L-Università ta' Malta
Faculty of Information & Communication Technology
Department of Artificial Intelligence

ARI 2129 - Principles of Computer Vision
Group Project - Part B

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Study-unit: **Principles of Computer Vision for AI**
Code: **ARI2129**
Lecturer: **Dr Dylan Seychell**

Q4: Implementation of Data Augmentation Techniques

Comparison of your implementation with a framework

All the transformations below were implemented in PyTorch, TensorFlow and from first principles, in accordance with the assignment brief requirements. Below are the relevant evaluations with respect to each transformation type.

Geometric Augmentation

Horizontal / Vertical Flipping

Given the simplicity of the augmentation, all three implementations provided the same result as can be seen in the images and the cumulative histograms below (Figures 1-2 and 4-5). The SSIM and MSE values show high similarity between one transformation image to another and a notable difference in value when compared to the original image as can be seen in Figures 3 and 6. This further supports the cumulative histograms which indicate that TensorFlow, PyTorch and our implementation yielded identical results.

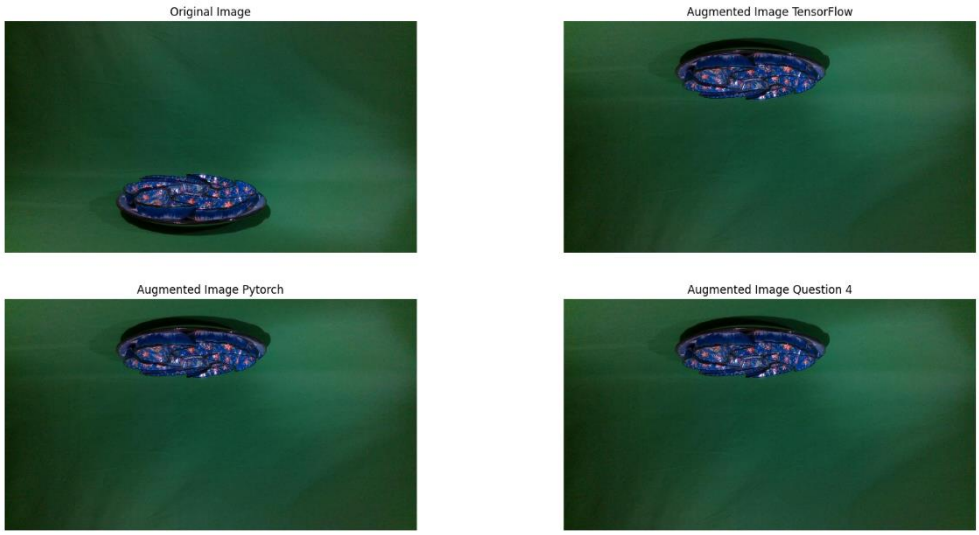


Figure 1 - Vertical Flipping Resultant Images

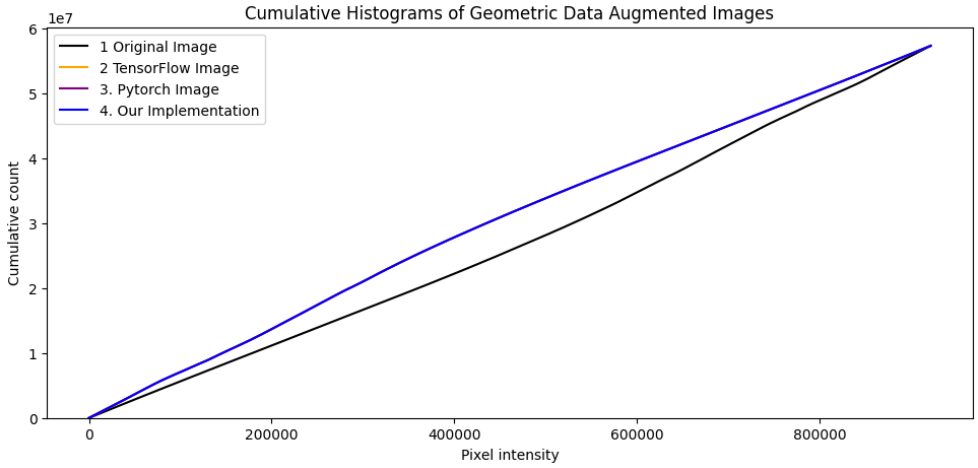


Figure 2 - Vertical Flipping Cumulative Histogram

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 86.167
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 92.81
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 75.259
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 84.746

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 0.313
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 0.148
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 0.277
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 0.246

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 0.313
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 0.148
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 0.277
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 0.246

SSIM of Augmented Image Question 4  vs  Original Image : 0.09
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 1.0
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 1.0
```

Figure 3 - Vertical Flipping MSE & SSIM Values

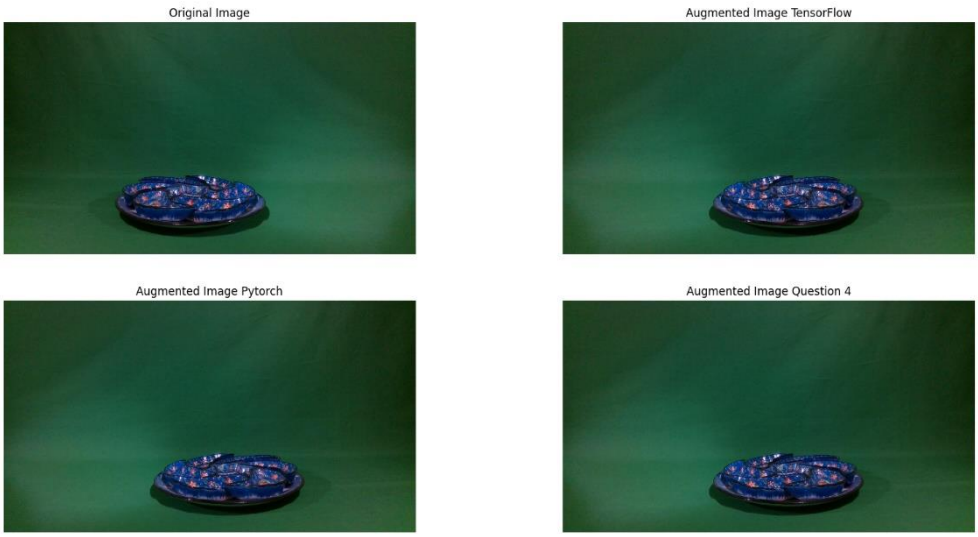


Figure 4 - Horizontal Flipping Resultant Images

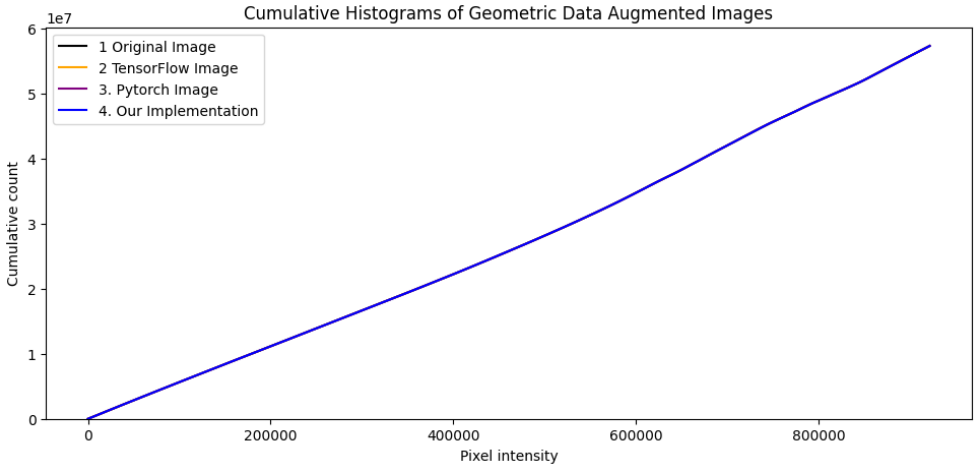


Figure 5 - Horizontal Flipping Cumulative Histogram

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 84.32
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 84.387
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 68.983
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 79.23

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 0.345
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 0.157
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 0.297
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 0.266

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 0.345
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 0.157
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 0.297
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 0.266

SSIM of Augmented Image Question 4  vs  Original Image : 0.204
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 1.0
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 1.0
```

Figure 6 - Horizontal Flipping MSE & SSIM Values

Rotations

As seen in Figure 9, the first principles resultant image had the smallest MSE value when compared with the PyTorch image. However, the SSIM value contrasts with this as the original image produced the largest result indicating the high degree of similarity. TensorFlow, given the same rotation parameter provided different results. This is because rotations in those implementations fill empty spaces with black pixels whereas the TensorFlow image remains green. Furthermore, the rotation angle itself seems to differ between TensorFlow and the others, even though the same rotation parameter was used. By looking at the graphs it can be concluded that TensorFlow and the Original Image are quite similar and so is the PyTorch implementation. However, the function from first principles offered very different results not necessarily because it is incorrect, but most likely because it is a lossless transformation whereas both TensorFlow and PyTorch are lossy transformations. The rotated image in our implementation keeps the original dimensions but the entire image is scaled to fit the new angle which introduces empty pixels.

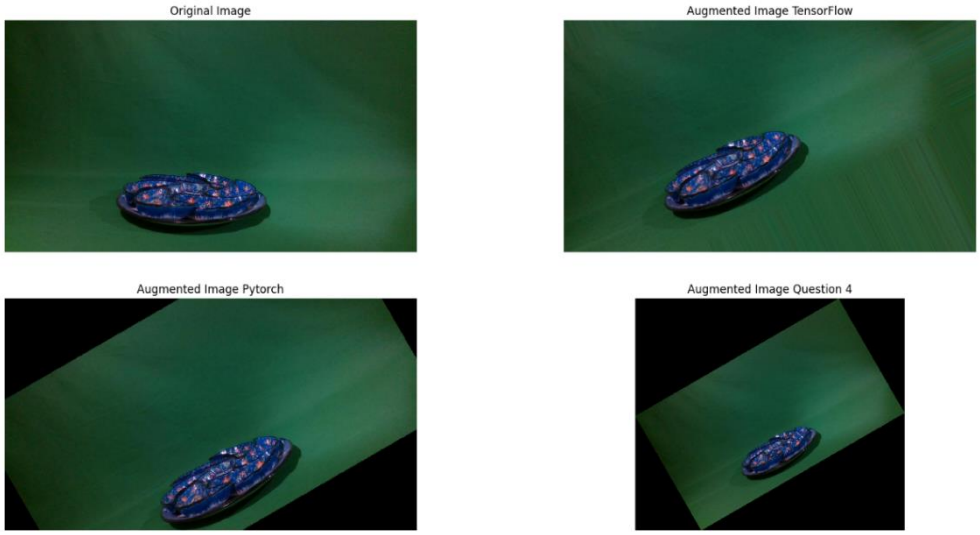


Figure 7 - Rotation Resultant Images

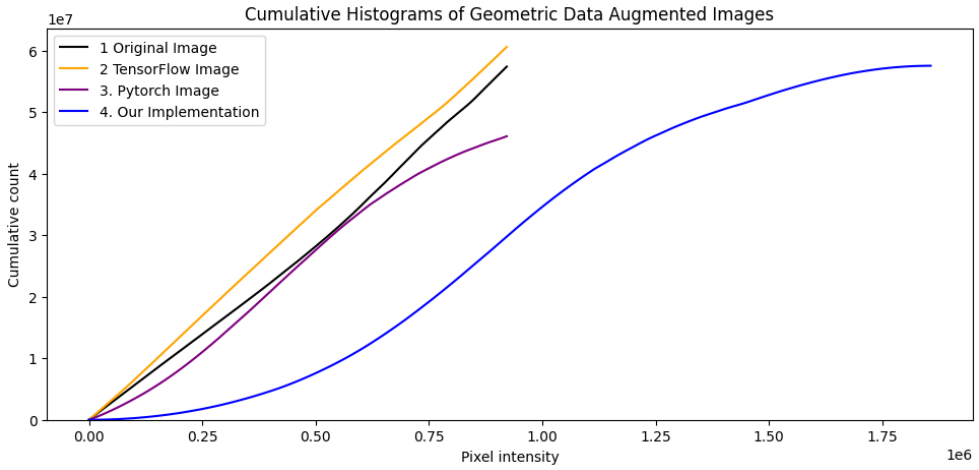


Figure 8 - Rotation Cumulative Histogram

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 96.317
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 92.137
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 90.075
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 92.843

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 62.618
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 63.768
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 56.515
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 60.967

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 106.726
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 106.568
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 97.729
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 103.674

SSIM of Augmented Image Question 4  vs  Original Image : 0.067
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.518
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.163
```

Figure 9 - Rotation MSE & SSIM Values

Shearing

Given the plots present in the cumulative histogram below, we can conclude that TensorFlow provided a similar result to the original image, this is further supported by the MSE and SSIM values below. This is in stark contrast with the PyTorch and first principles implementations which resulted in quite drastic changes from the former implementation. The above is supported by the shift in the cumulative histogram below. Given the same parameters, the resulting images were different, this is most likely because the shear parameter amount in TensorFlow is random with respect to the passed parameter. Also, the empty pixels reasoning mentioned in the above rotations section applies to this transformation as well.

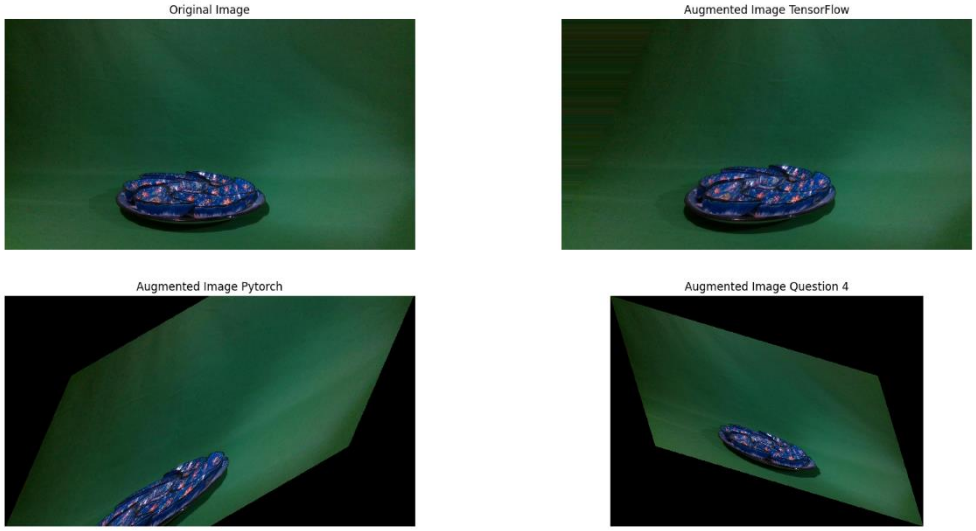


Figure 10 - Shear Resultant Images

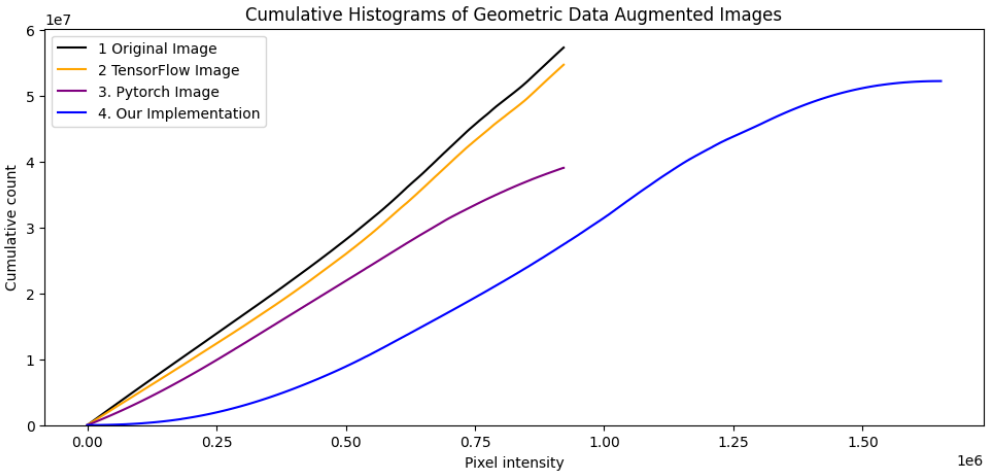


Figure 11 - Shear Cumulative Histogram

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 87.222
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 84.47
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 79.586
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 83.759

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 82.482
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 83.515
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 77.882
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 81.293

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 101.089
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 103.002
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 86.204
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 96.765

SSIM of Augmented Image Question 4  vs  Original Image : 0.241
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.174
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.155
```

Figure 12 - Shear MSE & SSIM Values

Translation

In Figure 14 below, the PyTorch and first principles implementation provided near-identical plots, whereas the TensorFlow implementation was more similar to the original image. This is possibly because TensorFlow chooses a random value between the specified range by which to translate the image in each axis. In the MSE and SSIM values below, it is observed that our implementation was very similar to the PyTorch implementation. As can be seen in the cumulative graph, PyTorch and our implementation's line graph dips at around the 900000 value, due to the number of pixel values. This is not present in the TensorFlow image due to its inpainting capability.

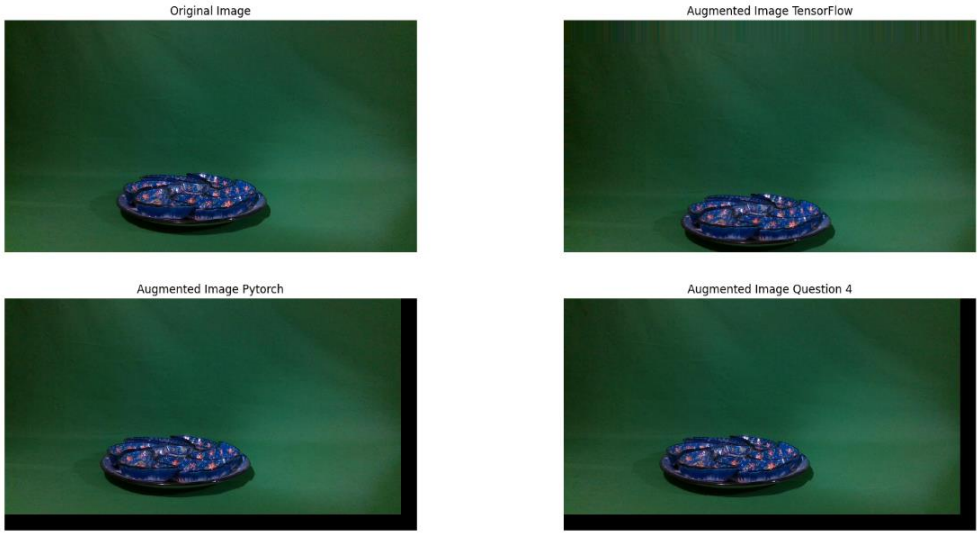


Figure 13 - Translation Resultant Images

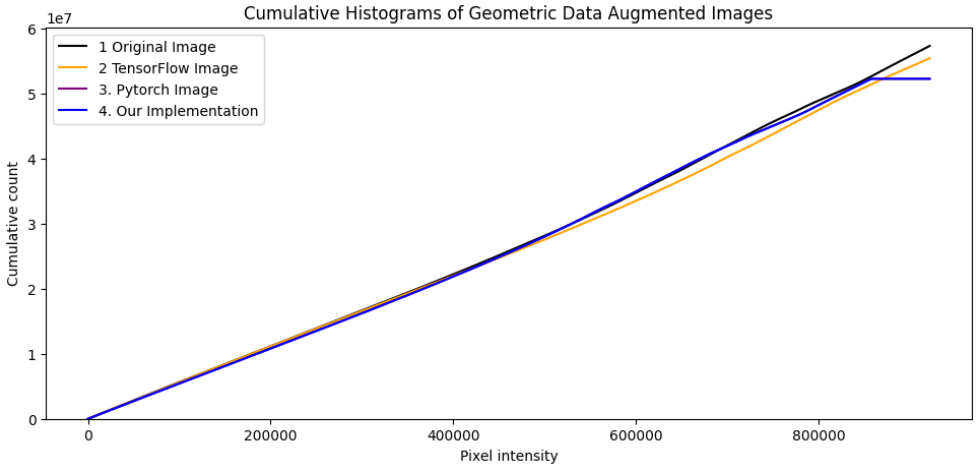


Figure 14 - Translation Cumulative Histogram

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 55.442
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 52.385
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 49.865
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 52.564

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 4.717
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 3.411
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 4.451
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 4.193

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 67.305
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 67.478
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 65.43
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 66.738

SSIM of Augmented Image Question 4  vs  Original Image : 0.299
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.998
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.293
```

Figure 15 - Translation MSE & SSIM Values

Photometric Augmentation

Brightness

As can be seen in Figure 17, TensorFlow and PyTorch offered results similar to each other whilst the gap between each colour channel in our implementation was slightly more evident. In the MSE and SSIM values below, it can be noted that our implementation was very similar to the TensorFlow and PyTorch images, since their SSIM values are both 0.981. All implementations utilised a weighted distribution as can be seen in the graphs below. Essentially the lighter areas are made significantly brighter than the darker areas. This can be noted in the graphs due to increase in the discrepancy between each colour channel.

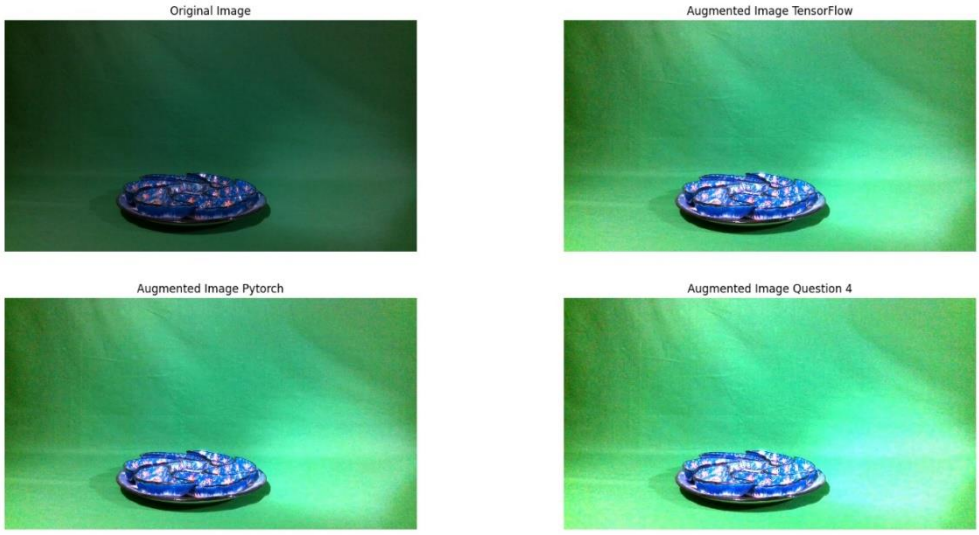


Figure 16 - Brightness Resultant Images

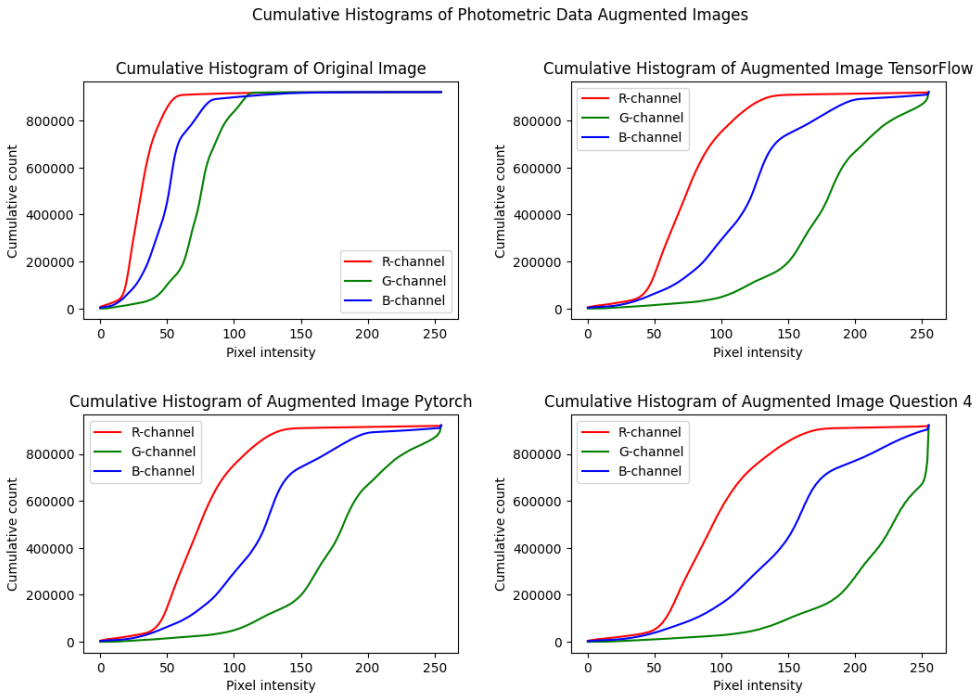


Figure 17 - Brightness Cumulative Histograms

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 109.863
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 102.852
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 114.548
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 109.088

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 111.715
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 115.003
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 115.911
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 114.21

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 111.715
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 115.003
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 115.911
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 114.21

SSIM of Augmented Image Question 4  vs  Original Image : 0.425
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.961
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.961
```

Figure 18 - Brightness MSE & SSIM Values

Contrast

As seen in the graph below, the darker areas in the image are darkened even further whilst the lighter areas are brightened. The PyTorch implementation even though given the same parameter, seems to have had the strongest increase in contrast, clearly visible in Figure 20. Moreover, in the SSIM values, our implementation was mostly similar to the original image but was still also relatively similar to the TensorFlow implementation, as shown in the MSE results. In the graphs below, our implementation depicted results similar to that of TensorFlow, although PyTorch exhibited contrastive results, with a high discrepancy in colour channel values.

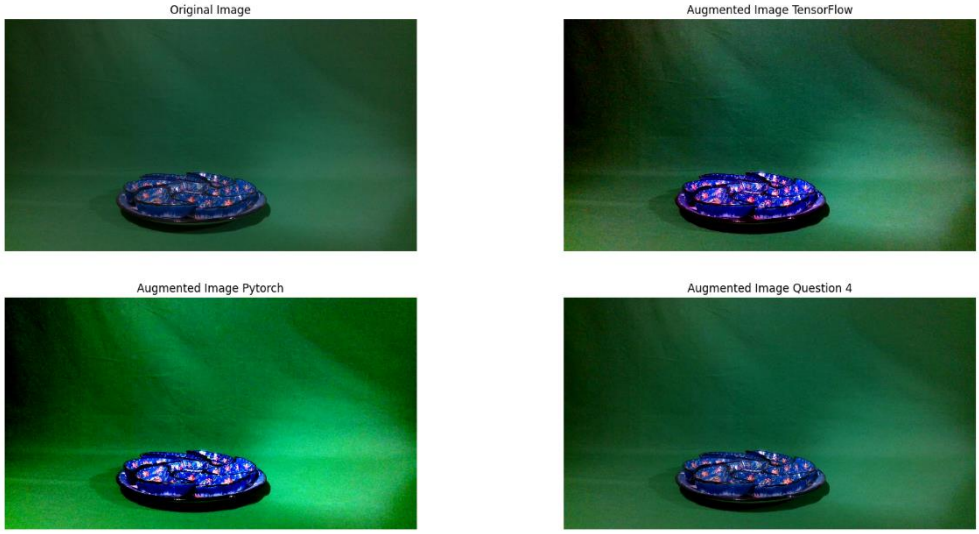


Figure 19 - Contrast Resultant Images

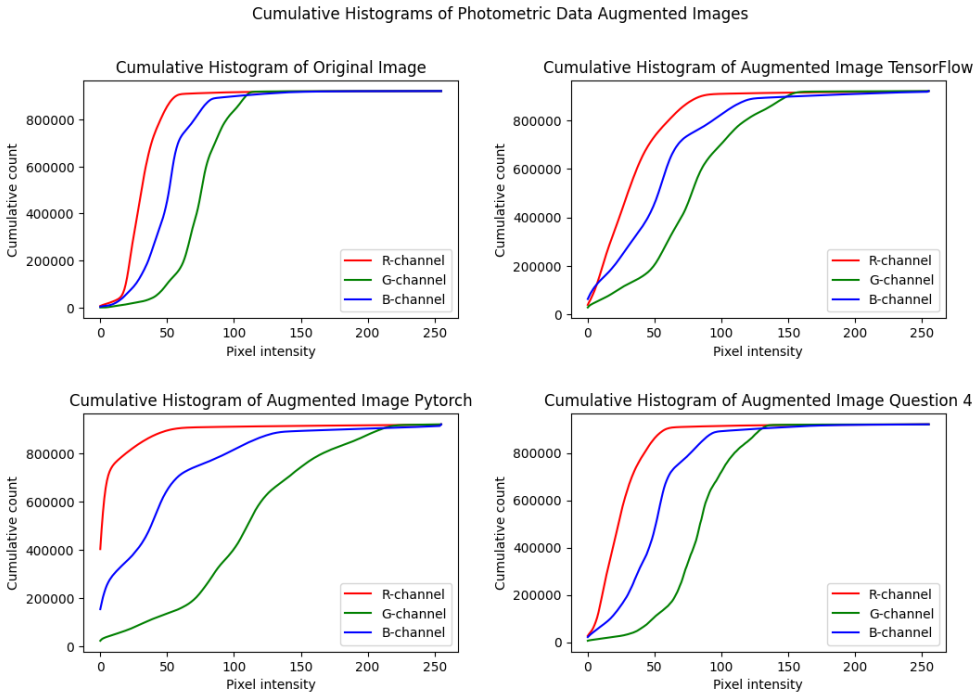


Figure 20 - Contrast Cumulative Histograms

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 38.534
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 71.299
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 73.409
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 61.08

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 96.618
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 105.783
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 99.508
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 100.637

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 60.153
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 78.949
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 56.799
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 65.301

SSIM of Augmented Image Question 4  vs  Original Image : 0.959
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.836
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.931
```

Figure 21 - Contrast MSE & SSIM Values

Saturation

In Figure 22, the hue and value are retained within the image however the intensity within each colour channel is increased. The saturation value however displayed a sharp spike in the higher pixel intensities as can be seen in Figure 22. The lack of change in hue is also supported by the graphs below as the total sum of pixels remains consistent for all colour channels. Furthermore, from the SSIM values we can conclude that our implementation provided results very similar to TensorFlow. This is also further proven by the average channel value in the MSE.

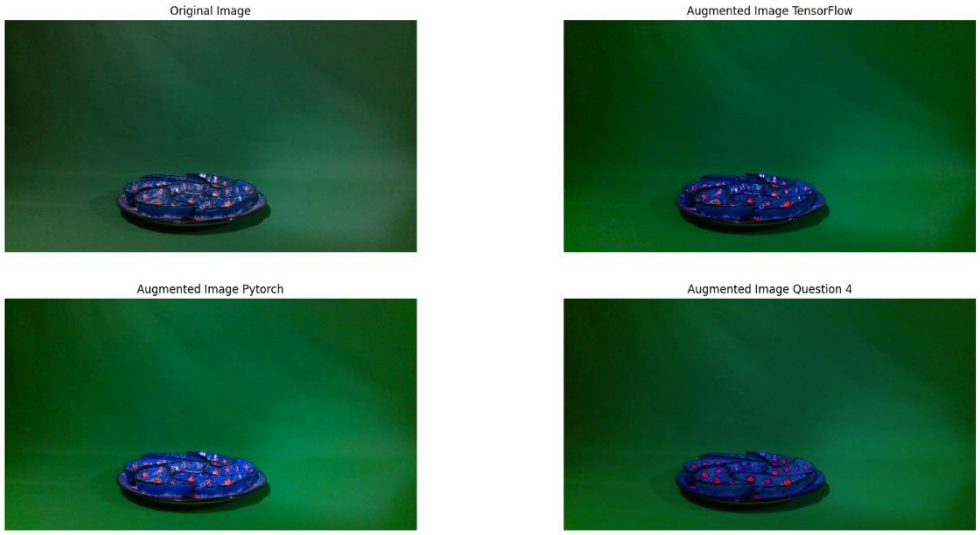


Figure 22 - Saturation Resultant Images

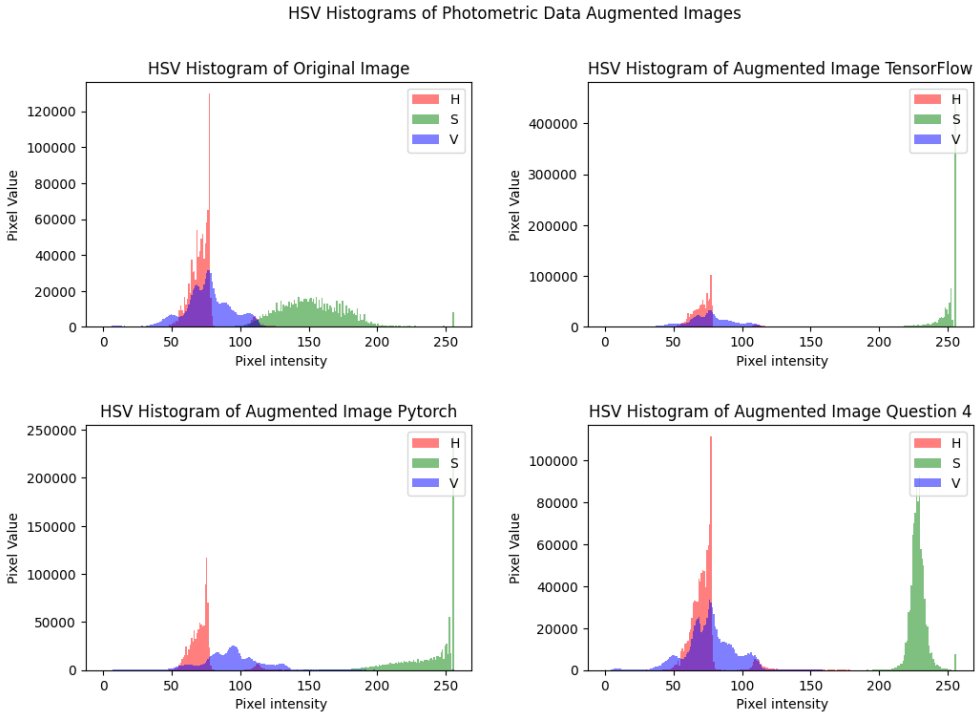


Figure 23 - Saturation HSV Histograms

```
MSE of Augmented Image Question 4  vs  Original Image : Red Channel: 97.749
MSE of Augmented Image Question 4  vs  Original Image : Green Channel: 5.47
MSE of Augmented Image Question 4  vs  Original Image : Blue Channel: 114.602
MSE of Augmented Image Question 4  vs  Original Image : Average Channel: 72.607

MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Red Channel: 44.477
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Green Channel: 112.848
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Blue Channel: 48.923
MSE of Augmented Image Question 4  vs  Augmented Image Pytorch : Average Channel: 68.75

MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Red Channel: 26.652
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Green Channel: 4.954
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Blue Channel: 53.222
MSE of Augmented Image Question 4  vs  Augmented Image TensorFlow : Average Channel: 28.276

SSIM of Augmented Image Question 4  vs  Original Image : 0.922
SSIM of Augmented Image Question 4  vs  Augmented Image Pytorch : 0.917
SSIM of Augmented Image Question 4  vs  Augmented Image TensorFlow : 0.968
```

Figure 24 - Saturation MSE & SSIM Values

Plagiarism Form

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

Declaration

Plagiarism is defined as "the unacknowledged use, as one's own work, of work of another person, whether or not such work has been published" (Regulations Governing Conduct at Examinations, 1997, Regulation 1 (viii), University of Malta).

I/ We*, the undersigned, declare that the [assignment / Assigned Practical Task report / Final Year Project report] submitted is ~~my~~ / our* work, except where acknowledged and referenced.

I/ We* understand that the penalties for making a false declaration may include, but are not limited to, loss of marks; cancellation of examination results; enforced suspension of studies; or expulsion from the degree programme.

Work submitted without this signed declaration will not be corrected, and will be given zero marks.

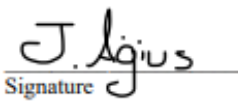
* Delete as appropriate.

(N.B. If the assignment is meant to be submitted anonymously, please sign this form and submit it to the Departmental Officer separately from the assignment).

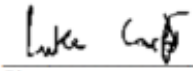
Matthias Bartolo
Student Name


Signature

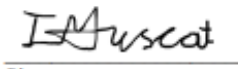
Jerome Agius
Student Name


Signature

Luke Cardona
Student Name


Signature

Isaac Muscat
Student Name


Signature

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Course Code

Principles of Computer Vision for AI Assignment (Part B)
Title of work submitted

11/05/2023
Date