Introduction to measurement of picture quality:

Picture quality can refer to the level of accuracy in which different imaging systems capture, process, store, and compress, transmit and display the signals that form a Picture. Another definition refers to Picture quality as "the weighted combination of all of the visually significant attributes of a Picture". The difference between the two definitions is that one focuses on the characteristics of signal processing in different imaging systems and the latter on the perceptual assessments that make a Picture pleasant for human viewers.

Picture quality should not be mistaken with **Picture fidelity**. Picture fidelity refers to the ability of a process to render a given copy in a perceptually similar way to the original (without distortion or information loss), i.e., through a digitization or conversion process from analog media to digital Picture.

The process of determining the level of accuracy is called **Picture Quality Assessment** (IQA). Picture quality assessment is part of the quality of experience measures. Picture quality can be assessed using two methods: subjective and objective. Subjective methods are based on the perceptual assessment of a human viewer about the attributes of an Picture or set of Pictures, while objective methods are based on computational models that can predict perceptual Picture quality. Objective and subjective methods aren't necessarily consistent or accurate between each other: a human viewer might perceive stark differences in quality in a set of Pictures where a computer algorithm might not.

Subjective methods are costly, require a large number of people, and are impossible to automate in real-time. Therefore, the goal of Picture quality assessment research is to design algorithms for objective assessment that are also consistent with subjective assessments. The development of such algorithms has a lot of potential applications. They can be used to monitor Picture quality in control quality systems, to benchmark Picture processing systems and algorithms and to optimize imaging systems.

Picture quality attributes:

- **Sharpness** determines the amount of detail an Picture can convey. System sharpness is affected by the lens (design and manufacturing quality, focal length, aperture, and distance from the Picture centre) and sensor (pixel count and anti-aliasing filter). In the field, sharpness is affected by camera shake (a good tripod can be helpful), focus accuracy, and atmospheric disturbances (thermal effects and aerosols). Lost sharpness can be restored by sharpening, but sharpening has limits. Over sharpening, can degrade Picture quality by causing "halos" to appear near contrast boundaries. Pictures from many compact digital cameras are sometimes over sharpened to compensate for lower Picture quality.
- **Noise** is a random variation of Picture density, visible as grain in film and pixel level variations in digital Pictures. It arises from the effects of basic physics— the photon nature of light and the thermal energy of heat— inside Picture sensors. Typical noise reduction (NR) software reduces the visibility of noise by smoothing the Picture, excluding areas near contrast boundaries. This technique works well, but it can obscure fine, low contrast detail.
- **Dynamic range** (or exposure range) is the range of light levels a camera can capture, usually measured in f-stops, EV (exposure value), or zones (all factors of two in exposure). It is closely related to noise: high noise implies low dynamic range.
- **Tone reproduction** is the relationship between scene luminance and the reproduced Picture brightness.
- **Contrast**, also known as gamma, is the slope of the tone reproduction curve in a log-log space. High contrast usually involves loss of dynamic range — loss of detail, or clipping, in highlights or shadows.

- **Color accuracy** is an important but ambiguous Picture quality factor. Many viewers prefer enhanced color saturation; the most accurate color isn't necessarily the most pleasing. Nevertheless, it is important to measure a camera's color response: its color shifts, saturation, and the effectiveness of its white balance algorithms.
- **Distortion** is an aberration that causes straight lines to curve. It can be troublesome for architectural photography and metrology (photographic applications involving measurement). Distortion tends to be noticeable in low cost cameras, including cell phones, and low cost DSLR lenses. It is usually very easy to see in wide angle photos. It can be now be corrected in software.
- **Vignetting**, or light falloff, darkens Pictures near the corners. It can be significant with wide angle lenses.
- **Exposure accuracy** can be an issue with fully automatic cameras and with video cameras where there is little or no opportunity for post-exposure tonal adjustment. Some even have exposure memory: exposure may change after very bright or dark objects appear in a scene.
- **Lateral chromatic aberration** (LCA), also called "color fringing", including purple fringing, is a lens aberration that causes colors to focus at different distances from the Picture center. It is most visible near corners of Pictures. LCA is worst with asymmetrical lenses, including ultrawides, true telephotos and zooms. It is strongly affected by demosaicing.
- **Lens flare**, including "veiling glare" is stray light in lenses and optical systems caused by reflections between lens elements and the inside barrel of the lens. It can cause Picture fogging (loss of shadow detail and color) as well as "ghost" Pictures that can occur in the presence of bright light sources in or near the field of view.
- **Color moiré** is artificial color banding that can appear in Pictures with repetitive patterns of high spatial frequencies, like fabrics or picket fences. It is affected by lens sharpness, the anti-aliasing (lowpass) filter (which softens the Picture), and demosaicing software. It tends to be worst with the sharpest lenses.
- **Artifacts** – software (especially operations performed during RAW conversion) can cause significant visual artifacts, including data compression and transmission losses (e.g. Low quality JPEG), oversharpening "halos" and loss of fine, low-contrast detail.

The Relationship of Picture Quality and Picture Resolution:
Or
Resoluti0n of picture and their quality depending upon the resolution:

When talking about Picture quality, the resolution often comes up in the conversation. Resolution of course, refers to the size of an Picture measured in pixels (picture elements). When you multiply the Picture resolution width and height, it gives the total number of pixels in an Picture. The quality means the Picture’s representation of details that are stored in the pixels, like the color, shadows, contrast, etc. I have heard some people explain that higher resolutions improve the quality of an Picture. That means that *if you have a low resolution shot Picture, increasing its resolution would also increase its quality*. Does that really make any improvements to the Picture’s quality?

I have a photo shot with a camera resolution of 1280 x 960 pixels. The original Picture is displayed along with a zoomed in view of 646%.

When zoomed in, the details are still noticeable to show the scene. Although the Picture becomes more pixelated and blurry as the Picture is zoomed, the quality still looks fine though not that great.

Will the quality in the Picture's details look much better if we were to increase its resolution?

Now, the original Picture will be up scaled to a resolution of 3800 x 2850 pixels. This uses a bi cubic interpolation algorithm at 300 PPI. This Picture will be displayed with a zoomed in view of 646%.

The quality itself does not show any improvements when increasing the resolution. While it looks fine at its maximum resolution, when you start zooming in the quality actually suffers. It looks muddier and more blurry. The colors also look more faded and the scene looks less coherent. A Picture captured with a lower resolution will not improve quality when scaled to a higher resolution.

So, Picture resolution does not determine the Picture quality?

Resolution and quality depends on certain things. To understand this better, digital Pictures captured by electronic sensors (in DSLR and mirror less cameras) use what is called a **raster** format. A raster format creates Pictures using pixels (in digital imaging) or dots (when printing digital Pictures). Raster files are created and stored on disk which can be retouched by photo editing software. Raster files (RAW) can later be compressed to decrease file size (JPEG), but with a trade off with details.

Once a Picture is captured in raster format, it stores all details in the pixels of the Picture. Thus, you really cannot add new details to improve the quality of an Picture by upscaling it to a higher resolution. Instead what happens is you actually add more of the existing information already stored in the pixels of the original Picture, through duplicating adjacent or the nearest pixel? For example if a pixel captured in the original Picture has an RGB value of "39, 48, 43", it will still be the same when the Picture is upscaled. No new information is captured at all.

This is the reason why professional photographers and seasoned imaging specialists prefer to work with higher resolution Pictures, because they have more pixels that store more information. More information means more details, therefore much better Picture quality than a lower resolution Picture. This shows in their work, so if this is done commercially it is important to have the highest quality Picture. If a photographer shot the Picture in 8 MP instead of 32 MP, it will not look as great when it comes to print but it may not make a difference on the web. This is because most web content, like Pictures, is not displayed in full resolution so the difference is not going to be noticeable. When printing though, the quality is really noticeable. This is why publishers give certain criteria to photographers when it comes to Picture resolution and quality.

Measure of Picture Quality:

Resolution is determined by the ratio of pixels in proportion to Picture size. This is measured in **PPI (Pixels per Inch)**. A high resolution Picture will usually have more pixels to every square inch in a Picture. This is measured in which the numbers of diagonal pixels are taken as a proportion of the length of the diagonal line that goes through an Picture. The higher the PPI, the higher the Picture resolution and this also means the higher the Picture quality.

Dot pitch is a measure used to determine the sharpness of a Picture. This is measured in millimeters (mm) and a smaller number means a sharper Picture. When you have closer spaced pixels, the Picture will look much sharper. The dot pitch is the distance from the center of one pixel to the next pixel. A lower dot pitch is considered better Picture quality based on its resolution. For example a 1024 x 768 resolution has a dot pitch of 0.297. A 3840 × 2400 resolution has a dot pitch of 0.125. The latter would be much sharper than the former, thus having better Picture quality.

Compression is another factor that measures quality. A Picture in its original raster format is called the RAW file. The RAW file contains the highest quality in a Picture, so some photographers just use what is called a lossless format to preserve the Picture quality. An example of this is the TIFF file format, which also takes up the most storage space on disk. The JPEG format, based on **DCT (Discrete Cosine Transform)** algorithms, allows further compression (lossy compression) of the Picture in order to reduce the file size. However, by compressing the Picture, quality is lost. The more compression applied to an Picture, the less quality preserved. JPEG became popular for web content in the early days of the Internet. Due to the smaller file sizes, it allows websites to load content faster when bandwidth is limited.

It's The Device That Determines Quality

This is probably what most people are aware of. Having a Canon 5D Mark IV camera is definitely going to capture better Pictures by default compared to a typical smartphone camera. The camera's specifications determine the quality based on the lens, sensor size, Picture resolution, firmware features, Picture stabilization and Picture signal processor. If anything, the sensor size is important because it is responsible for gathering the light to create the Picture. It is possible to have high resolution Pictures like on smartphone cameras. However, the quality to an equivalent DSLR will not be as great because smartphone sensor size is smaller.

The Light Must Be Right

Lighting is something that may not be considered in Picture quality, but it is just as important as the camera. You need light to create the Pictures. The best quality Pictures shot by great photographers like Annie Leibovitz, Ansel Adams and Herb Ritts have one thing in common — good lighting. No matter how high-end a camera is, if you have poor lighting you won't get high quality Pictures. Poorly lit Pictures are horrible to edit because certain details cannot be recovered from shadows and grainy areas. Lack of light also produces blurry Pictures which are not sharp and detailed. Colors also suffer in poor light, decreasing the overall quality of an Picture. Shooting an Picture intentionally even in poor light may be interpreted as artistic, but that is more for creative purposes and not best practice.

It Also Depends on the Display

Having a brilliant display that can reproduce the Picture is also probably the most important when it comes to viewing the highest quality in an Picture. A 4K display compared to a standard VGA display is a night and day comparison. When you try to view your 32 MP Picture on a VGA display, you won't get good quality. So this shows that even high resolution Pictures can have poor quality if your display is poor. You also won't see a 1 MP Picture any better with a 4K display. This is why in post-production studios, the editors require the best displays with resolutions of 5K and higher in order to produce the best and highest quality content.

The Answer

This can be confusing at first, but let's break down what has been discussed so far.

- Picture resolution and Picture quality are directly related when it comes to the time the Picture is captured (no post involved). For example, if you shoot high resolution you get a high quality Picture.
- Picture resolution and Picture quality are not related when you are editing the Picture. For example, when you upscale a low resolution Picture, you will not improve its quality.
- The type of media used for showing the Picture is very important. The highest quality is best viewed on a high resolution display (e.g. computer monitor, TV, movie screen). Published Pictures on print look best at the highest resolution available. Low resolution Pictures displayed on a high resolution display will not exactly look much better. Low resolution Pictures will appear fine on the web, but not in print.
- Compressing Picture files leads to a loss of quality.
- Overall Picture quality is determined by the camera or Picture capture device.

- Good lighting, higher quality. Poor lighting, lower quality.

Now there are new algorithms being developed that can upscale an Picture and at the same time add “new” details to improve Picture quality. Using AI methods of **Machine Learning**, researchers are testing imaging algorithms that use techniques of ***Deep Convolutional Neural Networks*** that use ***super scaling***. This may soon become the norm, and in this case increasing Picture resolution does improve Picture quality. For conventional imaging (no AI involved), Picture quality is still very much determined at the moment of capture and its quality will depend on the camera’s specifications (e.g. Picture resolution, sensor size, etc.).

Define the color property of picture:

Color is the element of art that is produced when light, striking an object, is reflected back to the eye: that's the objective definition. But in art design, color has a slew of attributes which are primarily subjective. Those include characteristics such as harmony — when two or more colors are brought together and produce a satisfying effective response; and temperature — a blue is considered warm or cool depending on whether it leans towards purple or green and a red whether it leans towards yellow or blue.

Subjectively, then, color is a sensation, a human reaction to a hue arising in part from the optic nerve, and in part from education and exposure to color, and perhaps in the largest part, simply from the human senses.

The Science of Color

Munson attended the Julien Academy in Paris and won a scholarship to Rome. He held exhibits in Boston, New York, Pittsburgh, and Chicago, and taught drawing and painting at the Massachusetts School of Art between 1881 to 1918. As early as 1879, he was having conversations in Venice with the design theorist Denman Waldo Ross about developing a "systematic color scheme for painters, so as to determine mentally on some sequence before laying the palette."

Munson eventually devised a scientific system for classifying all colors with standard terminology. In 1905, he published "A Color Notation," in which he scientifically defined colors, precisely defining hue, value, and chroma, something that scholars and painters from Aristotle to da Vinci had longed for.

Munson's operationalized attributes are:

- **Hue**: the color itself, the distinctive quality by which one can distinguish one color from another, e.g., red, blue, green, blue.
- **Value**: the brightness of the hue, the quality by which one distinguishes a light color from a dark one, in the range from white to black.
- **Chroma or intensity**: the quality that distinguishes a strong color from a weak one, the departure of a color sensation from that of white or gray, the intensity of a color hue.

Tonal value:

The relative lightness or darkness of shades between black and white

In art, tone refers to the degree of lightness or darkness of an area. Tone varies from the bright white of a light source through shades of gray to the deepest black shadows. How we perceive the tone of an object depends on its actual surface lightness or darkness, color, and texture, the background, and lighting. Tone may be used broadly ('global tone') to denote the major planes of an object; realist artists use 'local tone' to accurately denote subtle changes within the plane.

Dictionary entries sometimes use define tone or as referring to color, but artists use hue or chroma to refer to this quality, preferring to use tone, tonal value, or value to describe lightness or darkness. 'Value' by itself tends to be used by those speaking North American English, while those speaking British English use tone.

Tonal gradation:

Photographers often concentrate on the density and detail of highlights and shadows when they should actually be considering the most important or middle tones of the negative. Middle tones are the various tones of gray between the highlights and the shadows; that is, the densities that are not highlights or shadows are termed middle tones or intermediate tones. The middle tones vary with the type of film and the subject contrast .A negative should have a range of middle tone densities that correspond proportionally to the middle reflective brightness of the subject. A panchromatic negative that does not have proportionate mid tones is contrast. GRAININESS because photographic Pictures made from film are made up of fine silver grains, the Pictures may appear “grainy” or exhibit graininess (fig. 10-22).All negatives show graininess to some extent. The most important factors affecting negative graininess are as follows: The composition of the emulsion or the inherent graininess of the emulsion. That is to say, the size of the grains used to produce the emulsion. The type of developer used. When fine grain is desired, a fine-grain developer with the appropriate film should be used. The extent of development. Overdevelopment is a major cause of excessive graininess. Exposure or negative density. Over exposure is another key contributor to graininess. As negative density increases, so does graininess.

GRAINY

FINE GRAIN

Picture sharpness. The sharper the film Picture, the greater the Picture detail and the less apparent the graininess

Continuous tone:

Refers to Pictures that have a virtually unlimited range of color or shades of grays.

Photographs and television Pictures, for example, are continuous-tone Pictures. In contrast, computer hardware and software is digital, which means that they can represent only a limited number of colors and gray levels. Converting a black-and-white continuous-tone Picture into a computer Picture is known as *gray scaling*.

Continuous-tone printers can print each dot at many different shades of lightness and darkness. Though this isn't true continuous-tone because the level of shades is limited, there are enough shades (256 or more) so that the difference between one shade and the next is imperceptible to the human eye.

Halftone:

In printing, a continuous tone Picture, such as a photograph, that has been converted into a black-and-white Picture. Halftones are created through a process called dithering, in which the density and pattern of black and white dots are varied to simulate different shades of gray.

In conventional printing, halftones are created by photographing an Picture through a screen. The *screen frequency,* measured in lines per inch, determines how many dots are used to make each spot of gray. In theory, the higher the screen frequency (the more lines per inch), the more accurate the halftone will be. However, actual screen frequencies are limited by the technology because higher screen frequencies create smaller, more tightly packed dots. If you are printing on a low resolution device, therefore, you may get better results with a lower screen frequency.

Modern desktop publishing systems can create halftones by simulating the conventional photographic process. This is why some programs allow you to specify a screen frequency even when no actual screen is used.