Hvad er bedst fuldframe eller crop (APS-C). NY Ver. 2

Af Allan Kierulff - http://blog.allan-kierulff.dk/

Det er der slet ingen tvivl om – det er ganske enkelt "Watson".

Denne tekst er udarbejdet med fotografering af wildlife som udgangspunkt, hvor der skal foretages en cropping for at få motivet i en passende størrelse.

Den korte version.

Til portræt: **fuldframe** er bedst med sine ofte mange flere pixels. Fuldframe er altid bedst, når motivet kan udfylde hele rammen uden cop. Der vil være flere detaljer.

Til wildlife: er APS-c kameraet med sin større pixels density – mange pixels presset sammen på en mindre sensor bedst, hvis billedet fra FF-huset skal croppes.

Pixel-density er alfa og omega. Jo større pixel-density der er, jo flere detaljer kan der fremkomme i billedet.

Hvis man skal croppe et billede – så anvend et crop-kamera, som har en større pixel-density = større pixel massefylde. Men hvis billedet ikke skal croppes, så anvend fuldframe.

Her kommer så den lange og udpenslede version.

Men først:

Er Fuldframe (FF) linser skarpere til crop kameraet – er ofte et spørgsmål.

NEJ afgjort ikke, fordi et APS-C hus (crop-hus) anvender kun den midterste del at en fuldframe linse, og får så ikke det fulde lysindfald bragt ind til sensoren. Kun i kanterne kan en fuldframe linse syne skarpere på et crop-kamera, fordi kun den skarpeste midterste del af linsen anvendes.

Linser produceret til crop (APS-C) huse er skarpere fordi de kanaliserer ALT det lys de opfanger ind til sensoren, fra FF linser når kun en mindre del af det lys, der kommer ind i linsen frem til sensoren.

Hvorfor bruger vi så FF linser til crop-huse – Det er ganske enkelt Watson ☺
Det er fordi, der (så vidt jeg ved) ikke laves linses med den zoom-størrelse, vi ønsker os til fotografering af wildlive af denne type.

Hvorfor bruger vi så ikke udelukkende fuldframe huse – det er næsten lige så enkelt.

- Fordi der ofte er en væsentlig prisforskel.
- Fordi vi ønsker, at nå længere ud med et crop-hus, som jo har en forlængende virkning på den anvendte linse. Eller - måske fordi vi ikke har råd til at købe de helt store og dyre linser.

For at sammenligne fuldframe billeder, med billeder taget med crop-kamera, må man omregne fuldframe billedet til et billedudsnit, der er lige med et crop-huset billedudsnit, og finde antallet af megapixels der er indeholdt i dem. Det er jo her fra den "endelige" cropping sker mod, at få en lille fugl til at fylde tilstrækkeligt på billedet.

Hvordan sætter man så lighed mellem billeder taget med et fuldframe kamera og et crop kamera! Hvordan beregner man antallet af tilstedeværende megapixels ved brug af en crop sensor, eller et croppet billede taget med et fuldframe kamera.

Til det skal vi bruge en formel MP/CF 2 (i anden.) ved ikke lige hvordan jeg hæver 2-tallet.
Hvor MP står for megapixel og CF for crop-faktor.

Vi tager en FF Canon 5D MK lll som har et udgangspunkt i 22 MP, og vi vil sætte billedudsnittet lige med billedet for en crop 7D MK ll med 20 MP som udgangspunkt.

Vi sætter megapixels og crop-faktor ind i ligningen MP/CF i anden.
Hvilket svarer til at vi gør motivet på de to billeder lige store.

Det bliver så: (MP) 22 / (crop 1.6 i anden) altså 2,56 = 22 divideret med 2,56 som er lige med 8,6 MP.

Når FF kameraets første cropping udføres imod ønsket om at få et større motiv i det endelige billede, skal vi først gå til den motiv størrelse, der svarer til den motivstørrelse, vi får ved at bruge et crop kamera. Det vil som beregnet ovenfor indeholde 8,6 megapixel. Nu er de to billeder ens, motivet på billedet har samme størrelse – de er nu sammenlignelige.

Men billedet fra fuldframe-huset vil ud fra oven stående beregning kun indeholde 8,6 megapixel. Billedet fra 7D MK ll indeholder de 20 megapixels, som huset angives til at have som sit udgangspunkt. Når de to motiver har samme størrelse, har FF-billedet 8,6 MP og Crop-kameraets billede 20 MP at gøre godt med.

WAU - HVILKEN FORSKEL I DETALJE-RIGDOM.

Hvis vi så her efter ønsker at croppe billedet yderligere, fordi motivet ønskes større, starter vi således med at have et billede indeholdende 8,6 MP i det fra 5D MK lll, og 20 megapixel i billedet fra 7D Mk ll.

Udgangspunktet for det forhold at crop-huset har et betydelig mere detaljeret billede, at forsætte den videre crop med, er fordi det indeholder flere billed-data – pixel-densiteten er større. Det vil kunne ses - meget. Men måske ikke helt så slemt, som tallene kunne antyde på en skærm, som kun skal bruge meget få billeddata, til at vise den bedste kvalitet, som skærmen kan fremvise. Men en forskel i detaljegrad vil nok kunne ses. Men på print vil der være en ret så betydelig forskel.

Canon sammenligning af pixelværdier FF vs crop:
FF: 5D Mk-lll ucroppet 22 MP
FF: 5D MK-lll croppet til 1.6x: 8,6 MP udgangspunkt efter tilpasning til 7D's billedstørrelse.
Crop: 7D MK-ll: udgangspunkt 20 MP

Udtrykket: Det har ingen betydning at croppe i huset eller at anvende et hus med crop-faktor, jeg kan altid croppe under billedbehandlingen, holder kun hvis billedet ikke skal croppes. Det holder ikke hvis billedet skal croppes.

Det ligger jo fast, at jo flere pixels der er i et billede, jo flere detaljer kan der gengives. Men spørgsmålet kan så være "hvorfor sker det her! Hvorfor har det kamera med så mange pixel, kun så få i billedfeltet, når der foretages en cropping, der bringer motivet fra FF-kameraet på størrelse med motivet for crop-kameraet! For det er jo en meget stor reduktion af pixel-antallet, der tilsyneladende sker.

Svaret er: crop-kameraets antal af pixel findes på en meget mindre sensor-flade. Så – hvis der er 20MP hos crop-kameraet kontra 22MP hos FF-kameraet, så er de 20MP presset rigtig meget sammen for at være på den halvt så store sensor, end de 22MP på den dobbelt så store fuldframe sensor. Og når så vi foretager en cropping – gør motivet større men bibeholder samme fysiske billed-størrelse, så beskærer vi billedet, og trækker efterfølgende pixelene fra hinanden, ved at udvide den nu mindre billedflade til den ønskede billedstørrelse. Hvilket igen betyder, at den croppede/valgte fysiske billedstørrelse kommer til at indeholde færre pixels, end der var i det billede, der i ucroppet stand fra starten kom ud af kameraet.

Pixel-densiteten på en crop-sensor er tættere end pixel-densiteten på den større fuldframe-sensor. Hvis forholdet er 20 MP i crop-hus til 22 MP i fuldframe huset.

Når vi skal croppe et billede fra en FF-sensor, så starter vi med et billede hvor alle pixels er tilstede eks.vis 24 MP. Men hvis vi har et FF-billede hvor motivet, er sat lige med crop-billedets motiv, så er pixels-mængden blevet reduceret, fordi vi må skære en del af billedet og forstørre det, for at få de to motiver i samme størrelse. Den bortskårede billedflades pixels er smit væk, de findes ikke mere i det tilpassede billede, og de tilbageværende pixels er yderligere blevet trukket fra hinanden, for at få størrelsesforholdet til at være identisk.

Prøv lige at se de efterfølgende sammenligninger, taget fra den virkelige verden, hvor DxOMark har beregnet ”den synlige skarphed” fra udvalgte kamera-huse med udvalgte linser. FF-huse og APS-C huse monteret til den samme super gode linse.

For at foretage disse sammenligninger ud fra den skarphed hus og linse samlet repræsenterer, omsættes hus og linses samlede skarphed i såkaldte P-Mpix.

Men så er spørgsmålet lige ”hvad er disse P-Mpix”! Vi taler jo normalt om MP – hvor kommer det her ”P-” fra! og hvad angiver det ???

Her kommer vi ind på subjektive vurderinger og egentlige målinger, og her kommer DxOMARK's test-laboratorium ind i billedet.

DxOMark er den anerkendte branchestandard for kamera og objektiv billedkvalitet målinger og vurderinger. I årevis har DxOMARK været anerkendt for at levere den strengeste hardware test. Hvilket de gør ved hjælp i deres laboratorie og ved brug af deres industrielle værktøjer, som indgår i deres analyser. De er ligeledes meget anerkendt for etablering af den mest omfattende henvisnings-database, som fremkommer ved hjælp af deres tusindvis af kamera og objektiv testresultater.

Skarphed er selvfølgelig en subjektiv vurdering af kvaliteten af et billede eller en linse. Skarphed angiver den visuelle opfatteles af kvaliteten af detaljer i et billede eller den samlede sum af detalje-gengivelsen af hus og linse. Den synlige/visuelle skarphed er forbundet med den opløsning og kontrast, der samlet frembringer detaljerne i det enkelte billede.

DxOMark score angiveangivelser for ”skarphed” er baseret på Sanselig Megapixel (P-Mpix), et koncept der vægter ”Modulation Transfer Function (MTF)” af linsen med den menneskelige synsstyrke.

På engelsk: Perceptual Megapixel = P-MPIX

Her nogle sammenligninger ud fra P-Mpix (den synlige/sanselige skarphed).

Canon 600mm F4	Canon 600 F4	Canon 600mm F4
+	+	+
Canon 5D Mk lll	Canon 600 1DX	Canon 70D
=	=	=
20 P-Mpix (FF)	17 P-Mpix (FF)	
8 P-Mpix (1.6x)	6,6 P-Mpix (1.6x)	14 P-Mpix (1.6x)

Man får således mange flere P-Mpix (synlig skarphed) at gøre godt med ved at bruge 70D, end ved at bruge de to fuldframe-huse hvis FF-billederne skal croppes.

5D MK lll giver 20 P-Mpix, hvis motivet fylder billedet (ikke er croppet), men kun 8 P-Mpix, hvis man skal croppes til det billedudsnit 70D's APS-C-hus har.

Den dyre 1Dx giver tilsvarende kun 6,6 P-Mpix i croppet stand – uha uha.

Lad os så lige sammenligne til en 7D MK-ll:

Den har 22 MP og en crop-faktor på 1,6. Den har ifølge DxOMark "kun" 12 P-Mpix med Canons optik 600mm F4.

Når motivet tages lige ud af crop-kameraet, er udgangspunktets indhold at P-Mpix (den synlige skarphed) sammenlignet til fuldframe-kameraets 1,6 croppede billede:

7D = 12 P-Mpix

5D = 8,7 P-Mpix

1Dx = 6,4 P-Mpix

Selv om 7D kameraets billede "kun" indeholder 12 P-Mpix, har alligevel flere P-Mpix og dermed langt flere detaljer, i forhold til de croppede FF-billeder.

Det er jo lidt vildt – ikke sandt.

Nikon eksempel med anvendelse af den super skarpe 400mm F2.8 linse til udvalgte kamera-huse.

Nikon 400 F2.8	Nikon 400mm F2.8	Nikon 400mm F2.8
+	+	+
Nikon D810	Nikon D610	Nikon D7100
=	=	=
33 P-Mpix (FF)	22 P-Mpix (FF)	
15 P-Mpix (1.5)	10 P-Mpix (1.5)	17 P-Mpix (1.5)

Nikon 400mm F2.8 + Nikon D500 = 15 P-Mpix (1.5).

Nikon 400mm F2.8 + Nikon D750 = 24 P-Mpix, men i tilpasset crop størrelse ”kun” 10,7 P-Mpix

Når motivet er taget fra det samme sted, med de samme linser, og motiverne på billederne er gjort lige store, ved at croppe FF-billederne så de passer til APS-C motivets størrelse, så har D810 kun 15 P-Mpix at gøre godt med til en yderligere cropping, mod at få motivet i en passende størrelse. D610 har 10 P-Mpix, D500 har 15 P-Mpix og D7100 har 17 P-Mpix.

Det langt billigere D7100 vil altså med 400mm F2.8 linsen lave et billede med flere detaljer, end de to dyrere fuld frame huse, samt i forhold til det meget dyrere D500.

Men egentlig er det jo logisk at FF-huset kommer i vanskeligheder, for motivet i det billede der kommer ud af FF-huset, vil være mindre end motivet i APS-C billedet, og for at få bragt dette forhold på plads, skal halvdelen af fuldframe-billedets pixels skæres fra og skrottes.

Det croppede billede indeholder efter den behandling under halvdelen af de pixels, det indeholdt fra starten.

Hvad er så bedst?

- ***Giver crop-huset flere detaljer, når der skal croppes/beskæres?***
  Ja – det gør det helt afgjort.

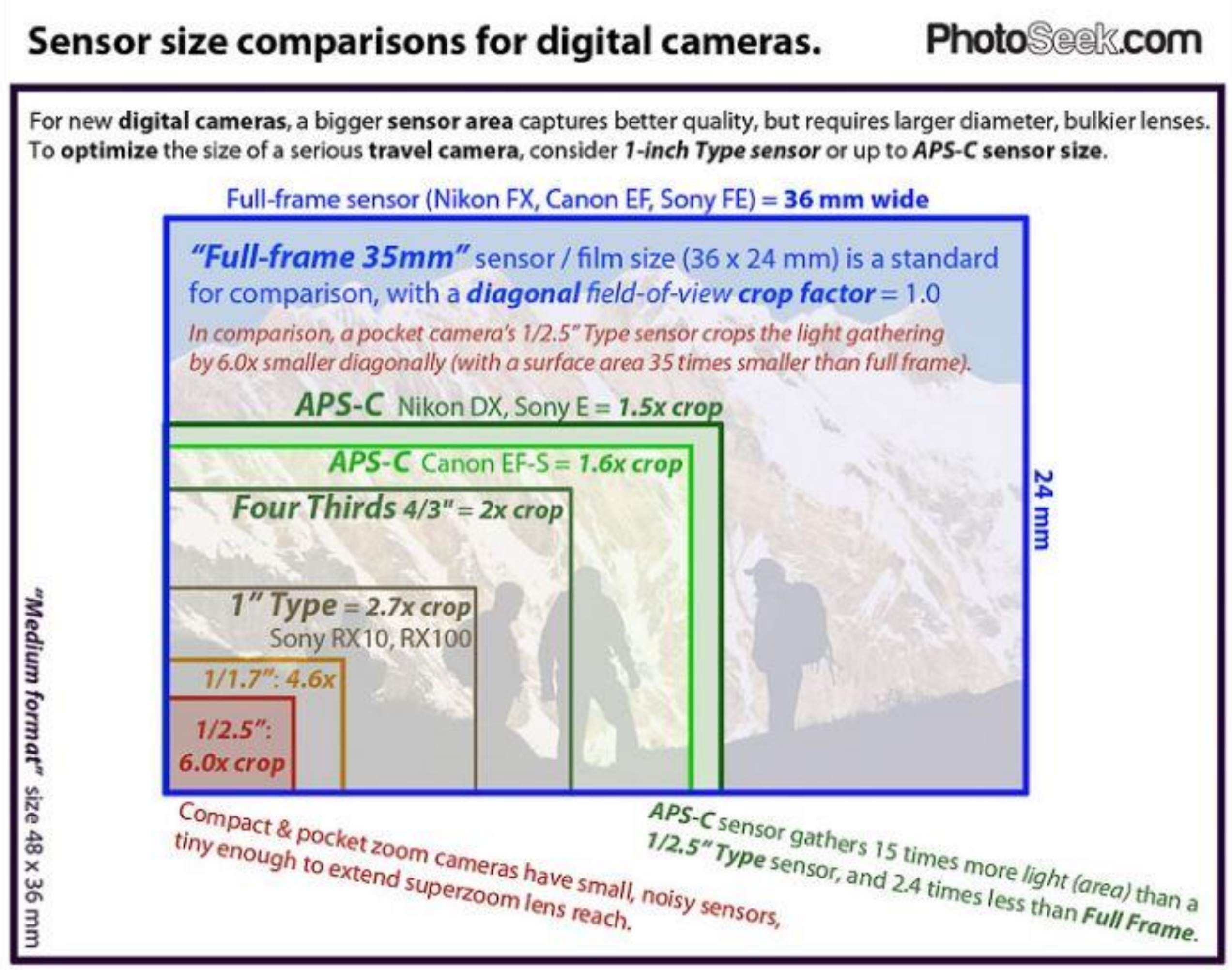
Skal man bruge fuld frame linser til crop-huset?

- ***Ja – men kun til wildlife fotografering.***

Til Wildlife er et APS-C hus langt at foretrække, frem for et fuldframe hus ☺

Selvfølgelig er der andre ting der gør sig gældende for vurderingen af et hus samlede værdi end skarphedsværdien (selv om den er af stor betydning), samt det forhold, at i forbindelse med andre linser, fremkommer andre skarphedsværdier (P-Mpix). Hvilket gør, at det er uhyre vigtigt, at tjekke op hos DoXMark, før der anskaffes en ny linse. Problemet kan bare være, at en ny linse, ikke er testet i købsøjeblikket. Der er store forskelle på hvilke huse og hvilke linser der kombineres.

Hvis det er tilfældet, så forsøg derfor altid, at få mulighed for at prøve en kostbar linse med dit hus, før købet gøres permanent. Og det er ikke nok, at tage et par billeder uden for forretningen – prøven skal foregå i naturen, og helst med en fugl i søgeren. For først der, kan skarpheden vurderes ordentligt.



In the above illustration, compare digital camera sensor sizes: full frame 35mm, APS-C, Micro Four Thirds, 1-inch, 1/1.7" and 1/2.5" Type. For new digital cameras, a bigger sensor area captures better quality, but requires larger diameter, bulkier lenses. To optimize the size of a serious travel camera, consider 1-inch-Type sensor or up to APS-C sensor size. "Full-frame 35mm" sensor / film size (36 x 24 mm) is a standard for comparison, with a diagonal field-of-view crop factor = 1.0. In comparison, a pocket camera's 1/2.5" Type sensor crops the light gathering by 6.0x smaller diagonally (with a surface area 35 times smaller than full frame).

Men nu er spørgsmålet "hvad er disse P-Mpix! Vi taler jo normalt om MP – hvor kommer det her "P-" fra! og hvad angiver det ???

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På engelsk: Perceptual Megapixel = P-MPIX

Her under kan der læses mere og dybere om DxOMark's.

Looking for new photo gear? DxOMark's Perceptual Megapixel can help you!

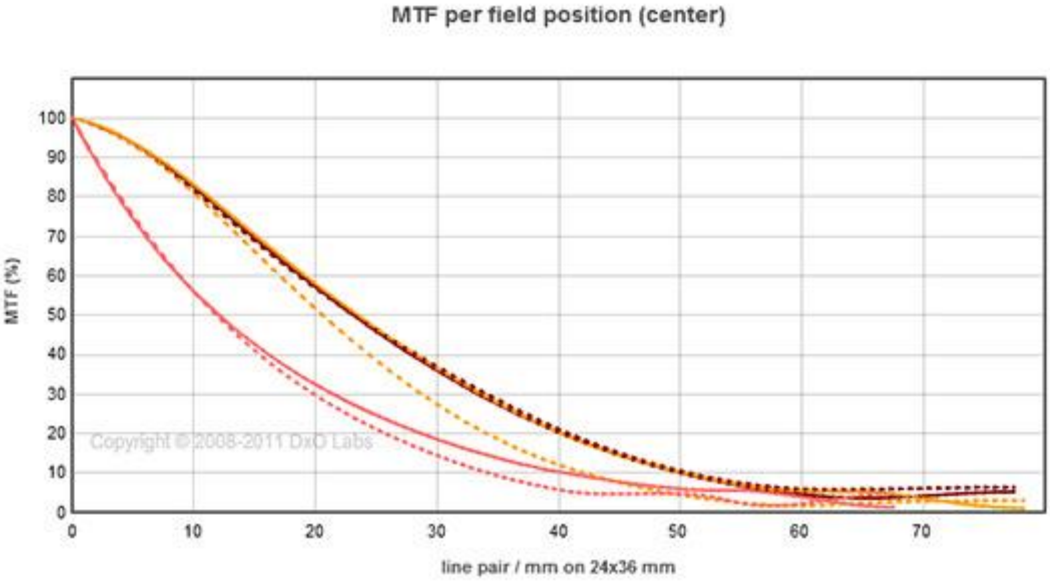
Monday December 17 2012

Lens Insight

The optical science community has long used Modulation Transfer Function or MTF, to measure and describe the sharpness of a lens. They will continue to do so as it is a great way to characterize the physical performance of a lens, however it's both rather complex to understand and difficult to communicate how well a lens performs from the perspective of the human visual system. At the end of the day photographs are primarily produced for humans to look at: so DxOMark is introducing the *Perceptual MPix* measure, a more intuitive way to describe lens and camera perceived sharpness.

Most of our readers were not looking at MTF graphs

Can you define MTF? Do you know if an MTF20% of 50lp/mm is better or worse than an MTF 50% of 30 lp/mm? And when reviewing an MTF chart, can you distinguish which curve is best? The short answer is probably no.



Modulation Transfer Function or MTF, describes how well a lens and a camera reproduce a scene's details and contrast in a final image. An integral part of DxOMark's image evaluation toolkit, MTF is understood by optics experts and by some of the 'geekiest' photo enthusiasts, but for the vast majority of people, MTF is an abstract measurement represented by opaque numeric scores, and swooping lines on a graph.

MTF provides a lot of information about optical performances, but can be overwhelming to manipulate for scoring and comparison. Therefore, DxOMark is introducing a new sharpness measurement unit called *Perceptual MPix.* This unit will help users to compare the perceived resolution of lens and camera combinations.

Perceptual MPix: a much simpler tool to score and compare lenses

P-Mpix is the unit of a sharpness measurement. The number of P-Mpix of a camera/lens combination is equal to the pixel count of a sensor that would give the same sharpness if tested with a perfect theoretical optics, as the camera/lens combination under test. For example, if a camera with a sensor of 24Mpix when used with a given lens has a P-Mpix of 18MPix, it means that somewhere in the optical system 6Mpix are lost, in the sense that as an observer you will not perceive the additional sharpness that these 6Mpix should have added to the photos if everything was perfect.

In other words it indicates the ability of the lens and other optical components of a camera to utilize, from a visual perspective, the number of pixels of the camera sensor. P-MPix expresses the result using a figure that can easily be compared to the camera sensor's MPix figure to show the quality of the lens.
This measurement bypasses the problems inherent to MTF:

- Describes resolution with a single number,
- Correlates with the way the human vision perceives resolution
- Uses a unit that is well-known to photographers — the megapixel.

The result is a more easily understandable measurement for users that makes comparisons between camera and lens combinations very simple: the higher the *Perceptual MPix* score, the better the perceived resolution.
Photographers of all types can relate to megapixels, as it is a figure that camera manufacturers provide to describe the resolution of their cameras' sensors.

45% of megapixels are lost due to lens or sensor defects

The *Perceptual MPix* measure provides photographers with a value that is more strongly associated with the true resolution of their camera sensor when coupled with a lens, or vice versa. For example, a photographer who shoots with a 20-megapixel sensor might produce images that are realistically only 15 megapixels in resolution. A number of factors can cause this loss in megapixels and resolution, including such lens defects as optical aberrations, light diffraction, or an ineffective anti-aliasing filter. The difference in number between a sensor's megapixels and *Perceptual MPix* quantifies this loss.

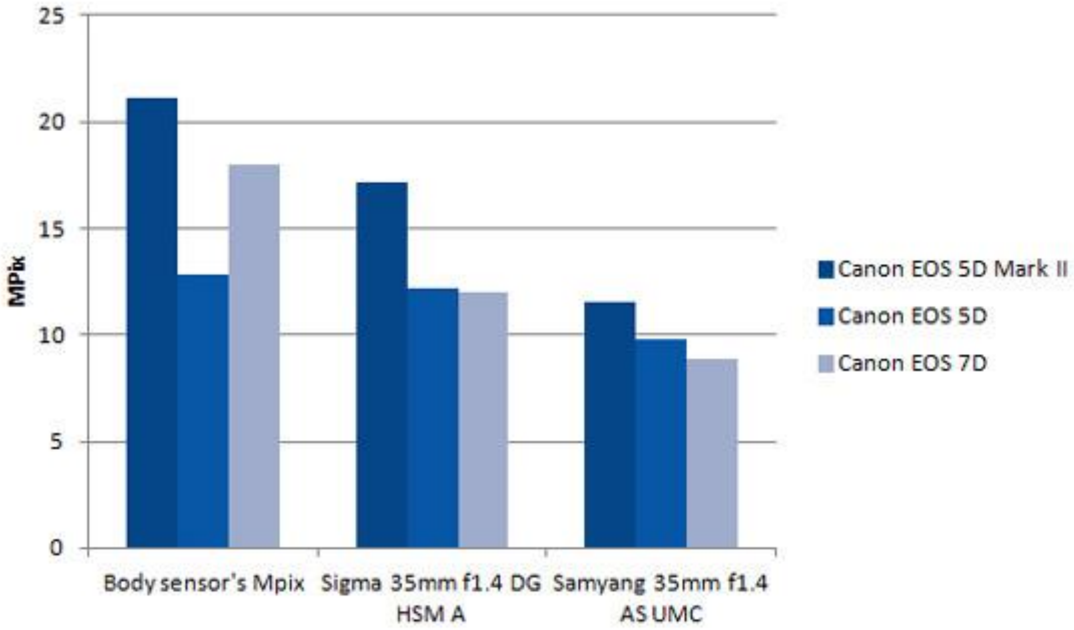
Comparison of perceived resolution between combinations of lenses and Canon EOS 5D mark II.

The example above is based on data from DxOMark's database of test reults for more than 2,500 camera and lens combinations. These tests reveal that roughly 45% of the resolution is lost due to lens or sensor defects.

A valuable tool for photographers looking for sharp images

Perceptual MPix quantifies the impact of lens sharpnes on camera resolution. This can be seen clearly when you look at the scores for two, superficially similar lenses when used on cameras with different resolution.

For example the Sigma 35mm f1.4 DG HSM A when mounted on a Canon EOS 5D Mark II scores 17.2 P-MPix, on the Canon EOS 5D it scores a near perfect 12. Samyang produce a lens with the same specification: the 35mm f1.4 AS UMC. It is around 30% cheaper so it is worth looking at. On the Canon EOS 5D it scores pretty well at just under 10 P-MPix a difference which many photographers would be prepared to live with. When you mount the Samyang lens on the newer Canon EOS 5D Mark II however, the score is 11.5 P-MPix, a loss of 45% of the camera's resolution. Effectively the results from the Samyang will be only marginally better from the Canon EOS 5D Mark II than from the Canon EOS 5D.
What this is actually showing is the inability of the cheaper lens to resolve detail well at the scale of the pixels in the 5D Mark II, while the Sigma lens seems to be limited only by the resolution of the sensor when used on the 5D and gives much more perceived detail when used with the 5D Mark II.
To further emphasize this, if you mount the Samyang 35mm lens on the Canon EOS 7D which is an APS-C camera and in which the pixels are about half the size of those in the older 5D, the P-MPix score drops to 8.9. This is less than half of the EOS 7D's actual sensor resolution, a camera with 50% more pixels but a Perceived MPix score lower than the 5D and that, using only the centre of the lens.



Comparison of perceived resolution between combinations of lenses and Canon EOS 5D mark II, 5D, and 7D bodies. The left bars show the Canon sensors' number of megapixels; the right bars show Perceptual MPix values.

Perceptual MPix can be particularly valuable for DxOMark users looking to purchase a new camera.
Looking at combinations of cameras and lenses rather than just the lens resolution makes it clear that there are times when there will not be a significant advantage in sourcing the finest lenses. The Sigma 35mm f1.4 DG HSM A is an excellent lens but used on the Canon EOS 5D performs only slightly better than the cheaper Samyang 35mm f1.4 AS UMC, but when the camera sensor no longer the limiting factor in the combination you see the quality benefit only with the better lens.
Perceptual MPix thus lets photographers take manufacturers' announcements about resolution with a pinch of salt, and answers an essential question when changing equipment: Is it better to buy a new camera or a new lens?

A great metric backed up by science and the industry

DxOMark's new Perceptual MPix measurements are based on acutance and human contrast sensitivity function (CSF) published in recently-released image quality standards from the International Standards Organization (ISO) and the International Imaging Industry Association (I3A). A member of the working groups involved in image quality, DxO Labs has been working diligently with giants in the digital imaging industry such as AMD, Nokia, Kodak, Nvidia, Fujifilm, HP, RIM, Intel, Microsoft, Google, and others. DxOMark has also relied on the very recent scientific research of CNES (the French space agency) with respect to the optimization of digital acquisition systems, notably those for satellite imagery.

What are the key lessons for the photographic community?

The Perceptual MPix measure confirms certain rules of thumb such as "a 12 MPix full-format camera is sharper than an 18 MPix APS," and can verify if the kits offered by manufacturers will properly support a hardware update, etc. Many exciting issues are now quantifiable, and DxOMark will soon offer detailed analyzes based on these scores.
Combined with DxOMark's long-standing position as the industry leader in image quality evaluation, this new *Perceptual MPix* measure with its single numeric score, its strong correlation with the human perception of image quality, and its usefulness for

easily comparing combinations of digital cameras and lenses, will give consumers, journalists, and experts in the field a better understanding of image quality, and more specifically, of lens and camera resolution.

DxOMark Lens scores

To rank and compare photographic equipment, DxOMark provides three types of image quality scores for lenses mounted on a camera: the DxOMark Score, five Metric Scores, and five Use Case Scores:

What does the DxOMark Score for lenses (with camera) show?

- DxOMark Score shows:
  - The amount of information captured by the lens for a given camera.
  - How well the lens and camera perform together.
- DxOMark Score does not show:
  - The intrinsic quality of the camera sensor.
  - The camera sensor's performance under high-light conditions.

Key points about DxOMark Score design:

The DxOMark Score reports on an average performance of lenses with camera for a defined use case.

- **The DxOMark Score corresponds to an average of the optimal** quantity of information that the camera can capture for each focal.The quantity of information is calculated for each focal length/aperture combination, and the highest values for each focal are weighted to compute the DxOMark Score.
- **DxOMark Score is based on low-light conditions** (150 lux and 1/60s exposure time). We chose these conditions because we believe low-light performance is very important in photography today, and because photographers need to know how well lenses perform at their widest aperture. Lenses with a high f-number are usually more expensive, so photographers want to know if the performance is worth the expense. The score does not account for depth of field, and only considers performance at best focus.
- **DxOMark Score is a linear scale** related to the largest print size that provides excellent quality. Doubling the size of the print requires doubling the DxOMark Score. A difference in scores of less than 10% can be considered irrelevant.
- **DxOMark Score is an open scale**, limited by the lens and camera resolution, and by sensor noise. As we can expect these to improve, the maximum DxOMark Score is bound to increase.

Lens metric score definitions

Sharpness

The DxOMark resolution score shows sharpness performance of a lens-camera combination averaged over its entire focal length and aperture ranges.

The resolution score is computed as follows:

For each focal length and each f-number, we first compute sharpness and then weight it throughout the field, tolerating less sharpness in the corners than in the center. This gives one number for each focal and aperture combination.

Then, for each focal length, we select the maximal value of sharpness over the range of available apertures. We average this value over the whole range of focal length to obtain the DxOMark resolution score that we report (in P-MPix).

Note that for a wide-range zoom, there are huge differences between the resolutions for different focal lengths.

Sharpness is expressed in PMpix and is typically between 50% and 100% of the sensor pixel count, Differences below 1 P-MPix are usually not noticeable.

Best resolutions are usually attained for fixed focal lenses and moderate apertures (depending on the lens, between f/2.8 and f/8).

DxOMark Sensor scores

To help photographers rank and compare photographic equipment, DxOMark provides four scores showing camera sensor image quality performance:

- Sensor Overall Score, showing the performance for a general-purpose use case, and computed from the following three use case scores:
- Portrait Score, based on optimum Color Depth.
- Landscape Score, based on maximum Dynamic Range.
- Sports Score, based on Low-Light ISO.

Key points about DxOMark Sensor Scores:

- **All sensor scores reflect only the RAW sensor performance of a camera body.** All measurements are performed on the RAW image file BEFORE demosaicing or other processing prior to final image delivery. DxOMark does not address such other important criteria as image signal processing, mechanical robustness, ease of use, flexibility, optics quality, value for money, etc. While RAW sensor performance is critically important, it is not the only factor that should be taken into consideration when choosing a digital camera.

Sensor Overall Score

- **Sensor Overall Score AND resolution are two independent metrics of sensor performance**. This means that just because camera A has more pixels than camera B (and thus sees more details) does not mean that camera A's Sensor Overall Score will be better. Rather, Sensor Overall Score measures the quality of the captured signal, either at a pixel level or at the full sensor level. So before comparing cameras with Sensor Overall Score, it is important to first determine the resolution you are looking for (which largely depends on the size of the screen or the print you intend to use or produce). Once you choose an appropriate resolution, the Sensor Overall Score becomes a fair and powerful tool with which to make comparisons.
  In a camera, resolution is dependent on both sensor and lens performances. So to compare and rank digital cameras while taking resolution into account, you should look at the DxOMark Score for lenses (with camera), which weighs a number of image quality parameters, including resolution.
- **Sensor Overall Score is logarithmic.** A 5-point difference on the scale corresponds to a gain or loss of sensitivity of 1/3 of a stop.
- **Sensor Overall Score is normalized for a defined printing scenario**—8Mpix printed on 8"x12" (20cmx30cm) at 300dpi resolution. Any other normalization, even at a higher resolution, would lead to the same ranking, given that any camera that could not deliver the chosen resolution would be eliminated from the comparison.
- **Sensor Overall Score is open and it is not a percentage**. This score has been computed so that the current set of cameras, from low-end DSCs up to professional DSLRs and medium-format cameras, show results within a range from 0 to 100. However, new technologies may well lead to higher performance models.

Sensor Use Case Scores

- **Each sensor use case score is defined by a specific image quality metric**. Therefore the reported value for each score is expressed with the unit of the corresponding metric, as follows:
- **Portrait Score is defined as the color depth performance** and its unit is a number of bits;
- **Landscape Score is defined as the maximum dynamic range performance** and its unit is an exposure value (EV);
- **Sports Score is defined as the low-light sensitivity performance** and its unit is an ISO sensitivity value.

To better use Sensor Scores:

1. Identify your preferred use case: General purpose, Portrait, Landscape, and/or Sports.
2. Choose the resolution that you need for the kind of photography you do.
3. If you shoot in RAW, Sensor Scores will help you rank the best cameras according to the resolution and use case(s) that you have chosen.

What does Sensor Overall Score show?

- Sensor Overall Score shows a camera's:
  - Sensor quality in terms of noise.
  - Ability to render high contrast.
  - Formation of colored noise.
  - Ability to shoot in low light.
- Sensor Overall Score does not show a camera's:
  - Resolution, i.e., its ability to render fine details.

- Lens quality.
- Optical aberrations.

How is Sensor Overall Score measured?

The Sensor Overall Score is an average of the Portrait Score based on color depth, the Landscape Score based on dynamic range, and the Sports Score based on low-light ISO.

Three use cases (with one score for each) — Portrait, Landscape, and Sports — report on different aspects of sensor performance. Each use case score is associated with one defined image quality metric as defined below:

Portrait photography: Color Depth

Flash studio photography involves a controlled and usually maximal amount of light. Even when shooting with hand-held cameras, studio photographers rarely move from the lowest ISO setting. What matters most when shooting products or portraits is to aim for the richest color rendition.
The best image quality metric that correlates with color depth is color sensitivity. Color sensitivity indicates to what degree of subtlety color nuances can be distinguished from one another, often meaning a hit or a miss on a pantone palette. Maximum color sensitivity reports, in bits, the number of colors that the sensor is able to distinguish.
The higher the color sensitivity, the more color nuances that can be distinguished. As with dynamic range, color sensitivity is greatest when ISO speed is minimal, and falls rapidly with rising ISO settings. DxO Labs has focused on measuring only maximum color sensitivity.
A color sensitivity of 22bits is excellent, and differences below 1 bit are barely noticeable.

Landscape photography: maximum Dynamic Range

Landscape photographers often carefully compose their images and choose the optimal time to shoot. This type of photography commonly involves mounting the camera on a tripod and using the lowest possible ISO setting to minimize noise, thus maximizing image quality.
Unless there is motion, relatively long shutter speeds are not an issue with a tripod. What is paramount is dynamic range, especially because photographers will often aim for detail in high-contrast settings, juxtaposing bright sky with shadowy foliage, mountains, etc. Ideally, the dynamic range of the camera should be greater than the dynamic range of the scene, otherwise details in shadows are lost or highlights are burned.
Dynamic range falls rapidly with higher ISO settings, as any analog or digital amplification performed will increase the noise in the darker areas, making it harder to distinguish between fine levels of contrast.
Maximum dynamic range is the greatest possible amplitude between light and dark details a given sensor can record, and is expressed in EVs (exposure values) or f-stops, with each increase of 1 EV (or one stop) corresponding to twice the amount of light.
Dynamic range corresponds to the ratio between the highest brightness a camera can capture (saturation) and the lowest brightness it can capture (typically when noise becomes more important than the signal, i.e., a signal-to-noise ratio below 0 dB).
A value of 12 EV is excellent, with differences below 0.5 EV usually not noticeable.
This scale is open, as incoming light is not a bounded quantity.

Sports & action photography: Low-Light ISO

Unlike the two previous scenarios in which light is either generous (studio) or stability is assured (landscape), photojournalists and action photographers often struggle with low available light and high motion. Achieving usable image quality is often difficult when pushing ISO.
When shooting a moving scene such as a sports event, action photographers' primary objective is to freeze the motion, giving priority to short exposure time. To compensate for the lack of exposure, they have to increase the ISO setting, which means the SNR will decrease. How far can they go while keeping decent quality? Our low-light ISO metric will tell them.
The SNR indicates how much noise is present in an image compared to the actual information (signal). The higher the SNR value, the better the image looks, because details aren't drowned by noise. SNR strength is given in dB, which is a logarithmic scale: an increase of 6 dB corresponds to doubling the SNR, which equates to half the noise for the same signal.
An SNR value of 30dB means excellent image quality. Thus low-light ISO is the highest ISO setting for a camera that allows it to achieve an SNR of 30dB while keeping a good dynamic range of 9 EVs and a color depth of 18bits.
A difference in low-light ISO of 25% represents 1/3 EV and is only slightly noticeable.
As cameras improve, low-light ISO will continuously increase, making this scale open.

Defining viewing conditions for normalizing measurements and scores:

Different DSLRs offer resolutions ranging from about 6 up to 24Mpix (with higher resolutions to come). Higher-resolution sensors offer more detail, but their smaller pixel size often leads to higher noise levels, and consequently to lower dynamic range, tonal

range, and color sensitivity. When printing under identical conditions, however, the performance differences can be either mitigated or accentuated by the choice of print size.
When one compares an 8Mpix image with a 32Mpix image printed on identical 20x30cm paper at 300dpi, the measurements for the original image do not give a good indication of the final result. The 8Mpix image will require no interpolation (2300 pixels for 20cm, or roughly 8 inches), while the 32MPix image will have to be reduced significantly, with 4 original pixels averaged into a single pixel. This averaging operation will significantly reduce the noise in the 32Mpix, and accordingly improves the measurements provided for the original resolution.
Original measurements can help gauge image quality when viewed at 100%, but to better predict how prints will compare, we provide a normalized (and thus more reliable) version based on 8Mpix.
See "Detailed computation of DxOMark Sensor normalization" for more information.