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Digital cameras and their impact on camera phone design

In last month's Hot Topic, we studied the hardware and software design requirements for a typical camera phone.

This month, we look at how camera (rather than camera phone) performance expectations are changing and how this impacts camera phone hardware, camera phone software and camera phone network hardware and software design.

35 mm cameras as a quality and functional performance reference

As users, most of us, consciously or sub consciously use 35 mm film cameras as a quality and functional performance reference.

The Leica A, the first commercially successful 35mm camera, was introduced in 1925. It was small, light weight, had a high top speed for fast action shots (1 500th of a second), a 50mm standard focal length lens, a focusing lever and infinity lock, a 50mm viewfinder and built in frame counter. It could take 36 pictures without reloading. 57000 units were built between 1925 and 1936 - a mass-market product by the standards of the day. Most camera phones today would struggle to match the image quality and functionality provided by this device.

The (80 year old) Leica A Compact 35mm camera

With thanks to Cameraquest
http://www.cameraquest.com/leicaa.htm

Digital cameras as a quality and functional performance reference

It is only relatively recently (within the last three years) that the image quality achievable even from high-end digital cameras has matched that achievable from traditional film based cameras. This is a function of the performance available from the sensor array and the image correction and image processing algorithms used.

Digital cameras have replaced film on the basis that they are more convenient. They offer some savings on film cost and the preview facilities mean we can throw away all those vastly embarrassing pictures we took on holiday **before** they get developed.

We have choice today of low cost entry level fixed focus digital cameras, mid tier compact or digital SLR cameras and high-end digital SLR cameras.

The table below compares a cross section of cameras in terms of cost, functionality and quality using resolution, zoom capability and ISO sensitivity as the chosen points of reference.

Note that resolution is stated in effective pixels. This is the total number of pixels **excluding** the pixels used for colour balancing and the pixels outside the range of the lens.

Zoom capability is simply a function of the lens design (optical zoom) or the resolution available (digital zoom depends on reasonably high resolution so that you can throw most of the picture away and still have acceptable quality).

ISO sensitivity is the sensitivity available from the sensor array and is equivalent to the sensitivity rating for 35mm film.

	Entry level		Mid tier		High End	
Retail price	£100	£200	£300	£400	£600	£6000
Resolution	2.1 Mpixels	3.24 Mpixels	4.0 Mpixels	7.0 Mpixels	8.0 Mpixels	16 Mpixels
Digital zoom	3X	3.4X	3.6X	6X	10X	>10X
Optical zoom	None	3.6X	10X	10X	10X	>10X
ISO rating	200	400	400	400	800	1250

Opinions might differ as to what constitutes a high-end camera so this has been widely defined above as anything that costs between £600 and £6000! .

High-end cameras tend to be **S**ingle **L**ens **R**eflex. Mid tier cameras can either be compact or SLR. Entry level are compact with limited optical capabilities.

There are a number of advantages to using an SLR camera. Firstly, what you see is what you get (a hinged mirror behind the lens reflects the image up into the viewfinder), secondly the user can choose from a vast range of standard and specialist lenses.

The disadvantage (for a digital SLR) is that the mirror only swings out of the way when the shutter is pressed which means that the image does not reach the sensor until the moment of exposure. Only then does the camera have a chance to do auto correction on the image.

Compact cameras, also sometimes described as lens shutter cameras, don't offer the optical choice or quality of an SLR camera but the fact that the sensor array itself is looking at the image before the shutter is depressed helps to improve the metering process. In other words, the image that comes out of a compact camera can actually look better than the image coming out of a digital SLR. The digital SLR demands more knowledge and skill from the user and may require more post editing to get the required colour and light balance effects.

In addition to the cost of the optics, a high-end SLR or compact digital camera also requires a substantial amount of storage bandwidth. To preserve image quality, images are either saved as raw data or as a TIFF (tagged image file format). A TIFF file uses lossless compression. The original image can be recreated after compression without losing any of the original source information. Even a TIFF of an 8 Megapixel image still produces a 20-Mb file. This takes 30 seconds to save on to a compact flash card. High-end cameras get round this problem by having buffer memory- typically enough to support ten or twelve seconds of 'fast shooting' at say 2 frames per second.

Mid tier compact cameras still have good quality optics - not perhaps as good as a high end SLR but still good enough for most print applications, at least up to A4 size.

If pictures are just being taken to put on the web, then a GIF image (Graphic Interchange Format) is used. Mid tier and (most) entry level digital cameras are therefore more than adequate for 'display on line' applications.

The effect on camera phone user expectations

The rapid increase in digital camera quality over the past two to three years and the rapid decrease in price has however had an effect on what users expect in terms of the quality available from a digital camera phone hardware platform.

For reasons of cost, size and weight, the lenses used in camera phones are of relatively poor quality. The use of a CMOS sensor (for cost and power reasons) instead of the CCD sensor used in most digital cameras also tends to result in higher image noise and lower sensitivity.

Most users of course just expect their camera phones to be just as good as an equivalently priced digital camera in terms of optical quality. While this is possible, it does imply additional cost and complexity and the only way in which a digital camera phone can be as good as an equivalently priced digital camera is either by subsidising the product, or to make the product in much higher volume.

Digital camera software

Users also expect their camera phones to be just as good as an equivalently priced digital camera in terms of **functionality.**

All digital cameras and camera phones use digital processing to improve or rebalance the captured image. High-end cameras however do the job better and faster than low-end cameras and a lot better and faster than most camera phones.

Digital camera manufacturers set out to differentiate their camera products on the basis of what might be described as **'algorithmic value'**. One example is the time it takes a camera to auto focus, and the accuracy of the auto focus. To be achieved accurately, **auto focusing** depends on multi pattern metering and averaging of the edge characteristics of the image. To be achieved quickly (within a few hundreds, or preferably a few tens of milliseconds), auto focusing depends on highly optimised and highly parallel processing algorithms. The same principle applies to almost all other functions including **auto exposure** (metering and averaging the luminance characteristics of the image) and **colour balancing** (metering and averaging the chrominance characteristics of the image. Today, mid-tier digital cameras can handle capture speeds of at least two frames per second with absolutely no compromise in image capture quality.

If camera phones aspire to replace digital cameras, or at least aspire to replace low end or mid tier digital cameras, then they must provide equivalent functional performance.

Digital Compact and digital SLR cameras as a quality and functional performance reference

What does this mean in practice? Let's consider two digital cameras, one a digital compact, one a digital SLR, both are from the same manufacturer, both are priced at about £700.

Specification	Digital Compact	Digital SLR
Resolution (Mpixels)	8	6.3
Sensor size (mm)	9x6	23.7x15.6
ISO range	50 - 400	200 -1600
Lens (35mm equiv)	35 - 350mm	27 -105mm
Aperture range	F2.8 - 5.2	F3.5 - 4.5
Shutter speeds	8 - 1/3000sec	30 - 1/8000sec
Metering	Multi segment (256), centre weighted, spot	3D colour matrix, centre weighted, spot (AF point)
EV compensation	+/-2EV in 0.3EV steps	+/-5 EV in .3 or .5EV steps
Viewfinder	.44 inch tft, 235,000 pixels	Optical fixed pentaprism
Continuous shooting speed	1.2 fps/2.3fps (display off)	3fps
Continuous shooting capacity	5 shots	4 shots (RAW), 9 shots JPEG fine
RAW file processing time	10 seconds	O seconds (up to 5 shots)
Start up time	3 seconds	0 seconds
AF speed	600 milliseconds	300 milliseconds

Battery life	240 shots	400 shots
Dimensions	116X85X121mm	140X111x78mm
Weight	600g	595g

Superficially, the compact camera seems to offer better performance given that it has a better resolution. However it has a smaller sensor which means the pixels are smaller which means they collect less photons which means they are less sensitive and have a lower signal to noise ratio. Note the maximum sensitivity of the Compact is ISO 400 whereas the digital SLR has an ISO of 1600.

The smaller the sensor, the more magnification needed to produce a same size print. For example, to produce an A4 size print, the compact will need a 12X magnification; the digital SLR would need a 1.2X magnification.

Smaller sensors also will tend to exhibit more severe chromatic aberration and sensor blooming (where a charge leaks from an overloaded pixel to its neighbours).

The lens on the compact gives a longer focal length than the standard lens of the SLR though the motor driver is quite slow.

Both cameras have a wide aperture range. A wider aperture will deliver more photons to the sensor array but will reduce the depth of field (the range over which different parts of the captured image remain in focus).

Other differences include the max shutter speed (1/8000 sec for the digital SLR versus 1/3000 for the compact), and the metering patterns, probably the one area (apart from size) that the compact has an advantage.

The time available to the compact for metering (given that the sensor array is looking at the image before it is captured) mean that the pictures coming out of the compact will probably look better than the pictures coming out of the digital SLR.

The digital SLR has a wider dynamic range for EV compensation. EV (the exposure value) is the amount of shutter speed or aperture adjustment needed to double or halve the amount of light entering the camera. Generally the digital SLR has an exposure system which will tend to preserve more highlight detail than the compact. Thus, although the image coming out of the SLR might look darker and muddier, the images will have a higher useable dynamic range and will respond better to photo editing.

The viewfinder in the SLR gives a true representation of the image (you are looking through the lens). The compact relies on a miniature LCD which by default is only giving you it's own version of the image.

The viewfinder and the LCD on the back of the compact camera both absorb power and processor clock cycles. The shows up both in terms of battery life (numbers of shots per recharge cycle) and when trying to shoot at more than 2 frames per second (only possible when the display is turned off).

RAW file processing time is a function of the embedded memory included in the devices (more in the digital SLR).

Start up time for the digital SLR is immediate, the compact takes 3 seconds. Auto focus(AF speed) with the compact is 600 milliseconds, the SLR does it in 300 milliseconds. (This makes a remarkable difference in terms of how responsive the camera feels to the user).

Although the compact is dimensionally smaller this actually makes it harder to hold steadily (to avoid camera shake). It also weighs the same as the digital SLR.

So although compacts generally have better resolution, image stabilisers and longer range zooms, they do not have the speed, viewing systems or ultimate image quality of their digital SLR equivalents.

The above examples are presently at the low end of what we have termed the 'high tier' digital camera market but we know for sure that the performance metrics and functionality very quickly trickle down to lower priced products.

Self evidently, it is not practical to replicate the optical quality and functionality packaged in a 600 gm digital camera in a 100gm cellular phone. However, users of digital cameras don't necessarily understand this and we cannot expect consumers to be particularly sympathetic to the cost and size and power budget constraints implicit in cellular phone design. All they will say is…. this phone doesn't take good pictures

Camera Phone Network Hardware

So perhaps it is wise to concentrate on some of the other user benefits that come from packaging phones with cameras.

Optical quality and functionality are not just a function of the digital camera or camera phone but a composite of the components used to store, process and handle images once they leave the users device.

Image stores, image servers and the way in which imaging storage is realised in hardware are all part of the 'quality and value' process.

For imaging, the amount of storage needed is partly driven by how often users take pictures but also by the imaging bandwidth. Given that high end cameras are now capable of capturing 16 Megapixel images, it seems churlish not to provide an equivalent increase in storage capability. Imaging bandwidth directly determines the amount of storage needed. Note we cannot automatically expect users to downgrade a RAW or TIFF image to a JPEG just for our convenience. What's the point of having a decent camera capability if you the throw 90% of the image in the bin.

Other metrics include the time it takes to upload and download images and the stability of the storage medium (non volatility over time and temperature) which brings us to:

Camera Phone Network Software

Image data such as the date and time a picture was taken and the exposure used can be stored in an EXIF (Exchangeable Image Format File). Devices that have GPS can add location information to the file, which can be stored either in a camera's memory card or sent with the image to be stored remotely.

Camera phone network software addresses three requirements - image editing, image cataloguing and image management.

These functions can to an extent be performed in the camera phone or digital camera but with either type of device, the expectation has to be that the images will at some stage be stored somewhere else.

A user can do image editing on a PC using PhotoShop or Paint Shop Pro - this is not software that you would want to load on to a portable device. These programmes typically take up at least 200 MB of RAM and 500 MB of hard disk space.

A cataloguing software programme (Photo Shop Album or Paint Shop Photo Album for example) will take up a similar amount of memory and you will also need to add some image management software. Microsoft Photo Premium sets up a browser so you can search images by date, keyword, folder or size but it takes another 300 MB of hard disk space.

Some (possibly most) of this browser functionality can of course be packaged in the user's device. Browser pre-sets are very useful for directing users in the 'right' direction (The Vodafone Live 'walled garden' business model). Companies like Opera www.opera.com are also active in developing similar added value embedded browser capabilities.

An alternative is to use an on line photo album like Kodak Ofoto www.ofoto.com or Snapfish www.snapfish.com . Ofoto limit you to 700 JPEG's of any size in an album but you can have as many albums as you like. Snapfish provide unlimited (JPEG or zip file) storage space. Both are free.

These on line albums provide some fairly simple image editing capabilities such as cropping, and red eye removal. Snapfish also provide some auto correction including auto contrast.

Both also provide view/ review and share facilities.

Companies such as Scalado www.scalado.com, YoSpace www.yospace.com, OurPictures, www.ourpictures.com, Arcsoft, www.arcsoft.com, Shutterfly www.shutterfly.com (together with Panasonic) and DXO www.dxo.com provide similar capabilities though optimised for camera phone applications supported via cellular network operators and integrated with existing MMS server topologies.

Just as camera phones have to at least aspire to have equivalent functionality to digital cameras, so these network-operator-specific service offerings have to be at least as good as existing and competitive on line services.

This is a challenge particularly when competitive on line services are free.

Summary

User expectations of camera phone image quality and functionality are increasingly dictated by the performance now available from entry level and mid tier digital cameras.

Optical quality is a function of lens quality, sensor quality and the effectiveness of the algorithms used to correct for optical and processing impairments.

Functionality includes capabilities such as auto focusing and auto exposure. The accuracy and speed with which these functions are performed provide differentiation between low end and high end products.

Camera phones have at least to aspire to providing quality and functionality that is equivalent to similarly priced digital camera products. This can only be achieved through subsidy or by producing products in much higher volumes. There are also fundamental form factor and power budget issues to address.

The user experience is also determined by how images are stored and managed in the network, and whether the quality of the original image is preserved.

In terms of image editing, cataloguing and management functionality, user expectations are increasingly dictated by the capabilities of third party on line service providers such as Ofoto and Snapfish who have no prior affiliation either to the cellular radio industry or to the traditional service provider community.

Image quality, functionality and interoperability (the absolute requirement to be able to interchange images between devices between networks) are obvious prerequisites for MMS based image capture and image sharing platforms.

This is both a challenge and opportunity but implies an increasing need to integrate camera phone design policy with network design and specification, particularly the sizing and specification of image storage bandwidth and performance metrics.

Engineers with knowledge of digital camera design have to understand the practical cost and form factor constraints of cellular phone design. Cellular phone designers have to appreciate the optical and functional performance expectations implied by present and future digital camera products.

Network hardware and software engineers have to understand that image bandwidth and image quality expectations will determine access network, transport network and storage network performance requirements.

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