University of Prince Mugrin

College of Computer and Cyber Sciences

Department of Artificial Intelligence

AI361 - Images Processing

Course Project – Semester I (Fall 2023 - 2024)

NIH Chest X-rays Image Enhancement

Team Name:

GroupTeam1

Team Members:

Salwa Shamma | 4010405

Samah Shamma | 4010403

Sana Shamma | 4010404

Instructor:

Dr. Othman Soufan

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INTODUCTION

Overview

AI361 course project is designed with a unique nature, specifically as a class competition of the data-centric type. The primary objective of the competition is to enhance 1400 images from the NIH Chest X-ray dataset. The NIH Chest X-ray dataset comprises chest X-ray images depicting 14 diseases (Atelectasis, Consolidation, Infiltration, Pneumothorax, Edema, Emphysema, Fibrosis, Effusion, Pneumonia, Pleural thickening, Cardiomegaly, Nodule Mass, Hernia). The project aims to train a hidden model using these enhanced images and subsequently test the model on other images. The focus here is on enhancing model accuracy only by improving the image, without adjusting the training parameters of the model, which is at the core of the project's challenges.

GroupTeam1 initiated the project by creating a list of various enhancement techniques, incorporating both those learned in the course and others discovered independently. For each technique, numerous methods were explored and analyzed. Combinations of these harmonious techniques were also considered. However, the scope of the report does not intend to dig into and examine many of the conducted trials. Instead, the report focuses on providing a comprehensive explanation and justification of the steps taken in achieving the best submission score on the competition's private leaderboard, both in terms of depth and breadth.

Objectives

The particular objective of this project lies in several key aspects:

1. Explore various methods and techniques to enhance fine details in chest X-ray images, enabling the model to provide accurate interpretations.
2. Apply the appropriate techniques from the exploration to increase the quality of chest X-ray images, enabling the model to better identify diseases in the images.
3. Further optimize the selected techniques to achieve better and more efficient quality chest X-ray images.

Significance

The particular significance of this project lies in several key aspects:

- The project provides students with the chance to apply image processing techniques learned in the course to a real-world challenge. This practical application improves students' field knowledge.
- The project serves as a platform for students to develop their skills in image processing, coding, and algorithm creation. It provides practical experience beyond theoretical learning.
- Undertaking and completing a project of this nature contributes significantly to personal growth. It increases confidence, resilience, and problem-solving abilities that will be useful in both academic and professional journeys.

BACKGROUND

Before proceeding, it is essential to provide a more detailed explanation of the Dragos Tone Mapping method. It is a technique used to adjust the dynamic range of an image, which refers to the difference between the brightest and darkest parts of the image. By emphasizing the darkest blacks and brightest whites, Dragos Tone Mapping enhances contrast and improves clarity, often referred to as HDR (High Dynamic Range) effect [1]. This effect is achieved by adjusting the intensity of each pixel in a non-linear manner using a logarithmic base of log10. This choice of base has proven to be more effective than log2 in preserving contrast and details, particularly in darker areas .[2]

Within the OpenCV library, there are specific parameters available that contribute to the tone mapping process. These parameters include:

- Gamma: This positive value is used for gamma correction. A gamma value of 1.0 indicates no correction, while values greater than 1 brighten the image, and values less than 1 darken it.
- Saturation: This positive value determines the degree of saturation enhancement. A value of 1.0 maintains the original saturation, values greater than 1 increase saturation, and values less than 1 decrease it.
- Bias: This value, ranging between 0 and 1, influences the bias function. Optimal results are typically achieved within the range of 0.7 to 0.9, and the default value is set to 0.85 [3]. The bias function is utilized to control the distribution of pixel values, ultimately adjusting the overall appearance of the image.

METHODS

This section will outline the algorithms and approaches that were employed to achieve an accuracy of 21.42 on the private board. The general steps include loading the images and resizing them to a resolution of 128 x 128, then normalizing the images and organizing them into 10 groups based on their mean brightness. After that, the Dragos Tone Mapping method is applied to each group with different settings. Finally, the processed images are converted back to the appropriate format and saved.

The process begins with the preprocessing phase, where the images are resized to various sizes to meet the 80 Mb constraint. After conducting tests, it was determined that a resolution of 128 x 128 yielded the highest accuracy compared to other resizing options such as 512 or 64. Therefore, the image size was fixed at 128 x 128. Next, the images were normalized to a range of 0 to 1 by dividing them by 65535.0, which corresponds to 2 to the power of 16 for 16-bit images. This normalization step was necessary to apply the Dragos Tone Mapping method.

Following the normalization process, the images underwent a series of steps to group them based on their brightness levels. Initially, the brightness was calculated for each image by using the mean of the image, and the resulting values were stored for each image. This allowed for a quantitative representation of the brightness of each image. Next, the images were divided into five distinct groups by establishing the maximum and minimum brightness ranges for each group. The classification of images into these groups was determined based on their brightness values falling within the specified ranges. This ensured that images with similar brightness characteristics were grouped together .

To enhance the images, the Dragos Tone Mapping method was applied to each group individually. This technique allowed for adjustments to the brightness and contrast of the images, resulting in an overall improvement. However, when applying the Drago's Tone Mapping method, it was observed that the resulting score was less than 20%. To address this issue, the number of groups was increased from five to ten. This adjustment provided a finer granularity in grouping the images based on their brightness levels. The entire process, including mean brightness calculation, grouping, comparison with range-based classes, and the application of Drago's Tone Mapping, was repeated with the increased number of groups. As a result, a better score of 21.42 was achieved.

In addition to increasing the number of groups, the manipulation of parameters also plays a critical role. The gamma values were adjusted as part of the process. As a baseline, the previously submitted Drago's Tone Mapping result without grouping was used, which had a gamma value of 0.5 and achieved around 20%. Incremental and decremental adjustments were made to the gamma values by 0.01, 0.02, and so on, to exploring different options for each group. This involved numerous attempts until it was discovered that using the companion gamma values = [0.5, 0.48, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5] yielded a score of 21.42. Unfortunately, due to time constraints, alternative computations for the other parameters, namely bias and saturation values, could not be explored. Finally, the image was converted back to the appropriate uint8 format, with pixel values ranging up to 255, and the processed image was saved.

RESULTS

Key Findings

As shown in Table 1, after 390 attempts submitted by GroupTeam1, they observed something very interesting: for the first submission, which only involved resizing, they obtained a score of 16.00%. In comparison, after implementing various image enhancements for the best submission, the score increased to 21.42%, a 5.42-point increase. This demonstrates the importance of training the model on a clean dataset. Focusing on having a good architecture for the model is not enough; there is another part of the story, which is the cleanliness of the trained dataset. Therefore, both models and the cleanliness of the data are highly coupled to achieve high model accuracy. As Abraham Lincoln said, "Give me six hours to chop down a tree, and I will spend the first four sharpening the axe." The same wisdom was proven during the project competition; the cleanliness of the data can change any AI game.

Additionally, GroupTeam1 noticed that applying the same methods showing high accuracy in other datasets doesn't mean they will have the same effect with their dataset or any other dataset. The concept applied on a small scale in the same dataset—applying the same enhancements to one image—doesn't mean that enhancement will work well with another image in the same dataset due to the different nature of those images. Therefore, grouping techniques solve this problem by grouping images together by similar characteristics and then applying the enhancement to the group instead of the overall dataset, making it a very case-by-case sensitive approach that yields good results.

Moreover, at the level of enhancement techniques themselves, it is not fair to judge the suitability of techniques from the first try and a few attempts, because sometimes it may require going deeper to tune the parameters of that technique. A small change in the parameters of the method can have a high impact on the overall model score. Overall, all of this can be solved by continuously trying and tracing the effects of those changes on a group level to the overall impact of the dataset. So, the golden rule in this type of competition is to follow a trial-and-error approach. Submitting many attempts in the competition can help address these issues and uncertainties.

Analysis Graphs

Months	Attempts	Average Score
September	1	16
October	175	15.91184
November	95	17.14586466
December	120	18.52381

Table 1 – Monthly Number of Attempts & Average Scores

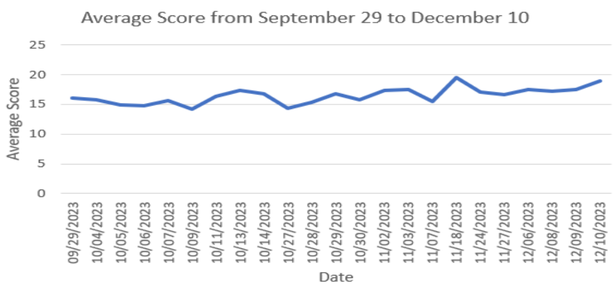

Figure 1 – Competition Daily Average Scores

TEAM NAME	MODEL ACCURACY
group_team1	19.523809523809526
group_z	19.523809523809526
group_oak	18.095238095238095
group_ai_girls	17.142857142857142

Figure 2 – October GroupTeam1 Rank

TEAM NAME	MODEL ACCURACY
group_oak	21.428571428571427
group_team1	20.952380952380953
group_9	20.0
group-G	19.523809523809526

Figure 3 – November GroupTeam1 Rank

As shown in Table 1, for 4 months, GroupTeam1 submitted around 390 attempts! This large number is due to having various parameters that need to be set for their best script code. Besides setting these different parameters for each group individually, in their case, 10 groups! This is one piece of our secret to achieving a high rank, first in the public leaderboard, and the second in the private leaderboard. So, depending on the default value of these parameters doesn't yield a good score in the competition. In other words, 390 attempts in 4 months means the average attempts in a day for the 4 months are around 4 attempts per day for 3 members, which is an acceptable effort put into the competition.

By the way, GroupTeam1 had one attempt in September, but this single attempt is the most valuable one! Because it was the first attempt in the entire competition that announced the competition had started, and it gave GroupTeam1 an extra one point as bonus marks. In October, GroupTeam1 had the highest number of attempts. GroupTeam1 had the momentum and enthusiasm to explore and try different image enhancement techniques, leading in the public rankings by using "Tonemap Reinhard & Histogram Equalization" on the 10th of October, as seen in Figure 2. For November, GroupTeam1 had fewer attempts compared to the previous month as the Midterm exam period had started, securing the second rank in the public leaderboard with a higher score from the previous month by using "Tonemap Reinhard," "Histogram Equalization," and a suitable image size method, as seen in Figure 3. Later in November, GroupTeam1 tried to recoup the situation by increasing the number of attempts to achieve the highest score among GroupTeam1's attempts, securing the first rank in the public and the second rank in the private leaderboard by using "Tonemap Drago," suitable image size, and the grouping technique as mentioned in the previous section.

CONCLSION

In conclusion, GroupTeam1 improved their understanding by applying some of the techniques and concepts they learned, both in their lectures and individually, through hands-on application. The best submission on the private leaderboard of GroupTeam1, achieved by resizing the images to 128x128 as a preprocessing step, then grouping the images based on brightness characteristics, and applying the tone mapping technique "Dragos" to each group with suitable parameters set for each group individually, adds significant knowledge value to GroupTeam1. It demonstrates the importance of preprocessing steps in every enhancement technique, enhancing their problem-solving levels by addressing critical issues related to the sensitivity of image nature, using new strategies like grouping techniques. It also highlights the importance of understanding the problem fields more, where knowledge of and focusing on the brightness area of the image in these types of diseases is key. As a result, choosing and sticking with the Dragos Tonemap method is the plan, as it plays a role as a gamma correction technique, which achieves good results here.

As we know, the competition time is limited, but the possibility of applying more enhancement techniques is almost unlimited. So, in the future, if GroupTeam1 has another chance, they will focus more on understanding the problem domain, trying to explore and examine it thoroughly. Besides, they will consult an expert about the best practices in the field and try to apply them to the project. Instead of starting from scratch and reinventing the wheel, this approach will allow them to spend more time adjusting to the specific needs of the problem.

Overall, this project allowed GroupTeam1 to gain practical experience and reinforce their understanding of the course material. Both soft skills, such as time management, teamwork, and communication, and other skills have increased. Meanwhile, technical skills, including contrast stratification, sharpening, smoothing images, and various enhancements, have also improved.

REFERENCES

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