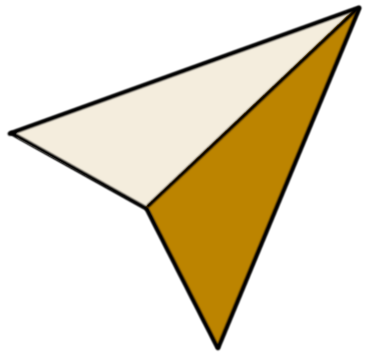


COMP4610/COMP6461

Week 12 - Anti-aliasing and Image Formats

<Print version>

Exam

Exam

- The exam is on the **11th of November at 2.50 PM**.
- This is an online (wattle) exam.
- The exam has 6 questions. The sixth question is different for COMP6461 and COMP4610. Please do not answer both of these.
- We listed this as a *closed book* exam, however because of the online nature we have decided to allow access to both **class materials**, and **public websites**. See https://comp.anu.edu.au/courses/comp4610/resources/exam/ for full instructions and previous exams.
- We recommend you record your desktop (e.g. using OBS).

Lab-6

- This lab involves using **Blender**.
- You must commit and push **PNG** files and your **project files**.
- Designed to be a 1-week lab (e.g. due this Friday).
- Due to the collision with the assignment. We have decided to extend the deadline by one week, so the lab is now due week later.

Assignment 2

- Assignment 2 is due this **Friday 5pm**.
- Please make sure to fill out all three sections of the **statementoforiginality.md**. Failing to do this will result in a *maximum score of 50%*.
- Late submissions will not be accepted. Make sure you have something submitted ahead of time just in case.
- Please read through the spec and make sure you have meet the requirements.

Anti-Aliasing

Nyquist Sampling Frequency

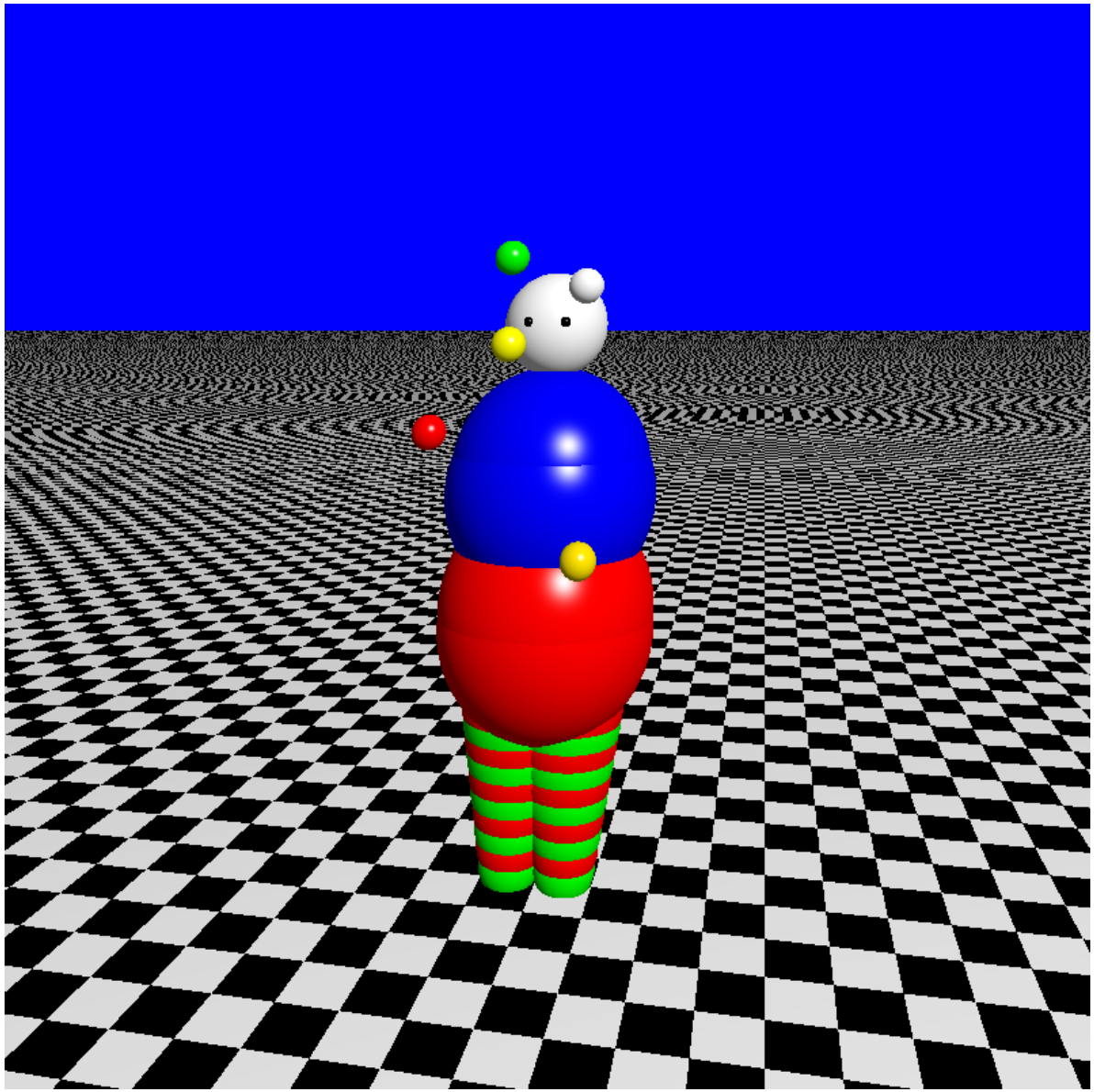
Nyquist-Shannon Sampling Theorem

If a function x(t) contains no frequencies higher than B hertz, it is completely determined by giving its ordinates at a series of points spaced 1/(2B) seconds apart.

Patterns which have 'high' frequency changes in colour are problematic in Computer Graphics. Note the sharp changes in object boundaries are also 'high' frequency parts of an image.

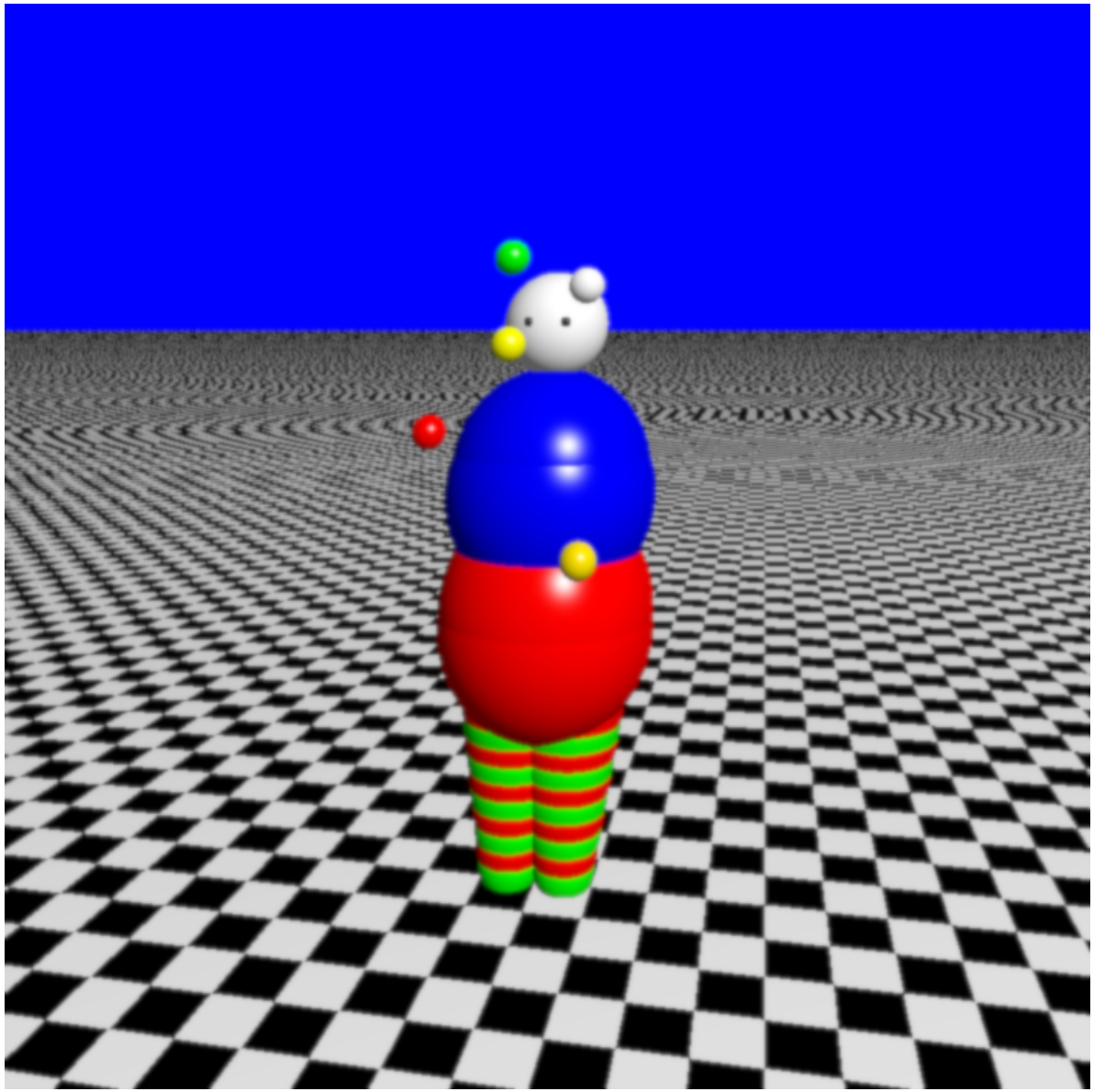
The problem caused by under sampling is called aliasing.

Frequency Aliasing Example



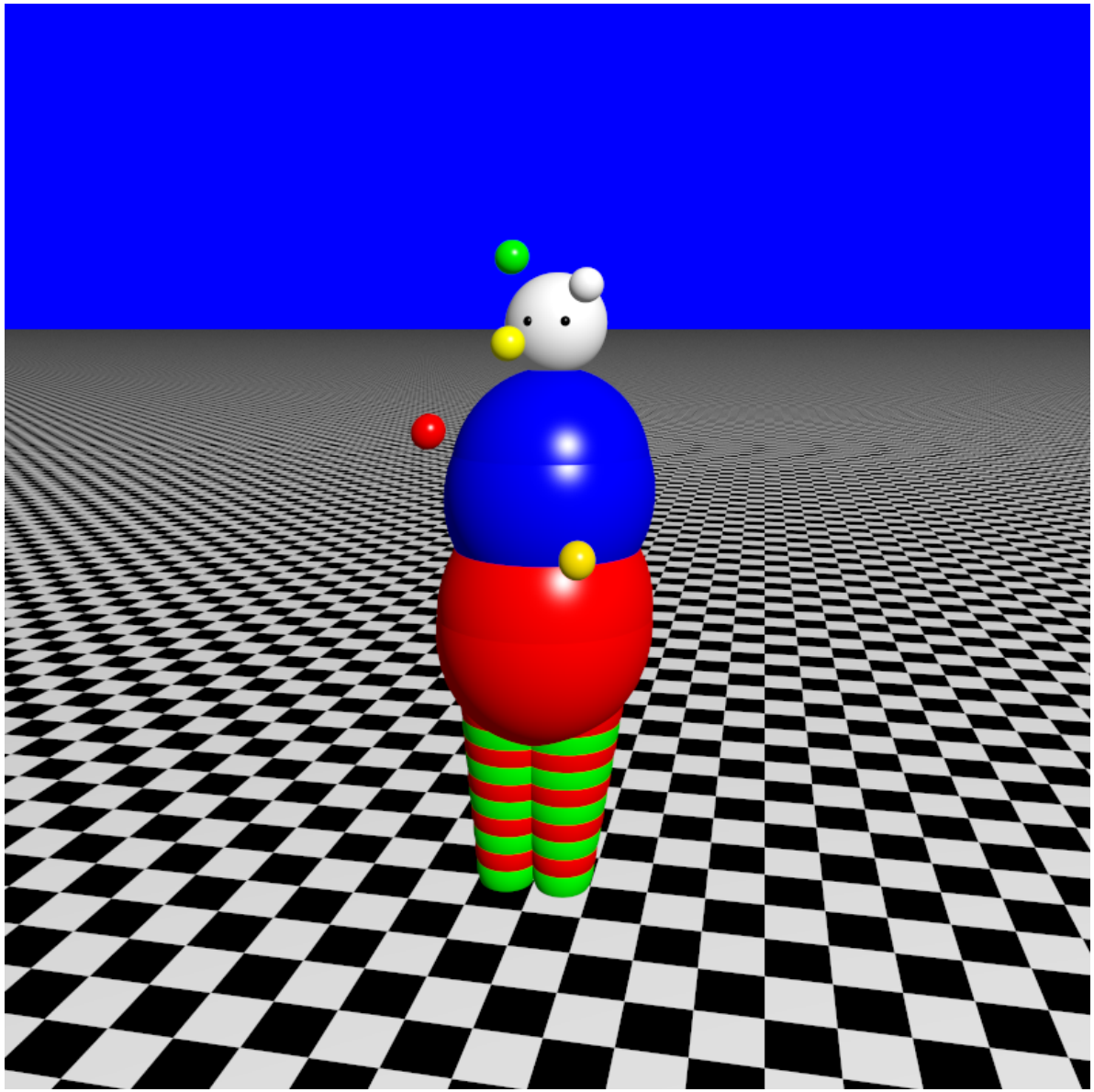
Aliasing

Frequency Aliasing Example



Low pass filter

Frequency Aliasing Example



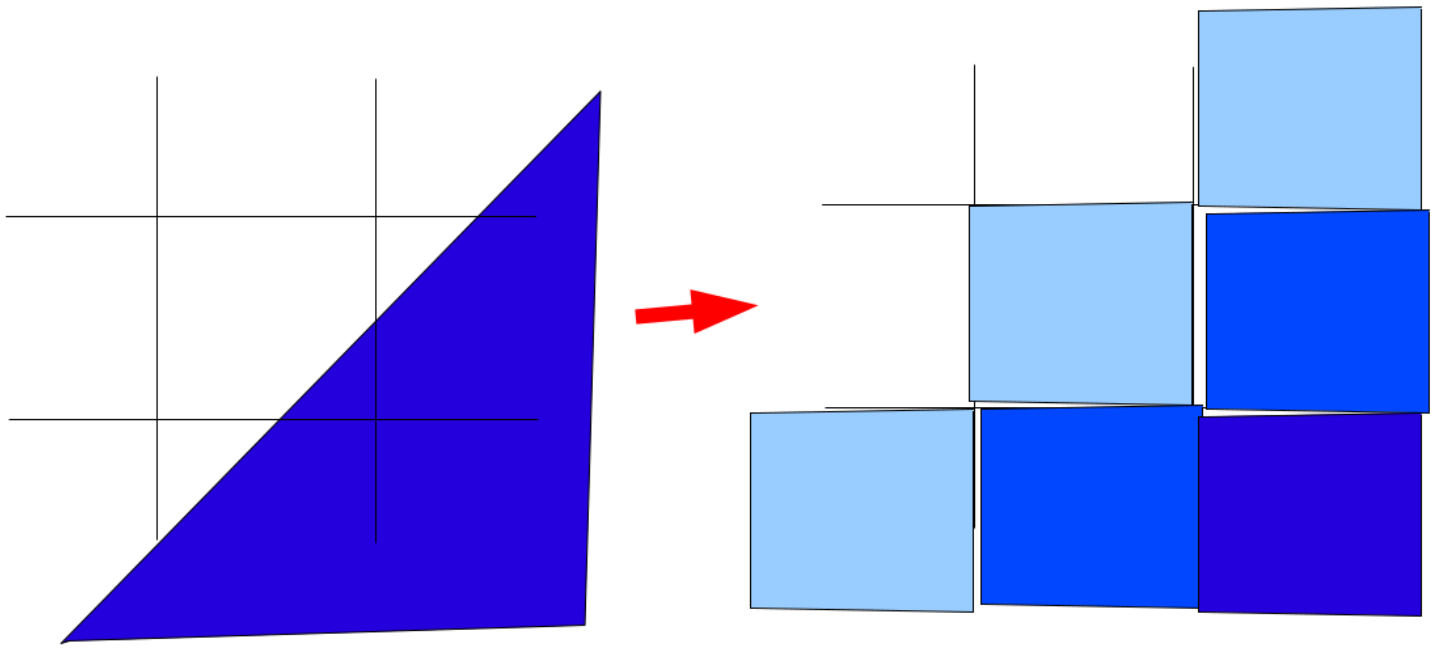
Super Sampling (1024 samples)

Supersampling

- Super sampling is an anti-aliasing approach that calculates intensities at sub-pixel grid positions and uses the average of these intensities to determine the pixel intensity.
- Super sampling is very costly both in terms of memory and processing requirements. One approach for reducing this cost is to use adaptive supersampling. Adaptive supersampling only supersamples pixels that are on boundaries.
- There are a number of variations on the sub-pixel position for obtaining samples, these include:
  - Grid.
  - Random.
  - Poisson disk.
  - Jitter.

Area Sampling

Rather than supersampling it is possible to calculate pixel intensity by working out the overlapping area within pixels of parts of the scene. The proportion of area within a pixel is used to calculate a weighted average over the contributing colours.



Filtering

Aliasing problems can be addressed by applying some form of filter to the image. A common filter to use is a Gaussian blur.

Gaussian blur is achieved by convolving a 2D Gaussian function with the image. This has the effect of replacing an image intensity with that of the average intensity of surrounding pixels.

$$g(x,y) = \frac{1}{2\pi\sigma^2}\ \exp(-\frac{x^2+y^2}{2\sigma^2}) \tag{1}$$

$$f_{\text{new}} = f_{\text{old}}(x,y) \circledast g(x,y) \tag{2}$$

$$= \int\int f(u,v)g(x-u,y-v)\mathrm{d}u\mathrm{d}v \tag{3}$$

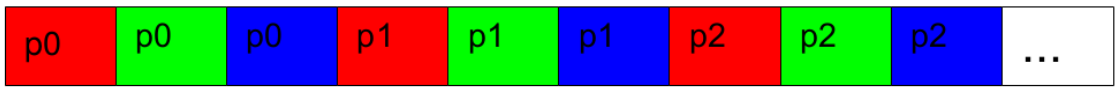
Note: Gaussian filters are separable. Which means we can decompose the filter into a two 1-d filters, which is much faster ($O(\sigma)$, instead of $O(\sigma^2)$).

Image Formats

Raw Image Formats

- Raw image formats are lossless formats that store data that closely maps the sensors/pixels of the camera/display device. These will often be in either **RGB** or **YUV** colour spaces.
- The metadata will include information like: resolution, byte/bit ordering, the number of bits per intensity, colour space used, palette (if one is used), etc.
- Often raw images will be 3-10 times larger than compressed formats like **JPEG**.
- The below is an example of an 3x3 image with 8 bit **RGB** intensity values

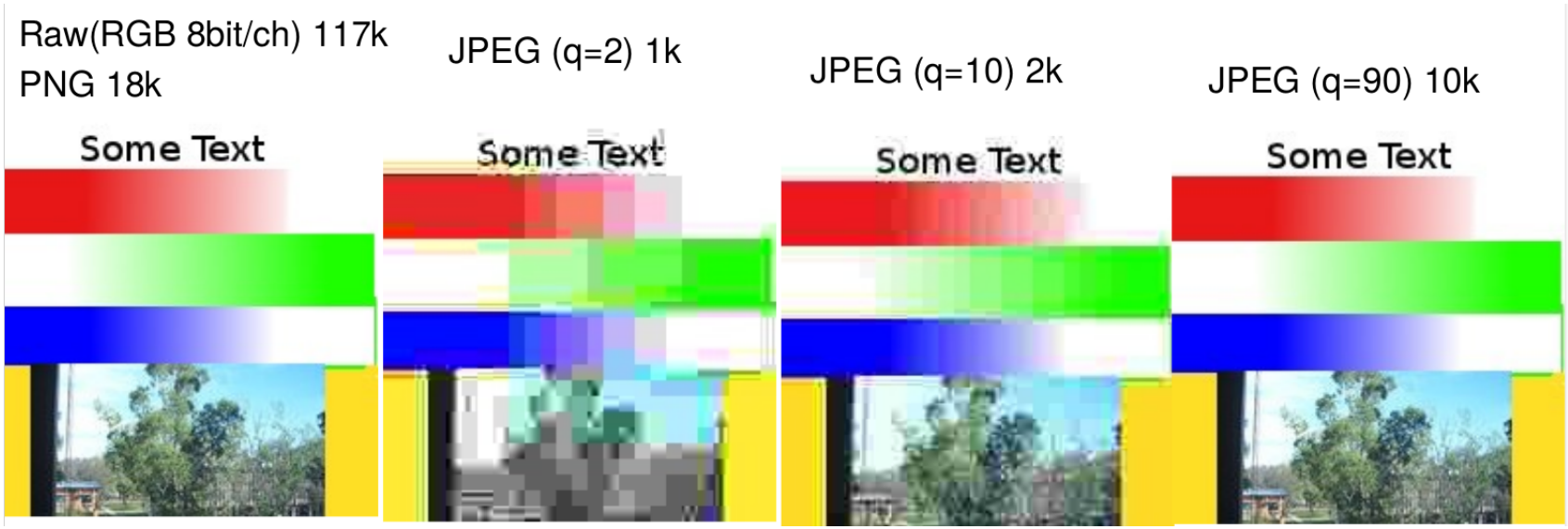
p0	p1	p2
p3	p4	p5
p6	p7	p8



Data will be 3*3*3 = 27 bytes long

PNG and JPEG

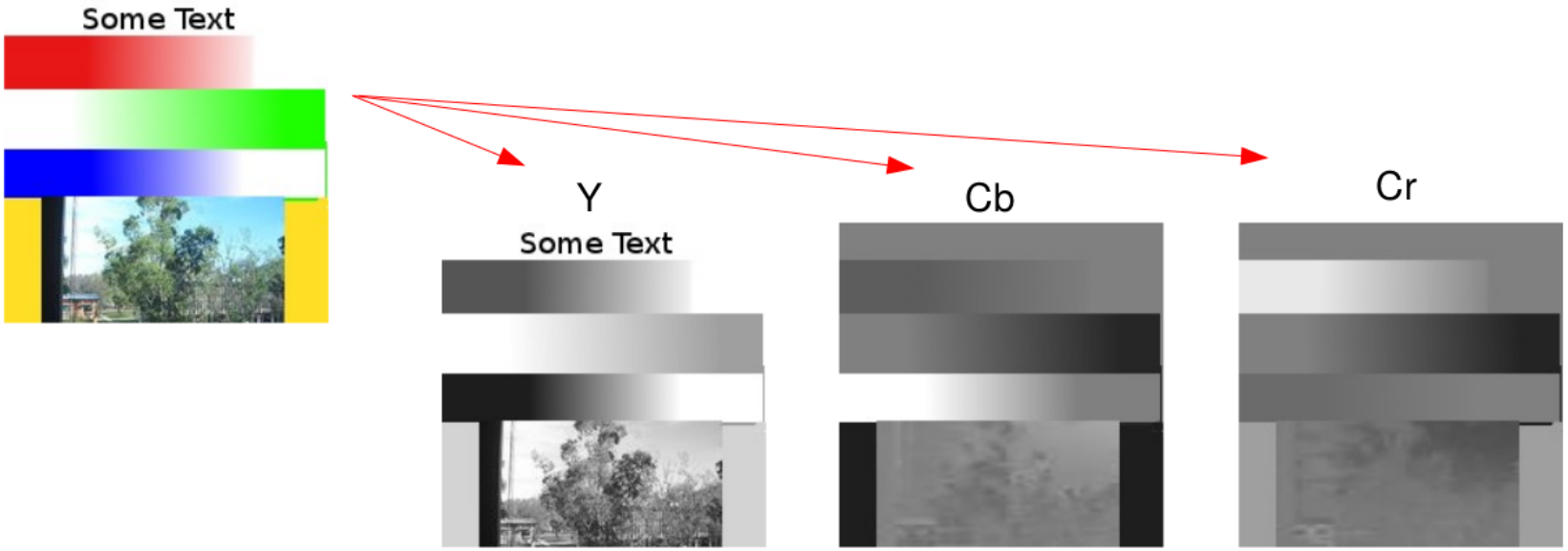
- PNG is a **lossless** data compression format for storing bitmap images.
- JPEG is a **lossy** data compression format also for storing bitmap images.



Storage size and quality of a 200x200 image.

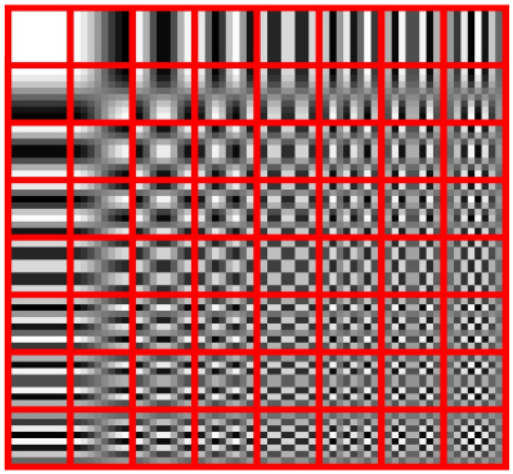
JPG

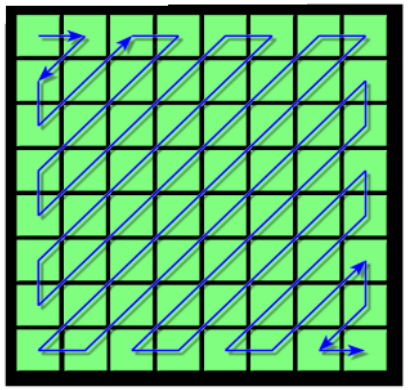
Images are converted to YCbCr and the croma components down-sampled.



JPG

Y, Cb, and Cr are divided into 8x8 blocks, these blocks are then transformed into the frequence domain (via a DCT). This produces an 8x8 block of numbers representing a linear combination of the different frequencies. These are quantised by dividing by constant values and rounded (this is the step which governs compression and quality). Lossless Huffman encoding is used for storing the bit length and runs of zeros of this zigzag sequence of quantised values.





Credit https://en.wikipedia.org/wiki/JPEG

PNG

- Supports RGB and RGBA (very useful).
- Has five filters (none, sub, up, average, paeth). That allow for efficient encoding of certain types of graphics.
- Then applies LZ77, and Huffman coding (essentially a zip).
- Great for graphics and text, bad for natural images.

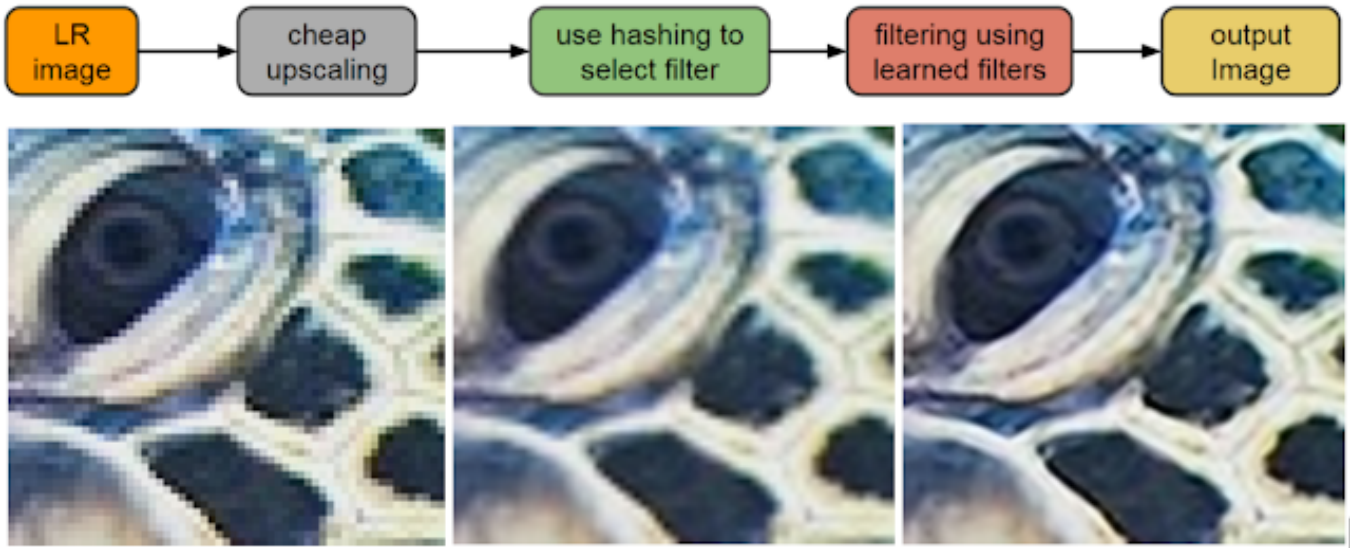
Image Formats

AI Compressed Images

AI Compressed Images - SuperResolution

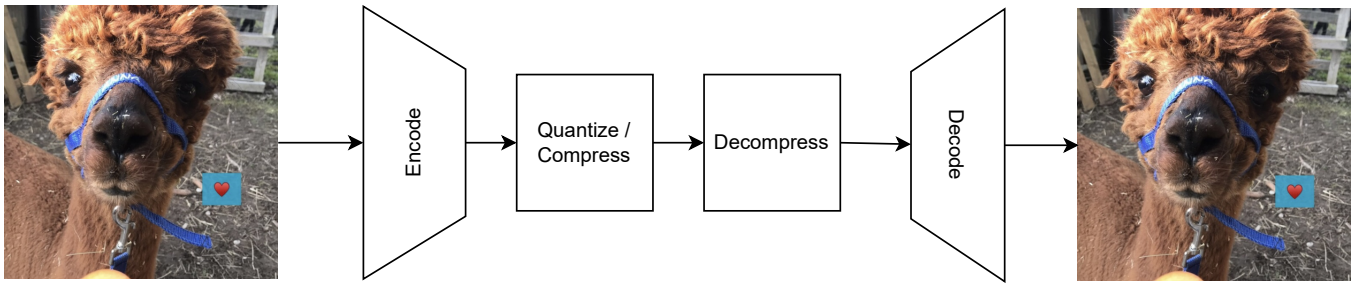
Transmit images at low resolution, then apply super resolution to upscale the images on the device. This is easy to integrate into existing systems, as the 'compressed' image is simply a JPEG at a lower resolution.

Romano, Y., Isidoro, J., & Milanfar, P. (2016). RAISR: rapid and accurate image super resolution. IEEE Transactions on Computational Imaging, 3(1), 110-125.



Left - low res, **mid** - bicubic upsample, **right** - RAISR.

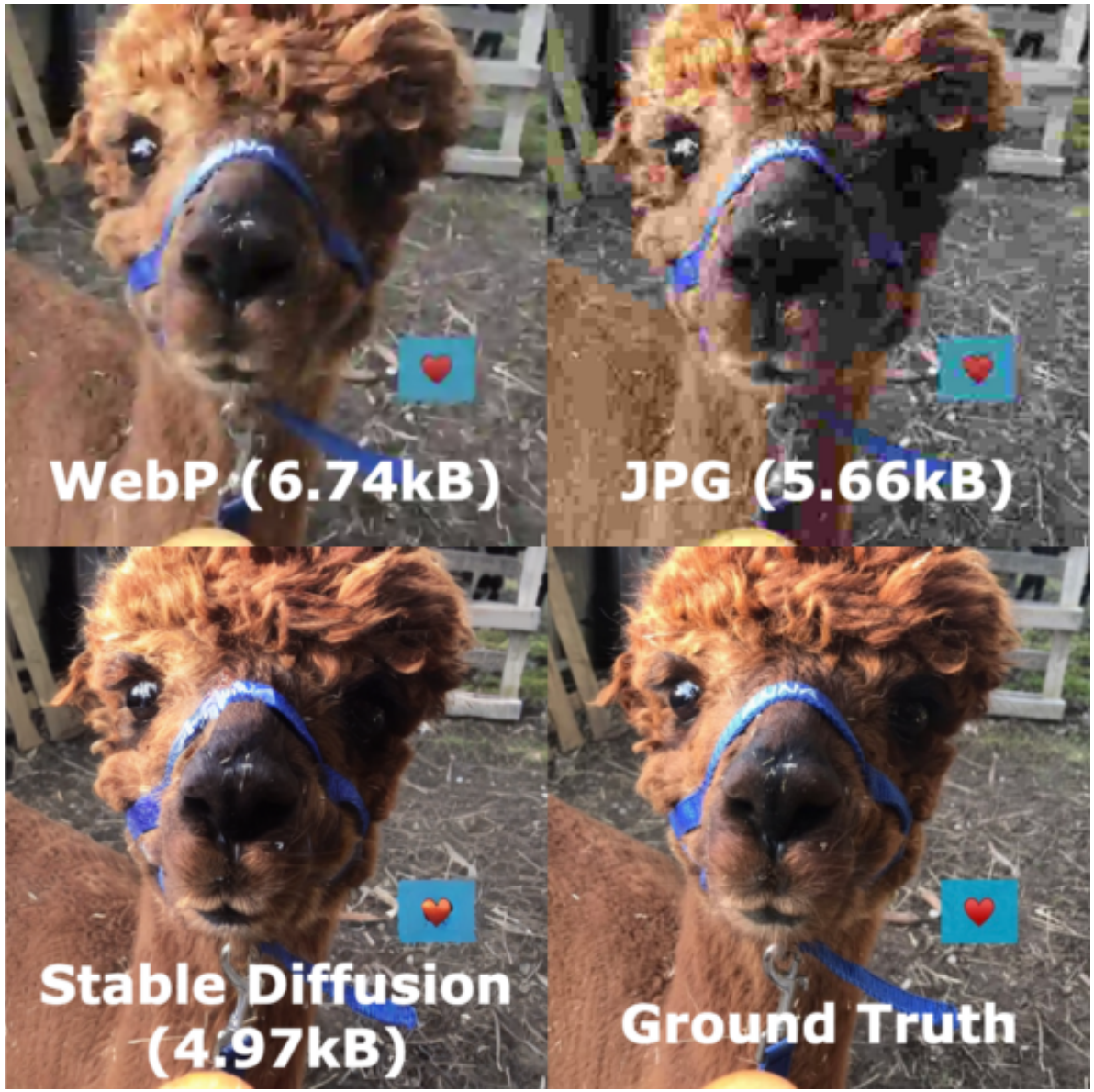
AI Compressed Images - StableDiffusion



Format	**Size**
Ground Truth (RAW)	(512x512x3) 768 KiB
Ground Truth (PNG)	429.4 KiB
Features (32bit)	(64x64x4) 64 KiB
Features (8bit)	(64x64x4) 16 KiB
Features (8bit - compressed)	4.97 KiB

See https://pub.towardsai.net/stable-diffusion-based-image-compresssion-6f1f0a399202

AI Compressed Images - StableDiffusion



The source image compressed with different image compressors.

Video Formats

MPEG-2

I-frames Essentially a JPEG image. Can be decoded independantly. These are much larger than the other types of frames.
P-frames Predictive frames that use a previous I or P frame, along with motion vectors, as a starting point. Only the error is encoded.
B-frames Bidirectional frames. These frames may reference a previous I or P frame, as well as a future I-frame.
GOP A group of pictures. Typically frames may only referece other frames with a GOP, although sometimes B-frames can reference the first I-frame of the next GOP
A typical GOP might look like

IBBPBBPBBPBB

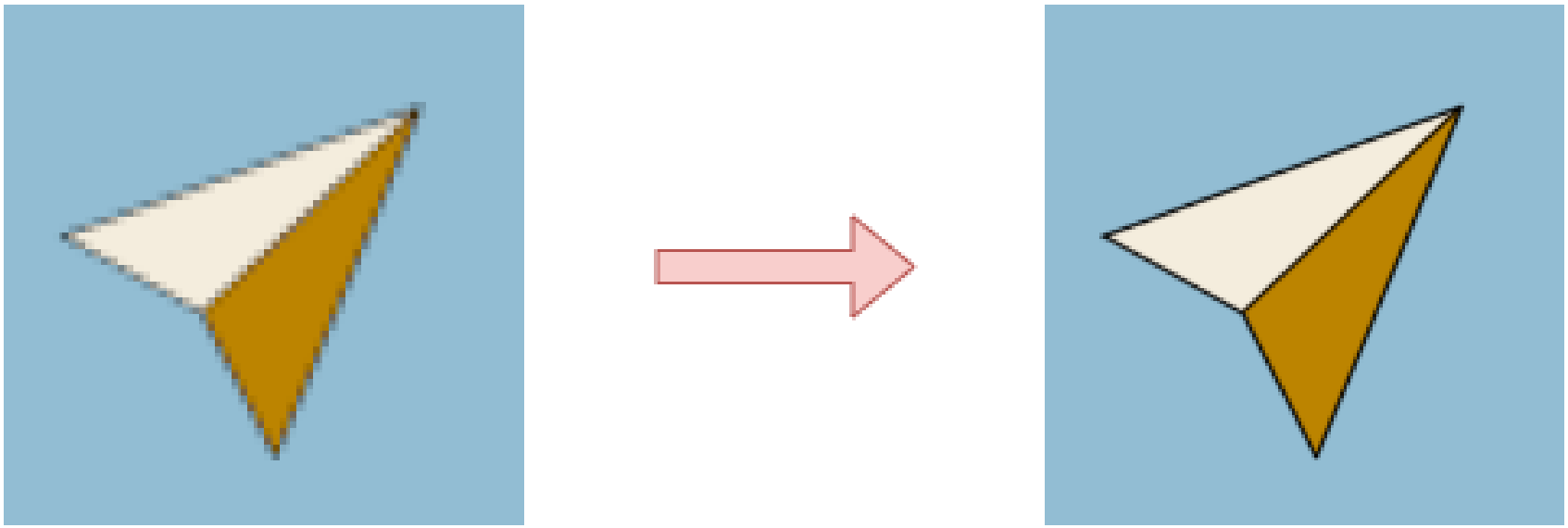
MPEG-4

- Several improvements over MPEG-2.
- **Integer DCT** allows for exact decoding, which enables much longer intervals between I-frames.
- **More efficient compression** (CABAC).
- **Inline post-processing** (e.g. deringing).
- Many other small improvements...

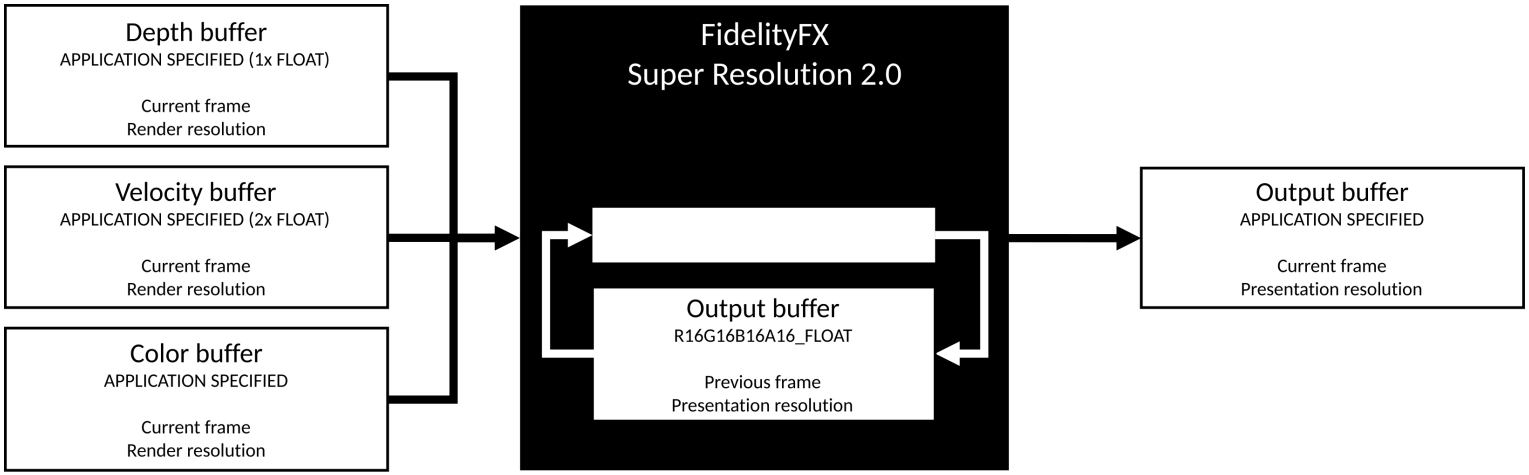
Super Resolution and Denoising

Super Resolution

Given a low resolution image, predict the high resolution version.



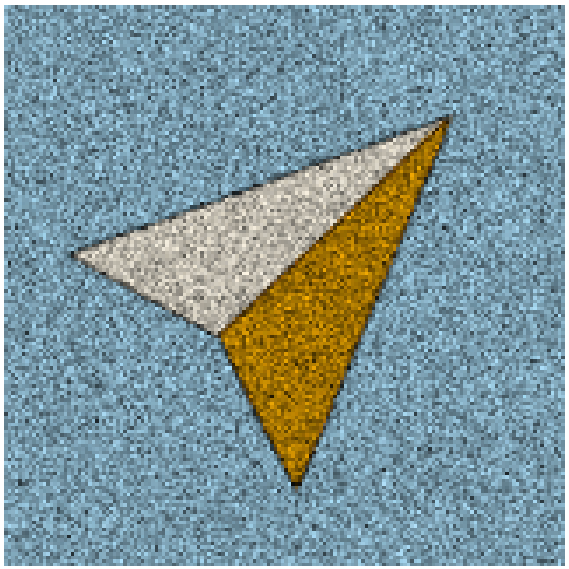
Super Resolution - FidelityFX

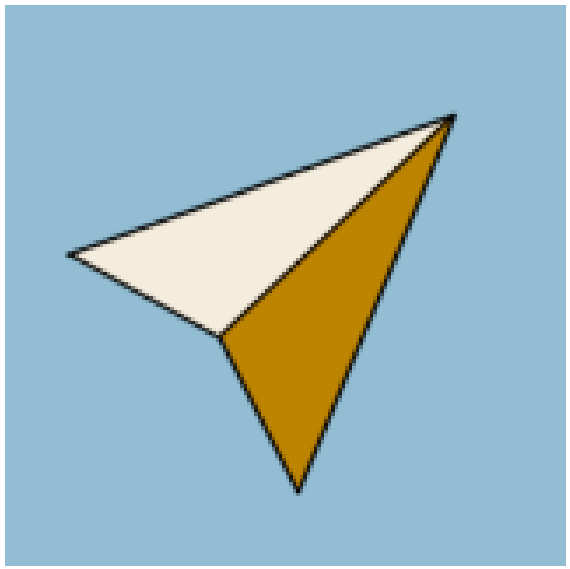


Source https://github.com/GPUOpen-Effects/FidelityFX-FSR2/blob/master/README.md

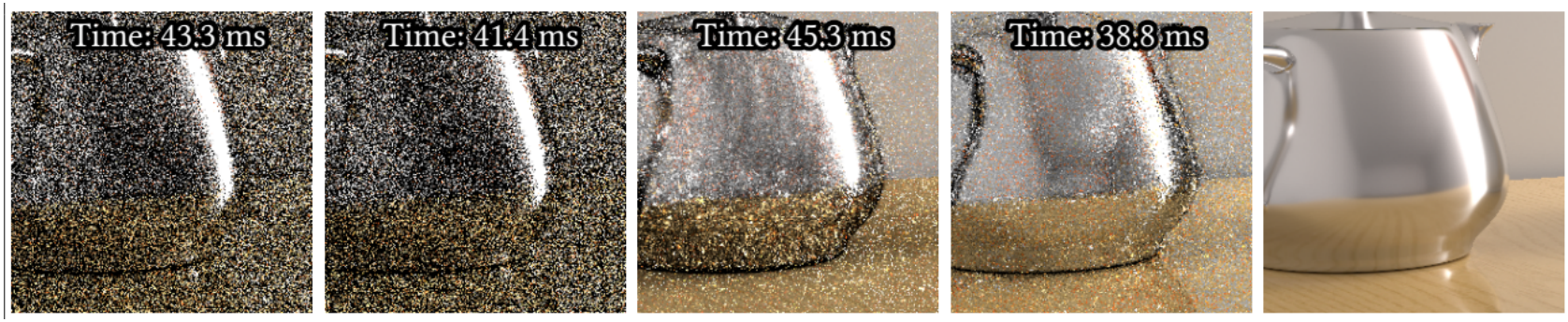
Denoising

Given a noisy version of an image, predict the original image.





Denoising - Raytracing



Lin, D., Kettunen, M., Bitterli, B., Pantaleoni, J., Yuksel, C., & Wyman, C. (2022). Generalized resampled importance sampling: foundations of ReSTIR. ACM Transactions on Graphics (TOG), 41(4), 1-23.

Summary

- AI is starting to be integrated into the rendering pipeline.
- It's a good idea to use the previous frame when rendering the next frame.
- Cooperation between the renderer and the anti-aliasing algorithm is important. (motion vectors, applying jitter etc).
- This results in surprisingly good light transport using only a few samples if we use the above methods.