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Author: Ando.Meritee
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TVL - The True Measurement of Video Quality

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Introduction

Not long ago VGA and D1 resolution IP cameras were common in the video surveillance market. At that time everybody knew how to evaluate video quality of the camera. With the appearance of 1-Megapixel and 1.3-Megapixel cameras it was still quite easy to compare products with each other. However, now multi Megapixel cameras are being introduced to the market – 2 MP, 3MP, 4MP, 5MP, 10MP, etc. Everybody is confused – how to compare these products with each other? Does a 10-Megapixel camera provide better video quality and more details compared to 4-Megapixel camera? Not necessarily! **The higher number of pixels does not guarantee more details or better video quality!**

Look at the example below. Two images with different resolution are provided.

Resolution: 250x130

Resolution: 375x195

With simple visual observation you can tell that the image quality of the left image is much better than the right one. The details are very clear on the left but quite blurry on the right. Yet in both cases the lens was adjusted to the best possible focus.

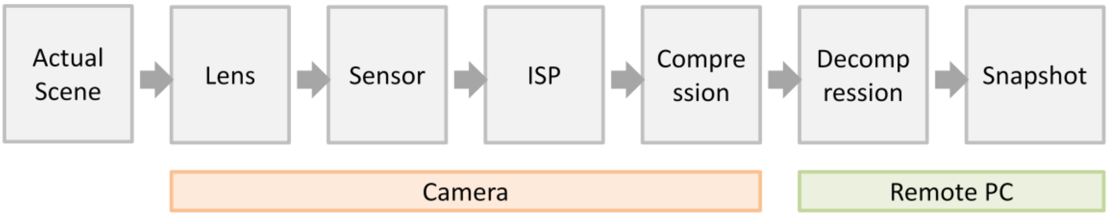
If your camera produces images with high pixel count but low clarity like the image to the right, you not only miss all the needed details, but also waste your bandwidth and storage space with needlessly large number of pixels.

The following chapters explain the factors affecting real video quality. We will also discuss how to test the cameras and decide which ones provide the best video quality.

The Factors Influencing Video Quality

Video quality can be evaluated with snapshots from the video stream. The process of turning the incoming light into an image is rather complex and includes many stages. Each stage affects overall video quality in important but different ways. Improving just the image sensor resolution in the chain of video processing gives little real improvement if the other parts in the chain are not improved – on the contrary, the final outcome might even get worse. The result would be something like you saw on the right image in the previous chapter.

Factors that influence video quality include **lens**, **image sensor**, **image signal processor** (with all the enhancement support like auto exposure, auto white balance, auto focus, WDR, DNR, Sharpening, etc) and **compression**.

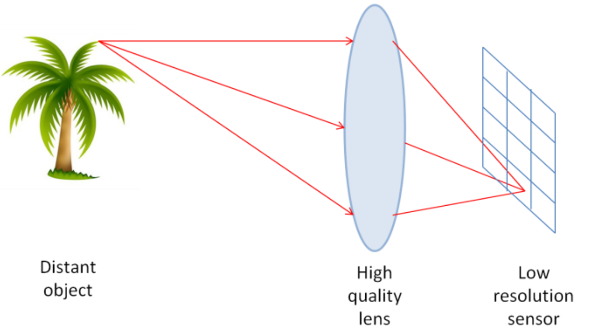


Each factor is explained separately below.

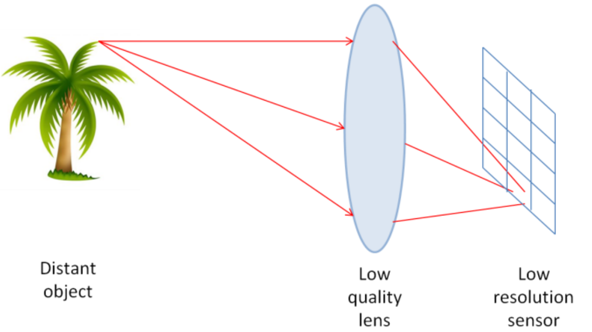
Lens

You may have noticed there are “megapixel” lenses available in the market. What does it mean? Each lens has its **optical resolution** –the accuracy of the lens design to be able to deliver each of the light rays to the right destination spot on the sensor board.

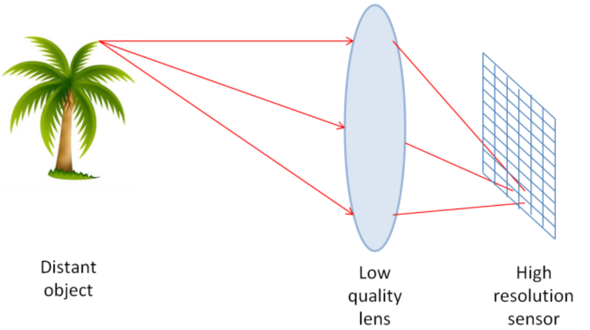
Look at the image – let’s say there is a tree in the view of the camera. Now let’s see how one point of that tree is delivered to sensor board through the lens. All the light rays coming from the same source point should end up falling onto the same pixel on the sensor board. In case of a high quality lens, the lens is so precise that all light rays indeed hit exactly the same spot within one pixel of the low resolution sensor. The image will be clear and there will be no noise or blur. (**PASS**)



What if we use a low quality lens instead? Although the light rays do not hit exactly the same spot any more, they are still within same pixel of a low resolution sensor and the overall result is the same as above. (**PASS**)

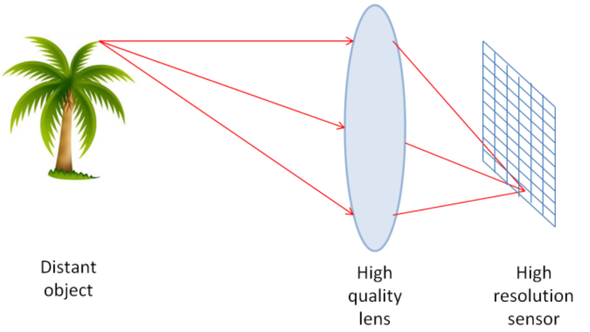


While you were using low resolution sensor the quality of the lens did not matter much as the pixel size is fairly large. However, when you use a high resolution sensor together with a poor lens, the light rays from same spot of the scene end up in different pixels where they pollute the energy level of each pixel, resulting in strange noise and blurred image. (**FAIL**)



Many multi megapixel camera manufacturers today are matching high resolution sensors with low quality lens not designed for such sensors.

The proper way to use the high resolution sensor is to use high quality lens in front of it. (**PASS**) The lens manufacturers introduce their lens quality by defining the maximum sensor resolution they can support (e.g. 3-Megapixel lens).



Below is the summary of relationships between lens and sensor.

	Low resolution sensor	High resolution sensor
Low quality lens	**Pass**	**Fail**
High quality lens	**Pass**	**Pass**

You may also notice that the manufactures of blurry image cameras do not admit that they are using 1-Megapixel lens in front of 5-Megapixel image sensor.

Image Sensor

With the lack of innovation and inability to provide video quality driven end-to-end video processing solutions, most manufacturers today are simply replacing their existing camera designs with higher resolution image sensors. The resolution standard of the IP surveillance will slowly shift from 1 Megapixel to 2 Megapixel (1080p) by 2011. The resolutions above 2 Megapixel are very vulnerable – a smallest weakness in lens, ISP or compression side would severely damage the video quality.

It is important to realize that the bigger the sensor resolution, the smaller the physical dimension of each pixel on the sensor board. After all, the total physical size of the sensor does not change much. Therefore less light photons enter each pixel which makes every single pixel even more vulnerable to inaccurate optical bending by lens.

To overcome this problem, some manufacturers (including ACTi) have started to use BSI (Backside Illumination) technology that would utilize the full size of each pixel as the light capturing area by moving the transistors behind the sensor. This results with much more accurate energy value of each pixel.

Image Signal Processor

Assuming that the camera uses a great lens and a high megapixel sensor, the next critical step in the production of high quality image would be the Image Signal Processor (ISP). The ISP of the camera is the **“brain”** – the duty of which is to produce best possible image regardless of the lighting conditions.

That “brain” can control several tools that have an impact on video quality – iris size of the auto-iris lens, shutter speed, gain control, white balance, auto-focus (if available), day and night mode, sharpness, digital noise reduction, wide dynamic range and much more. Although some of these items may be built as independent components, a highly integrated ISP can dynamically control all them and even customize their working sequence according to scenario.

While it is quite easy to process low resolution images, **it takes a lot more computing power and very complex formulas to properly apply image enhancements on high resolution images, especially under different lighting conditions.**

Most of the ISPs designed for 1-Megapixel cameras are not suitable for high Megapixel cameras. Using 3-Megapixel or higher resolution sensors would require a totally different approach in ISP technology. The camera manufacturers who are still using the old ISP in their new high megapixel cameras are likely suffering from the inability to release the ISP to the market that could make remarkable improvement in video quality.

One simple example would illustrate the limitation of old ISPs:
The higher the sensor resolution, the more difficult it is to adjust lens focus. Even if we use an appropriately high quality lens, the pixels on high megapixel sensors are so small that with the smallest focus ring rotation we create a big shift in focus. While it takes just 5-10 seconds to get a perfect focus in 1.3-Megapixel cameras, it may take 5 minutes of painful adjustment to get the focus right on a high megapixel camera.

The solution is to use auto-focus lenses with extremely intelligent ISP that can calculate and adjust the focus position with maximum possible accuracy. Many existing ISPs in the market are not able to deliver such level of accuracy and they need to be re-designed.

ACTi's newly designed ISP can control the KCM-series zoom cameras with high focus precision even in low light conditions, which has been an unsolvable obstacle for other camera manufacturers.

Another example would be the flexible use of image enhancement functions depending on the lighting conditions. Depending on the time of the day, the optimal solution might be to apply digital noise reduction before sharpening and vice versa, resulting in the clearest possible image with least amount of noise. In case of old ISPs, the flow of such image enhancement functions has a fixed sequence and cannot be changed, despite the lighting conditions.

Compression

Last but not the least – the compression is also extremely important in the flow of video production. Multi Megapixel cameras produce large amounts of data. It is a challenging task for a compression chip of the camera to reduce the data size as much as possible without significant losses in video quality. While 2-6 Mbps is still an acceptable compression level, likely nobody would accept 10 Mbps or higher video feeds considering the bandwidth limitations and storage space costs. Many compression chips are restricted to MJPEG for high megapixel images due to lack of processing speed. This means that precisely when one needs the best compression, the chip cannot handle the full video load and is barely able to keep up with MJPEG images that take up huge storage spaces. Should the image be compressed any more in this older codec, the image quality may suffer.

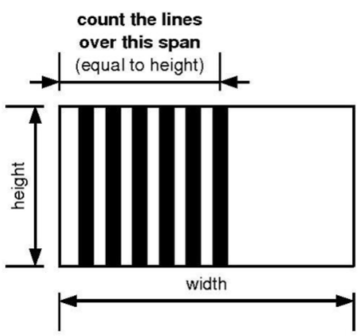
The growth of sensor resolutions also puts higher demands on compression technology. Today many camera manufacturers are trying their best to improve the compression technology in order to deliver the promised video quality within acceptable bitrate.

How to Measure the Video Quality

Now that you know that high resolution does not necessarily guarantee high quality and clear details, you might want to know how to evaluate the final output from different Multi-Megapixel cameras and compare them to each other.

Let's look at the flow again:

There exists a method that can give you a **simple and clear single numeric value that represents the accumulated effort of lens, sensor, ISP and compression**! It is called "**Television Lines"** or simply TVL, measured from the final output (snapshot). It is a classic quality measurement in analog CCTV and can be used in IP surveillance as well.



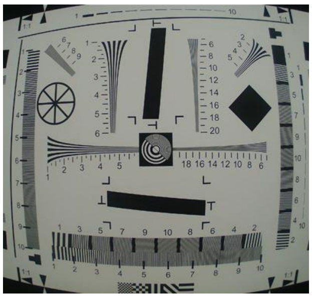
TVL is defined as the maximum number of alternating light and dark lines that can be resolved. A resolution of 400 TVL means that 200 distinct dark lines and 200 distinct white lines can be counted over a horizontal span **equal to the height of the picture!**

In other words TVL shows the true **horizontal resolution** of an image – the higher TVL, the more detailed the image is.

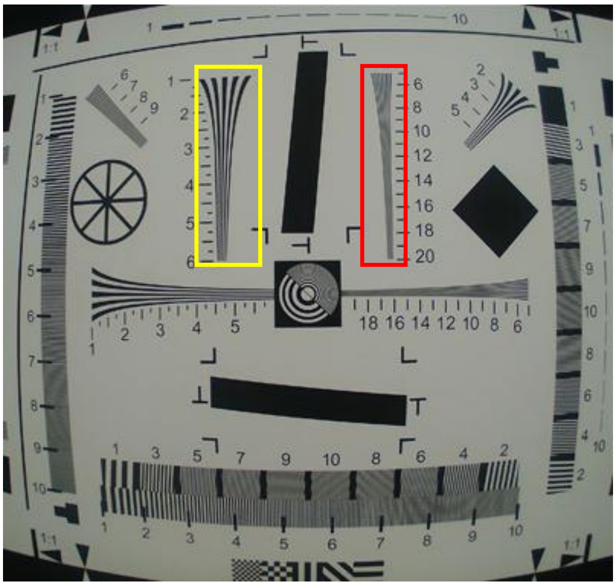
Coming back to those images that you saw in the beginning of this article – although the left one has a smaller number of pixels, its TVL value is much higher. The simple conclusion is – **regardless of the number of pixels, the image with highest TVL value has the best image quality**!

Camera Comparison Using TVL

To check the TVL of different IP cameras you need to prepare 2 things – the **actual printed TVL resolution chart** and the **TVL checker software** for reading the TVL value.

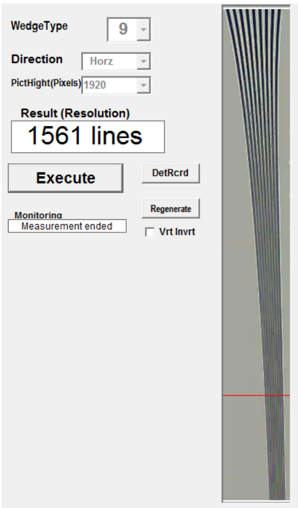


Once you have obtained the printed TVL resolution chart (ISO 12233), point the camera that you are testing at the chart so that the camera view covers it from the top to bottom. Remember to fine tune the focus ring of the lens to get the clearest possible image. Use the camera to capture a snapshot (bmp file) of the view and export the image to the PC.



Now you need TVL checker software to analyze the image and generate the TVL value. You may use free software from Olympus, named **Olympus Hyres 3.1**. Once you have installed the software, load the image into it.

Our goal is to measure the Horizontal Resolution of the image. There are two sections (5 lines and 9 lines) in TVL Chart that are used for measuring horizontal resolution, marked with yellow and red squares. If you are testing megapixel cameras then you would need to use the red one because it has sufficient density of lines to detect the quality limitation of the megapixel camera. Use the Trim function to crop the needed red area for measuring, and use wedge type 9 (the group of 9 vertical lines).

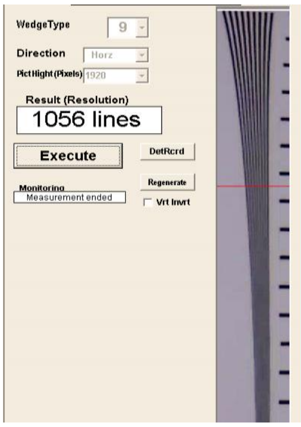


After that the software will analyze those 9 lines of the cropped area and produce the TVL value – it is read from the point where those 9 lines get so close to each other so that it is impossible to separate dark and light lines any more.

The TVL testing of KCM-5111 gave an excellent result – **1561 TVL**. This is by far the best performance in surveillance market.

For comparison, most Multi-Megapixel cameras on the market get **only 800-1200 TVL** in video quality tests.

Example: The **5MP camera** from a well known IP camera manufacturer produces only **1056 TVL**. This is a typical example of force-fitting high resolution image sensor to a low resolution lens, with no special effort to improve the ISP and compression.



Are you ready to try it out on your own?

You may download Olympus Hyres 3.1 from here:

http://www.acti.com/download_file/KnowledgeBase_UploadFile/HYRes3_1_by_Hideaki_Yoshida_Olympus_Corporation_20101026_001.zip

And below is the link to the captured bmp snapshot from KCM-5111 (using its bundled lens) for testing:

http://www.acti.com/download_file/KnowledgeBase_UploadFile/KCM-5111_Resolution_eve_4M_1000LuxD65_20101026_001.bmp

If you are not quite sure how to use that software then take a look at this YouTube video clip:

http://www.youtube.com/user/ActiProducts?feature=mhum#p/c/9639435AF592696F/15/pHfrJLHCqcg

If everything goes well, you will see the result of 1561 TVL with your own test.

Conclusion

Here are the most important facts about video quality:

- TVL is the only true measurement of video quality regardless of the numbers of pixels on sensor board
- TVL provides fair and accurate comparison of all surveillance cameras
- TVL testing is a simple and affordable validation method for every System Integrator
- To improve TVL value, all the factors of video processing should be improved – lens, sensor, ISP and compression
- Most of the high megapixel cameras in the market today provide only moderate quality image (800-1200 TVL), which is about the same as 1 megapixel cameras.
- ACTi has achieved a remarkable video quality with 1561 TVL thanks to the high quality lens, multi megapixel sensor, newly designed ISP and a powerful compression chip.