CS 771: Homework Assignment 1

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1 Section 3.3

Q1: What is the benefit of PyTorch dataloader? Please compare the dataloader to a solution that simply loops over a file list and batches the images.
A1: DataLoader automates the process of creating mini-batches and shuffling the data for each epoch.
DataLoader supports multi-process data loading (via the numworkers parameter), which can significantly speed up the data loading process by utilizing multiple CPU cores to fetch and preprocess data in parallel, while the GPU is busy with model computation. This is particularly effective for extremely large datasets where the entire dataset might not fit in the memory. Not easy to achieve this with a simple loop over batches which have to be loaded in the memory entirely.
DataLoader also integrates seamlessly with torch.utils.data.Dataset and torchvision.transforms, allowing for efficient application of data augmentation and preprocessing steps to individual samples before they are batched.

Q2: Note that this assignment uses the same training conditions as in Tutorial 1. As part of your report, please compare the accuracy and loss trend you obtain here with those from the tutorial. Can you provide possible explanations for their differences?
A2: The final accuracy on the validation set is very slightly better compared to tutorial 1, (74 vs 73) But this difference is not significant. The important thing to note is that during the training in Tutorial 1, the training loss dropped rapidly (reaching 0.384 after 6 epochs), while the training with the augmentations dropped more smoothly (0.518 after 6 epochs) Given the validation accuracy is similar for the two models, the training with augmentations can train for longer before overfitting (probably with better validation accuracy) and will likely be more robust because of the augmentations

Q3: Does the order of image transforms make a difference in the data augmentation pipeline? E.g., can you arbitrarily switch their order?
A3: Yes changing the order of image transforms can change the final output in certain cases. For example, Scale to a given size followed by RandomRotate will give a different output when doing RandomRotate first then followed by

Scale. Even if the angle of rotation is fixed. Its because downsampling and interpolation methods depend on the size of the input image

AI disclosure: AI was used to help with edge case testing/implementation in the RandomRotate class, also I forgot to use cv2.warp affine in this class, so no interpolation support, but I don't think the current solution (which uses closest integer pixel values) is unoptimal.

Answer for the center-aligned rectangle that maximises the area is a rectangle with half sides as:

$$h = \frac{a}{2\sin\theta}, \quad w = \frac{a}{2\cos\theta} \quad \text{when} \quad \sin(2\theta) \geq \frac{a}{b}$$

$$\& \quad h = \frac{b\cos\theta - a\sin\theta}{\cos 2\theta}, \quad w = \frac{a\cos\theta - b\sin\theta}{\cos 2\theta} \quad \text{when} \quad \sin(2\theta) < \frac{a}{b}$$

where a, b ($b > a$) are two half-sides of original rectangle & θ is the angle of rotation, h, w are half sides of center aligned cropped rectangle that maximises area.

Proof sketch

⇒ Since optimisation is concave, we need additional constraints

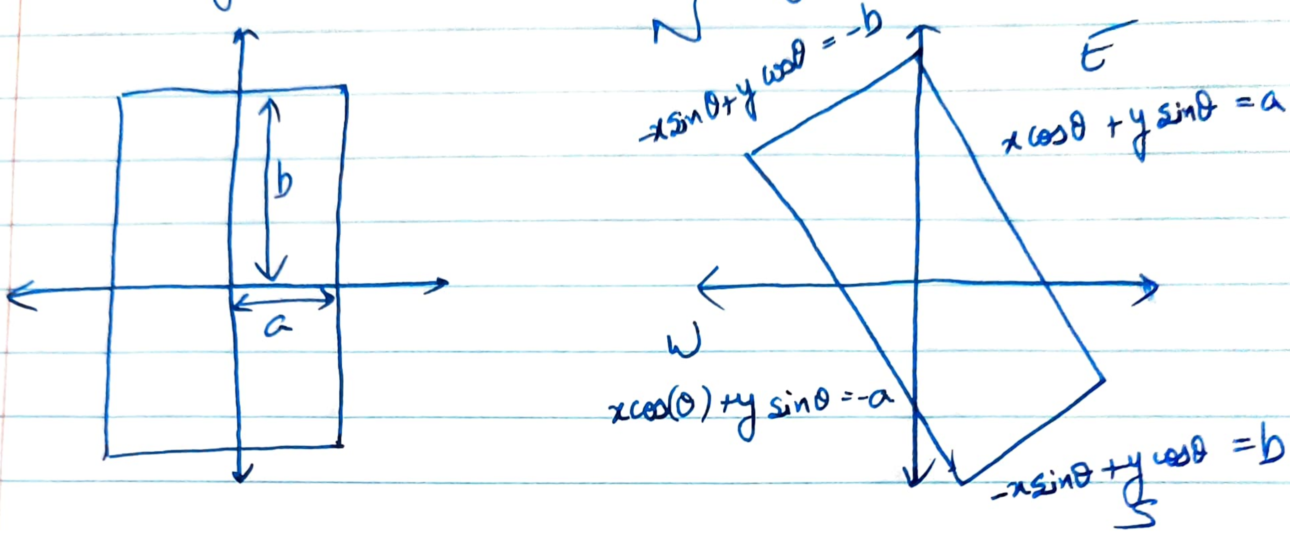
⇒ A general solution should have at least 2 corners touching the sides of the rotated rectangle (if only one side is touching the corner we can increase area by moving the corner)

⇒ If two corners are touching, they have to be opposite corners (same arguement as above, otherwise we can move the side that's not touching until it touches)

⇒ Start with 2 corners touching, find a convex objective, where infeasible, go for 4 corners touching.

⇒ (An optimal 3 corner solution will have the same area as an optimal 2-corner solution.)

Assuming the same setup as defined in the writeup



If C is the region of the rotated image, any point $p = \begin{bmatrix} x \\ y \end{bmatrix}$, $p \in C$ iff

$$\begin{bmatrix} -a \\ -b \end{bmatrix} \leq \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \leq \begin{bmatrix} a \\ b \end{bmatrix}$$

or $\quad -a \leq x\cos\theta + y\sin\theta \leq a \quad$ — (1)

& $\quad -b \leq -x\sin\theta + y\cos\theta \leq b \quad$ — (2)

for the rectangle that maximises the area, it is important to see that a general solution will have 3 of the 4 corners on the edges of the rotated rectangle.

We can always 'center' this rectangle by shifting it then '2' opposite corners will be on the edges (NEWS). This will depend on a, b, θ

Since the points are in the 4 quadrants, we can modify the inequalities 1 & 2 as

$$x\cos\theta + y\sin\theta \le a \quad -(3)$$
$$x\sin\theta + y\cos\theta \le b \quad -(4)$$

maximise this by replacing $-x \to x$

now assuming the optimal rectangle with shifted center (aligned with original rectangle) has half sides as h & w

one of (3), (4) has to be satisfied as an equality.

Case I

~~hcos~~ $w\cos\theta + h\sin\theta = a$

$$\Rightarrow w = \frac{a - h\sin\theta}{\cos\theta}$$

$$\Rightarrow A = (2w)(2h)$$

$$A = 4\left[\frac{a - h\sin\theta}{\cos\theta}\right]h$$

$$\frac{dA}{dh} = \frac{4a}{\cos\theta} - \frac{4\sin\theta \times 2h}{\cos\theta}$$

$$\frac{dA}{dh} = 0$$

$$h = \frac{a}{2\sin\theta}$$

$$w = \frac{a}{2\cos\theta}$$

$$A = \frac{a^2}{\sin\theta\cos\theta}$$

Case II

$w\sin\theta + h\cos\theta = b$

$$\Rightarrow w = \frac{b - h\cos\theta}{\sin\theta}$$

$$A = (2w)(2h)$$

$$= 4\left[\frac{b - h\cos\theta}{\sin\theta}\right]h$$

$$\frac{dA}{dh} = 0$$

$$\Rightarrow \frac{\cancel{4}b}{\cancel{\sin\theta}} = \frac{2 \times \cancel{4}h\cos\theta}{\cancel{\sin\theta}}$$

$$h = \frac{b}{2\cos\theta}$$

$$w = \frac{b}{2\sin\theta}$$

$$A = \frac{b^2}{\sin\theta\cos\theta}$$

(3)

However, this still must satisfy the inequality

$w \sin\theta + h\cos\theta \le b$

$\frac{a}{2}\frac{\sin\theta}{\cos\theta} + \frac{a}{2}\frac{\cos\theta}{\sin\theta} \le b$

$\frac{a}{2}\tan\theta + \frac{a}{2\tan\theta} \le b$

$a\,\frac{1}{2}\left(\tan\theta + \frac{1}{\tan\theta}\right) \le b$

$a\,\frac{1+\tan^2\theta}{2\tan\theta} \le b$

this is the sol^n when

$\frac{1+\tan^2\theta}{2\tan\theta} \le \frac{b}{a}$

$\frac{\frac{\cos^2\theta + \sin^2\theta}{2\cos^2\theta}}{\frac{\sin\theta}{\cos\theta}} \le \frac{b}{a}$

$\boxed{\frac{1}{2\sin\theta\cos\theta} \le \frac{b}{a}, \quad \sin 2\theta \ge \frac{a}{b}}$

$w\cos\theta + h\sin\theta \le a$

$\frac{b}{2}\frac{\cos\theta}{\sin\theta} + \frac{b}{2}\frac{\sin\theta}{\cos\theta} \le a$

$\frac{b}{2\tan\theta} + \frac{b}{2}\tan\theta \le a$

$b\,\frac{1+\tan^2\theta}{2\tan\theta} \le a$

since $\frac{1+\tan^2\theta}{2\tan\theta}$ is always $\underline{\ge 1}$ (plotted on desmos)

this cannot work as $\underline{b \ge a}$ ✗

Otherwise

There is also ~~the~~ a solution when both eq^n's are satisfied. ⟹

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When the optimal rect has all 4 corners on the edges

~~the case~~ $\Rightarrow$ both 3, 4 are satisfied.

$$w\cos\theta + h\sin\theta = a$$
$$w\sin\theta + h\cos\theta = b$$

$$w = \frac{a - h\sin\theta}{\cos\theta}$$, putting in the other eq^n

$$\frac{a - h\sin\theta}{\cos\theta}\sin\theta + h\cos\theta = b$$

$$a\sin\theta - h\sin^2\theta + h\cos^2\theta = b\cos\theta$$

$$a\sin\theta + h(\cos^2\theta - \sin^2\theta) = b\cos\theta$$

$$\boxed{h = \frac{b\cos\theta - a\sin\theta}{\cos 2\theta}}$$

$$\boxed{w = \frac{a\cos\theta - b\sin\theta}{\cos 2\theta}}$$

$$\boxed{\text{when } \sin 2\theta < \frac{a}{b}}$$

constraint (from other solution)