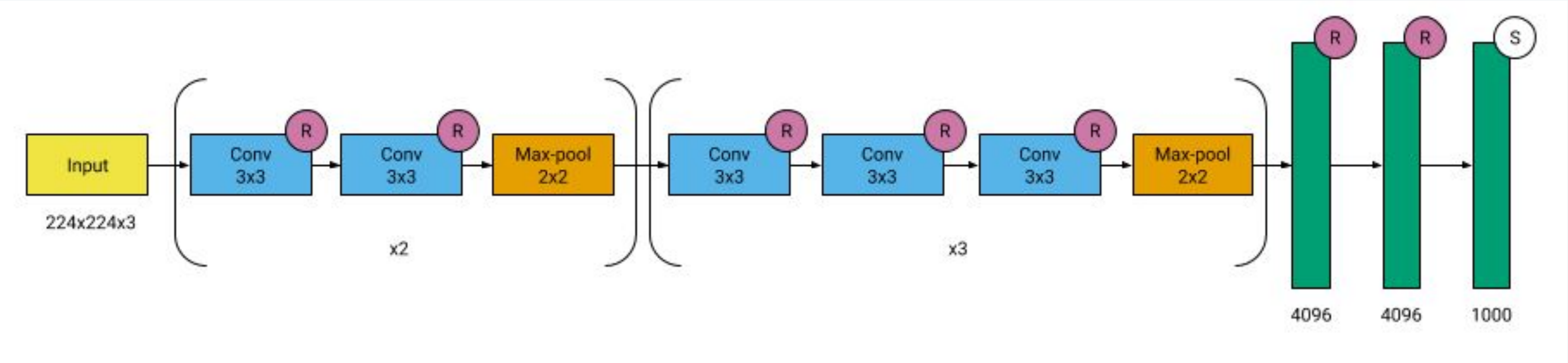
- Gradient descent and backpropagation

- Convolutional Neural Networks

Architectures

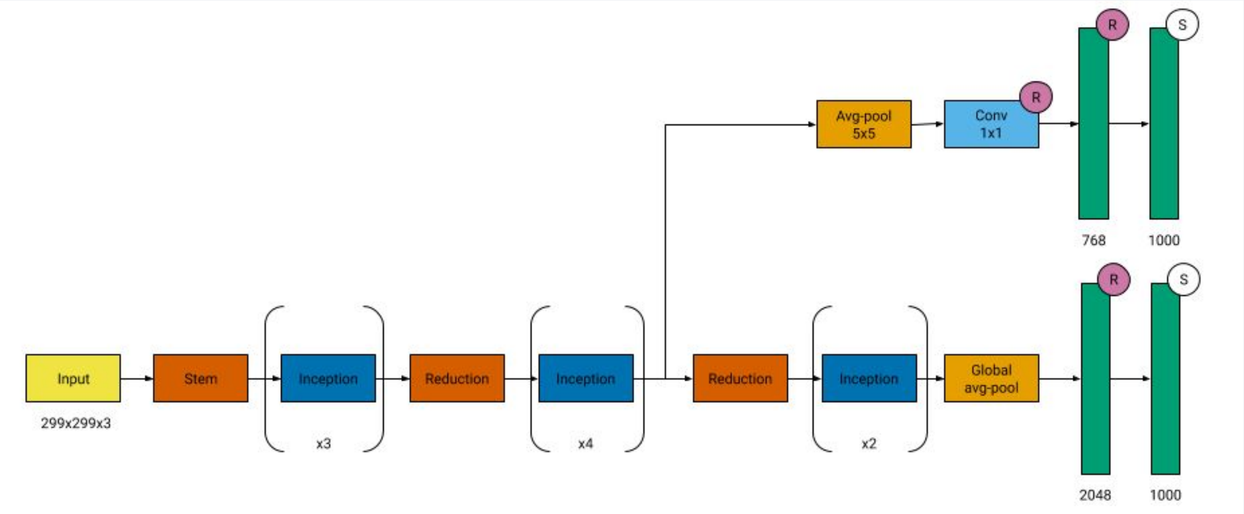
VGG-16

- Created by the Visual Geometry Group at the University of Oxford (2014) [1]
- 138 Million parameters
- 13 convolutional layers and 3 fully-connected layers



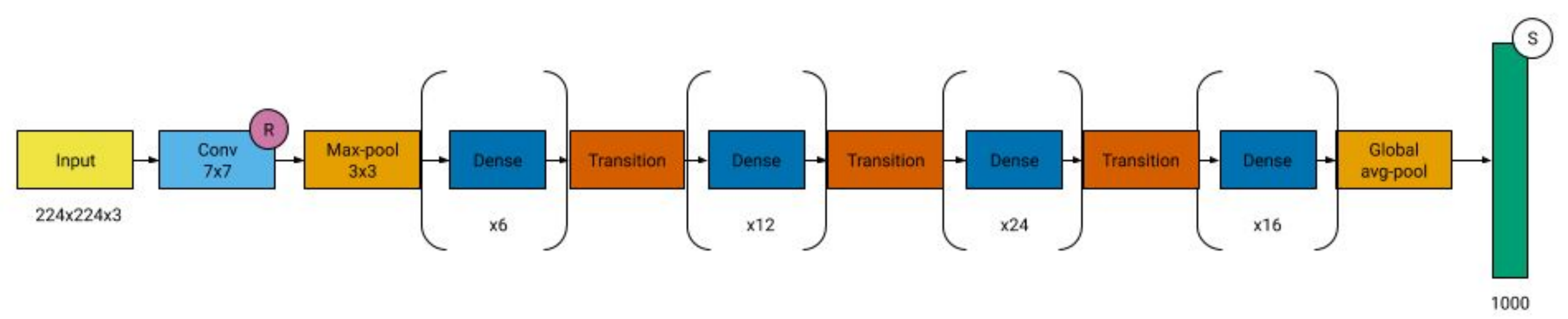
Inception-v3

- Created by the Google AI team (2016) [2]
- Inspired by the movie Inception and the quote “We need to go deeper”
- 24 million parameters, stacks dense blocks of convolutional layers and uses batch normalisation in auxiliary layers



Densenet-121

- Created by Facebook AI Research (2017) [3]
- Adds shortcuts among layers
- Only 0.8 Million trainable parameters
- Features a growth rate hyperparameter

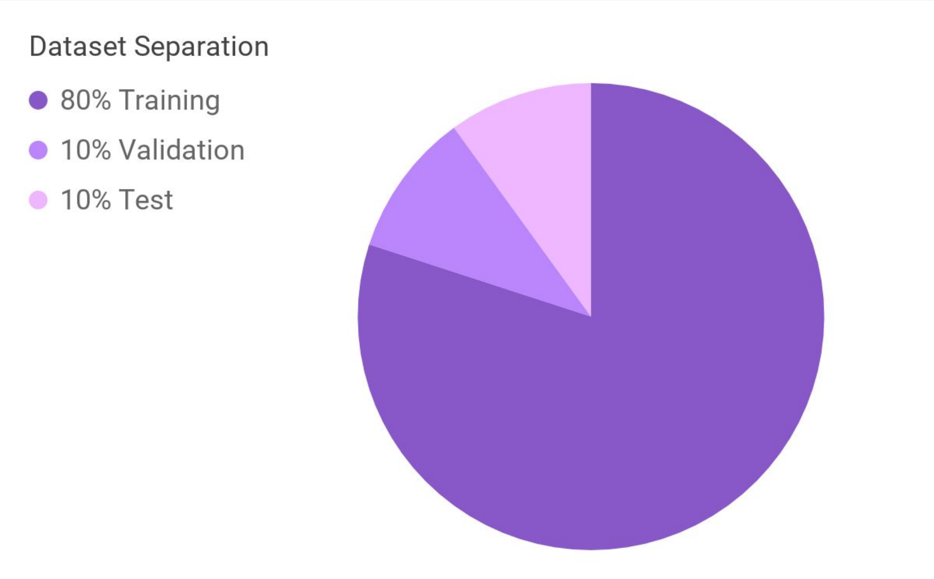


Methods

Dataset

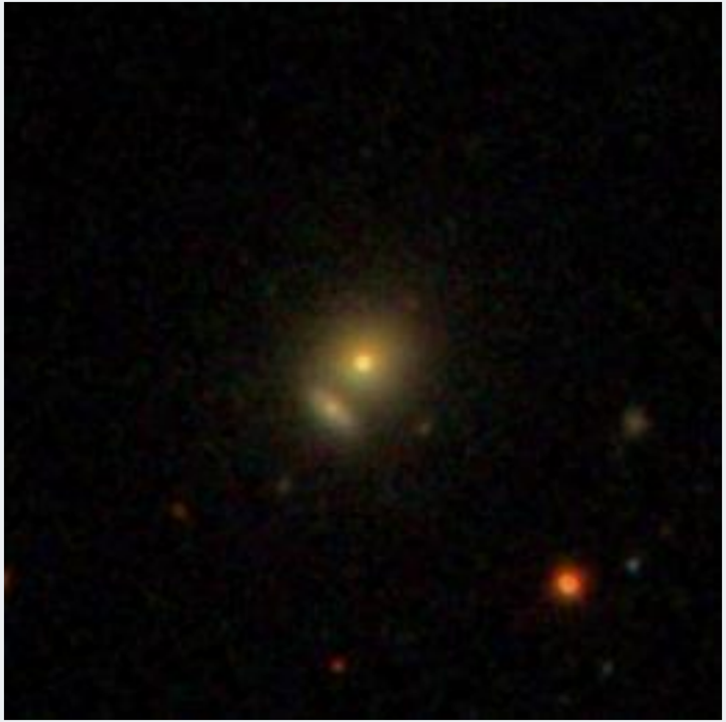
- 16000 RGB images from the Sloan Digital Sky Survey (SDSS) Data Release 7.

- two classes:
  - Merger
  - Non-interacting

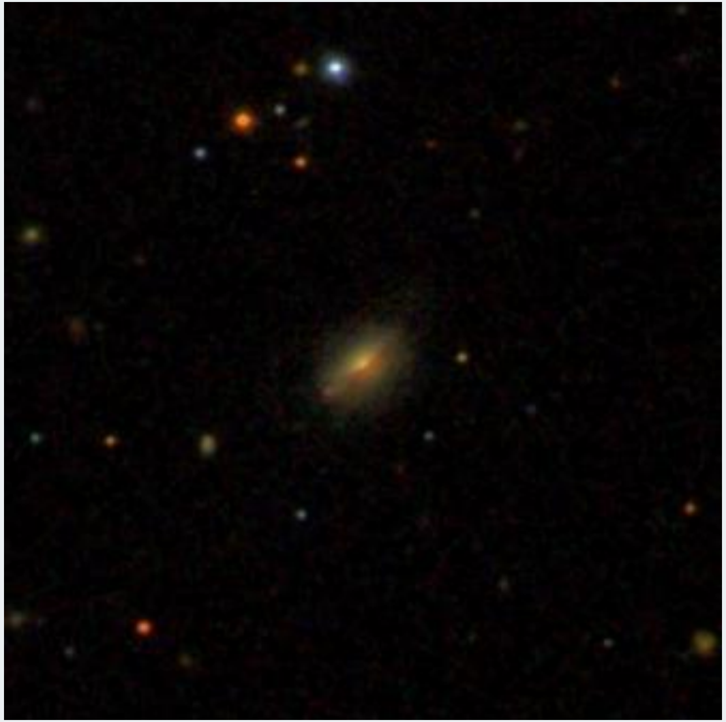


Binary Classification

Merger



Non-interacting



Dataset Preparation

1. Loading and normalizing the images

2. Resizing the images

3. Splitting the dataset and augmenting the data

Experiment 1: From Scratch

1. Use random initialization to the weights

2. Add top layers

3. Train using mini-batch SGD with a standard learning rate

Experiment 2: Transfer Learning

1. Load the pre-trained CNN with weights

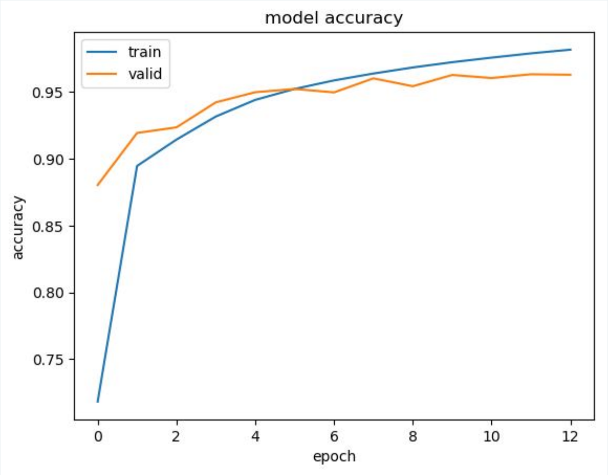
2. Add the top layers and use the ADAM optimizer to train only them

3. Fine-tune using mini-batch SGD with a small learning rate and momentum.

Results

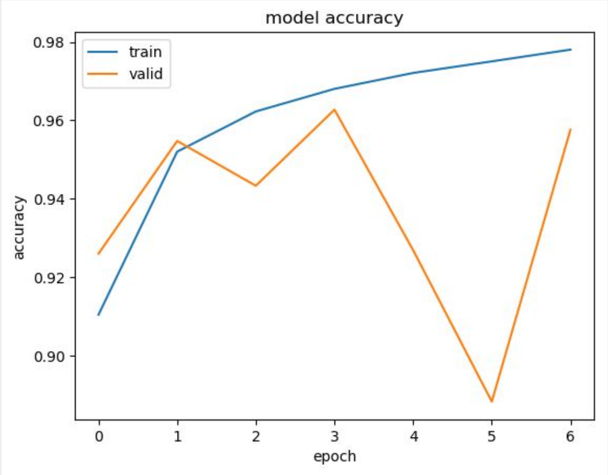
Experiment 1 Results

VGG-16



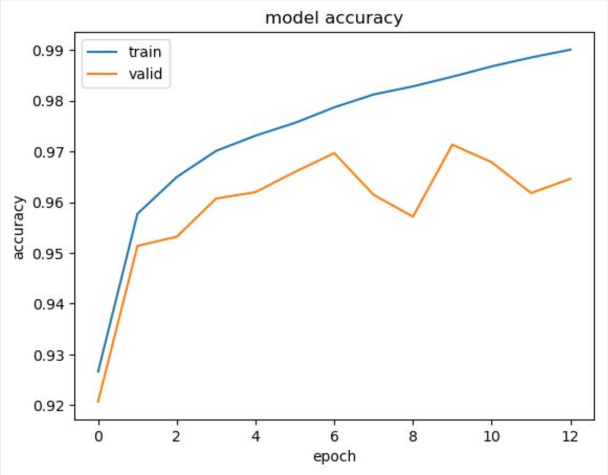
95.87%

Inception-v3



95.53%

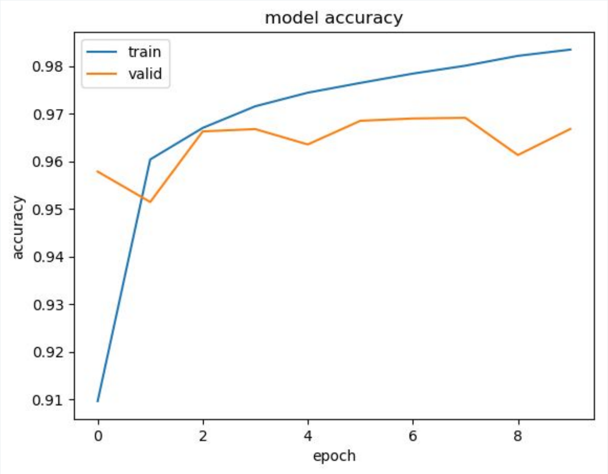
Densenet-121



96.10%

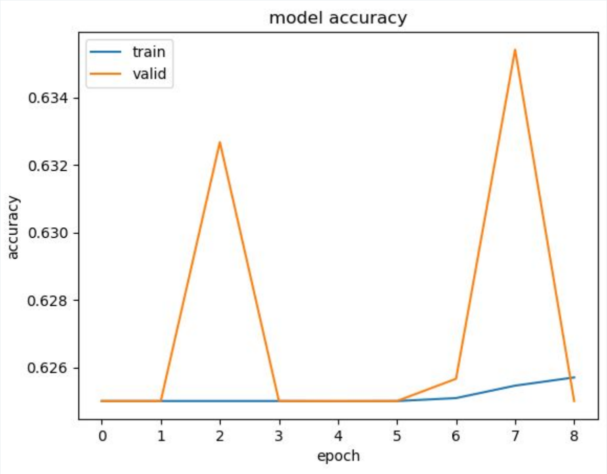
Experiment 2 Results

VGG-16



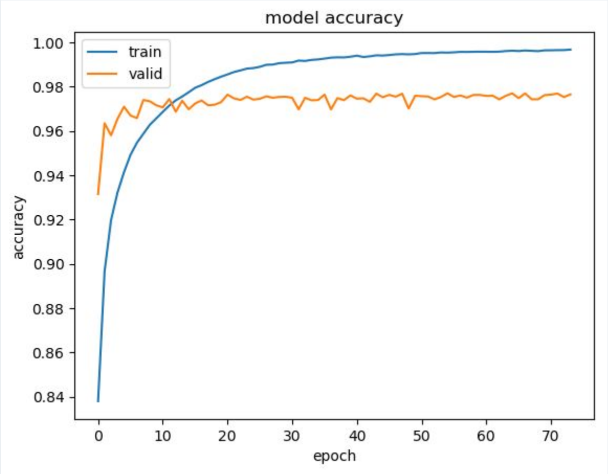
96.81%

Inception-v3



36.82%

Densenet-121



96.82%

Comparing Experiments

Architecture	Experiment	Precision	Recall	F1-Score
VGG-16	1	0.96	0.96	0.96
	2	0.97	0.97	0.97
Inception-V3	1	0.96	0.96	0.96
	2	0.25	0.37	0.20
Densenet-121	1	0.96	0.96	0.96
	2	0.97	0.97	0.97

Comparing Results

Method	Precision	Recall	F1-Score
Hoyos et al.(2012) [4]	0.92	0.29	0.44
Goulding et al.(2017) [5]	0.75	0.90	0.82
Ackermann et al.(2018) [6]	0.96	0.97	0.97
Experiment 1	0.96	0.96	0.96
Experiment 2	0.97	0.97	0.97

Conclusions

- A high accuracy can be achieved

- By using transfer learning there was a slight increase in performance

- Reliable approach that outperforms previous methods

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[4] Hoyos et al. (2012) “A new automatic method to identify galaxy mergers–i. description and application to the space telescope a901/902 galaxy evolution survey”. In: Monthly Notices of the Royal Astronomical Society, 419(3):2703–2724.

[5] Goulding et al. (2017) “Galaxy interactions trigger rapid black hole growth: An unprecedented view from the hyper suprime-cam survey”. In: Publications of the Astronomical Society of Japan, 70(SP1):S37.

[6] Ackermann et al. (2018) “Using transfer learning to detect galaxy mergers”. In: Monthly Notices of the Royal Astronomical Society, 479(1):415–425.

Thank You

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