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## **Designing an IP Camera Project:**

Is pixels per square foot an important measurement?

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**H**ow can you effectively determine how much resolution is needed. In this white paper you will learn about the real specification you should focus on when designing an IP camera solution and how camera resolution and the lens field of view impact the final results.

Historically with an Analog camera system, detail and resolution was determined by the TVL or television lines. This measurement determined the horizontal lines of resolution by resolving alternating white and black lines which represented how much detail the camera could reproduce. So a camera that had 380 lines of resolution could not reproduce as detailed a picture as a 540 line camera. In the IP camera world, the most important factor for determining detail is Pixels per Foot.

### RESOLUTION

Before we talk about Pixels per Foot, let's discuss resolution. Resolution has many definitions and no one definition is correct for all situations.

As I mentioned, resolution can be expressed as the number of TV lines or pixels of the image sensor that are used to record an image. In order to record greater detail or a larger field of view, you will need a higher TVL count. For analog cameras, TVL is the usual definition. The number of TV lines in the image can be 320, 480, 570, etc.

Resolution can also be expressed as the total number of pixels. With megapixel cameras, the resolution is generally the total number of pixels, divided by 1,000,000, and rounded off. Table 1 shows examples of typical megapixel camera resolutions.

**Table 1**

Megapixels	Total Number Of Pixels	Vertical Pixels	Horizontal Pixels
HD* 720	921,600	720	1280
1.3 MP	1,310,720	1024	1280
HD* 1080	2,073,600	1080	1920
2 MP	1,920,000	1200	1600
3 MP	3,145,728	1536	2048
5 MP	4,915,200	1920	2560

Resolution can be specified in pixels per foot at the object. This mapping of the image sensor dimensions onto the object is most intuitive for calculating what level of detail can be seen in the image. Fundamentally it is the horizontal field of view (HFOV) of the camera divided by the horizontal number of pixels. This gives the pixel per foot measurement that can be related to image quality.

### What does Pixels per foot measure?

As you might expect, the greater the number of pixels in the camera sensor, the finer the detail will be present in the picture. That is why more and more integrators and camera manufacturers are turning to megapixel cameras. Pixels per Foot represent the amount of detail or resolution you will see in a specific area of the image. The greater the number of pixels per foot the more detail you will see in the image.

### How many pixels per foot are necessary?

Best practices in the industry have determined that a minimum of 40 pixels per foot is necessary for facial or license plate recognition. Less than 40 pixels per foot is good for overall surveillance and greater than 40 is necessary for forensic work like cash counting, currency evaluation or casino chip recognition.

### What factors impact the Pixel per foot measurement?

The horizontal resolution of the camera and the field of view are the factors that impact the pixel per foot measurement. For example, to maintain a minimum of 40 pixels per foot specification using a 640x480 IP camera with a 3.0mm lens, the horizontal field of view would be 34 feet wide at a distance of 25 feet from the camera. To maintain facial recognition, the subject would be at 7 feet or less from the camera and at 25 feet there are only 17 pixels per foot, not enough for facial or license plate recognition.

Changing to a 4.7mm lens would effectively double the distance from the camera to the 40 pixel per foot measurement at about 14 feet but the field of view would narrow to about 24 feet and at about 25 feet from the camera you would only see about 25 pixels per foot.

If you change to a higher resolution 2MP camera that same 4.7mm lens at a distance of 25 feet from the camera will give you 62 pixels per foot more than enough for facial or license plate recognition. And if you need the wider field of view of the 3mm lens of say 35 feet, at a distance of 25 feet from the camera you still have 40 pixels per foot.

The take away here is if you know the horizontal resolution or pixel count of the camera and the horizontal field of view which is determined by the distance from the camera and the focal length of the lens, then divide the horizontal field of view into the camera horizontal resolution and that will give you the pixel per foot calculation at that point.

### Image Detail

The more pixels, the higher the resolution and the easier it is to recognize faces and license plates. The downside is that higher resolution requires more bandwidth and storage space. So determining how much detail is required using the pixel per foot measurement is most important when weighing detail vs. budget for bandwidth and storage.

### Field of view



With megapixel cameras and higher resolution comes the ability to cover a greater field of view as compared to an analog camera. Wide angle lenses can be used because the total available pixels spread across the field of view is greater therefore the field of view can be increased without decreasing image resolution.

**Table 2**

Camera Resolution	Focal Length	HFOV	Pixel Per Foot	Subject To Camera Feet
640x480 Analog	4.8	14	40	14
1.3MP	4.8	33	40	35
2MP	4.8	40	40	42

Figure 1 is shown at different pixel per foot measurements. Each image has the same number of pixels but as the field of view increases, the pixels per foot in the image decreases. Because there are no more pixels in one image compared to another, there is no effect on the amount of data transferred over the network and no degradation of network performance by going to either higher image resolution or greater field of view.

**Figure 1**

Resolution level	Pix/f t	Pix/ m	Resolution level	Pix/f t	Pix/ m
Identification (high detail)	60	200	Detection (general security)	20	70
					
Resolution level	Pix/f t	Pix/ m	Resolution level	Pix/f t	Pix/ m
Recognition (forensic detail)	40	130	Overview (motion, tracking)	10	30
					

*As field of view increases the pixels per foot decreases so that each picture has the same number of pixels and thus causes the same amount of network loading. (Courtesy of TheiaTechnologies)*

Table 2 compares the field of view of different cameras at a constant of 40 pixels per foot and a constant focal length of 4.8mm. The variation of field of view and the distance from the camera available to maintain 40 pixels per foot show the advantage of using megapixel cameras. As the camera resolution (total number of pixels) increases, so does the field of view at constant image resolution (pixels per foot). The conclusion is that as the number of pixels increases in the camera, the wider the field of view becomes with a constant image resolution or PPF.

### How much resolution do you need?

Do you want to make out the shapes of leaves on a tree or the activity of a crowd of people? Or do you need to pick out a face in the crowd? The more detail needed then the greater the resolution needed which is determined by the number of pixels in the camera. As mentioned earlier, the minimum number of pixels required for facial or license plate recognition is 40 pixels per foot, an industry standard.

< *Than 40 pixels per foot used to view general security and crowd activity*

> *Than 40 pixels used for facial recognition, license plate recognition or currency recognition.*

A simple formula can be used to determine how much horizontal resolution is needed based on the 40 pixel standard. HP is the number of Horizontal Pixels and WD is the width of the field of view

$$HP = 40 \times WD$$

As an example let's say the maximum width in the field of view is 40ft. So if you multiply the 40 PPF times the 40ft width you come up with 1600 pixels as your horizontal resolution. And conversely, if you know the HP of the camera you are using or plan to use, then divide that figure by 40 PPF and you will come up with the maximum horizontal field of view for that camera.

### Lens Selection

So how do you select the proper lens for a camera? Keep in mind the closer the subject is to the camera, the wider the angle needs to be or a smaller millimeter lens. The farther away the subject is the more narrow the angle is or a higher millimeter lens is needed. The formula is as follows:

$$D = fl \times W / CCDw$$

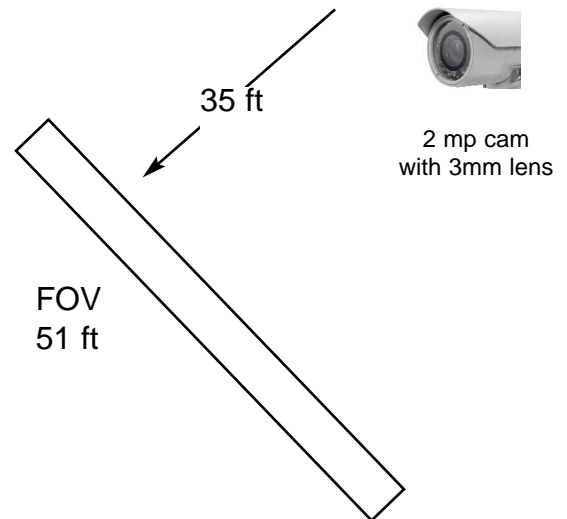
D = distance from the camera to the FFV

fl = lens focal length in mm

W = width of the FFV

CCDw = the width of the CMOS or CCD sensor

There are numerous lens calculators available on the web that are easy to use and will give you viable results. The example here shows a 2mp camera a w/3mm lens at a distance of 35ft. There are 40 PPF and a 51ft horizontal field of view.



One other consideration when choosing a lens for your camera is that if you are using a megapixel camera, you must use a megapixel lens. Because megapixel cameras have smaller pixel sizes in general, you must use a lens that can resolve down to the smaller pixel size. In general, lens manufacturers are manufacturing "megapixel" lenses but not all megapixel lenses are the same. For the general discussion of this whitepaper, just know that you should use a megapixel lens with a megapixel camera if you want to take advantage of the full resolution capabilities of the camera.

In conclusion, the resolution of the camera and the lens determine the field of view and what the camera will see. A higher resolution camera is capable of greater detail at a wider field of view but the trade off is higher bandwidth and storage usage. Both the camera and the lens work together to provide the view needed for the application. Know the amount of detail needed, the position of the camera and measure the field of view then use these factors to determine the lens and the camera resolution so you neither over engineer or under estimate your customers needs. ■