Applications of Deep Learning in Image Upscaling

Yuanxi Wang
a1805637
University of Adelaide

Abstract

As hardware improves in quality, higher and higher resolutions are becoming readily available, but most videos and games and still only given HD support, usually up to 1080p quality (1920px by 1080px). By using image upscaling techniques, these advanced 8K monitors can finally make use of their full potential to display the most detailed and realistic experiences. This paper will discuss image upscaling methods which involve the traditional image processing, and modern solutions using deep learning, and compare the advantages and disadvantages of each.

1. Introduction

In pursuit of ever-increasing resolution, computer monitors which support 4K resolution, or even 8K, are more prevalent each year. While most hardware cannot support 8K at a satisfactory frame rate, this problem will undoubtably be solved in the coming years. However, most online applications still lack 4K support, maintaining at 1080p. This is mostly true of gaming and video, the former of which cater to a general public that does not need ultra-high resolution, and the latter of which is usually capped by download speeds instead of hardware.

1.1. Problem

In many applications, there is a lack of ultra-HD support, as the existing infrastructure does not incentivise it. For gaming applications, most game producers must build their games in accordance to the average user's specifications. This means that most games only offer up to 1080p support. Similarly, for video streaming services, such as YouTube, the videos are bottlenecked by the speed of the users' internet connection. This means that while services like YouTube and Netflix provide 4K support, users require, at minimum, a stable 15mbps connection. Thus, it can be more efficient for users to upscale a lower resolution video locally, than to stream a high resolution video.

1.2. Solutions

Both AMD and Nvidia have attempted solutions for real-time upscaling, upscaling each frame right before being drawn onto the screen. However, AMD uses a more traditional image processing approach known as FidelityFX Super Resolution (FSR), while Nvidia's approach uses deep learning, and is known as Deep learning super sampling (DLSS)

1.3. Image Processing

In the AMD implementation for real-time upscaling, the game is run at a lower native resolution, then upscaled using the Lanczos algorithm, to provide a higher framerate than using a high native resolution. For example, running a game at 2160p quality (4K) might result in 60fps (frames per second), but using FSR, the game can be run at 1080p quality at a much higher fps. Then, by using Lanczos resampling, each frame is upscaled to 2160p quality, but the frame rate will be preserved. By further applying Temporal Anti-Aliasing (TAA), pixels from previous frames are blended together with current pixels to avoid artifacts from motion (Roach 2022).

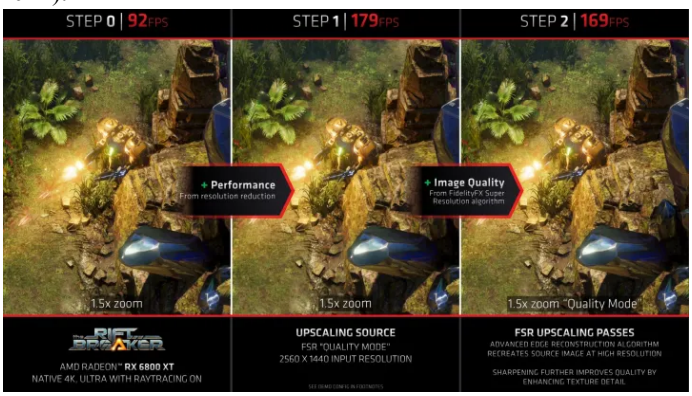

Fig 1. Image Upscaling using image processing (FSR)

1.4. Deep Learning

Similar to AMD's FSR implementation, Nvidia's DLSS uses the same strategy of loading the game at a lower native resolution, then upscaling each frame to a higher resolution to preserve a higher frame rate. However, instead of using traditional image processing techniques, such as Lanczos resampling used in FSR, DLSS uses convolutional autoencoder neural networks to resolve anti-aliasing. However, since this implementation only takes 1 frame of input, the output can have a lot of noise and artifacting, as shown below (Smith 2020).

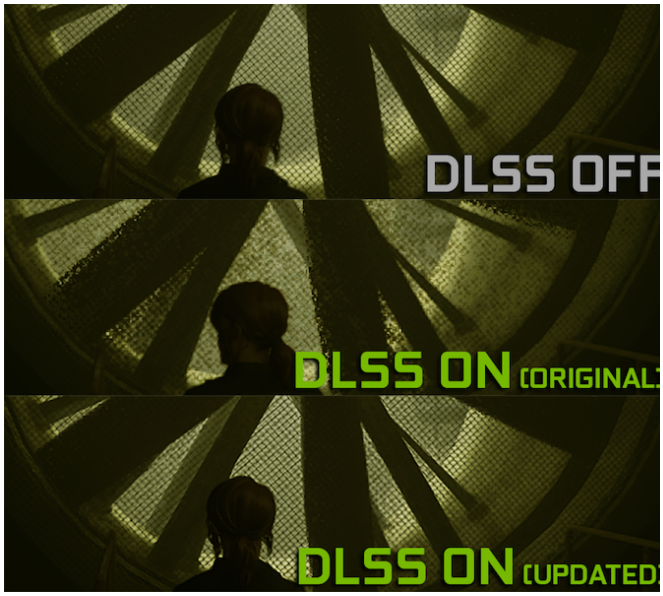

Fig 2. Image Upscaling using DLSS 1.0 and DLSS 2.0

As can be seen from the image above, the original 1.0 implementation of DLSS resulted in an image with a lot of artifacting. However, in the DLSS 2.0 implementation, there is a marked improvement in performance, due to convolutional autoencoder neural networks also being used to implement TAA, meaning that the model is trained to identify temporal artifacts. Traditional TAA implementations make use of manually written heuristics to prevent artifacting, such as making sure each pixel does not deviate too much from its neighbors. However, this implementation can produce blurry images, which DLSS 2.0 outperforms. In the image below, it can be seen that DLSS 2.0 can not only provide a higher resolution image, but also at a higher framerate (Ene 2020). However, there are still some artifacting and aliasing issues, particularly in the shirt and wall design.

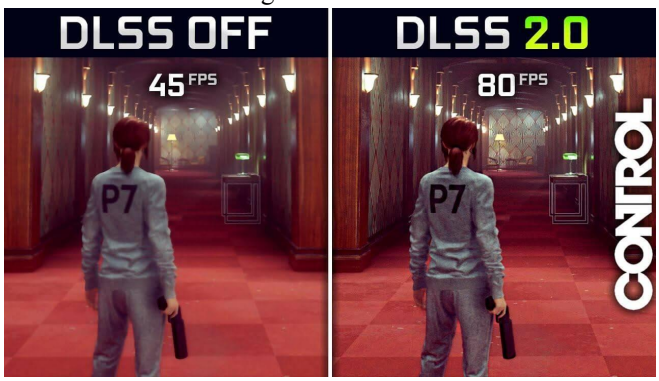

Fig 3. Performance difference of base game vs DLSS 2.0

2. Advantages and Disadvantages

2.1. Standardization

While FSR is open-source, it still requires developers to include it. Currently, only some games support FSR, and there is no standardization amongst them, so each game uses different FSR settings, with games like DOTA 2 providing a slider to adjust the scaling percentage. Furthermore, FSR 2.0 has recently been announced, with drastic improvements over FSR 1.0, but only being implemented in a couple of games, such as *Ghostwire Tokyo* and *Deathloop*. Since FSR 2.0 is still very new, it remains to be seen how many games will implement it, but currently, it lacks the standardization that DLSS has, since DLSS can be implemented on any game.

2.2. Hardware Requirements

When it comes to hardware, FSR is available for graphics cards from either AMD or Nvidia, but DLSS is only available for the Nvidia RTX 20 series and above, which are much more costly than FSR.

3. Conclusion

While both methods, using Image Processing and Deep Learning, are both viable for image upscaling operations, and each have their benefits, there are still many improvements to be made, especially for real-time upscaling. This topic is still in its infancy, and it is worth keeping up with the progress of this field.

References

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