Areascan Cameras: How to Choose Between Global and Rolling Shutter

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Do you think shutter is a brand new question which appeared with digital photography? Well… just consider this old well-known picture made with a roller-blind shutter by Jacques Henry Lartigue (a French photographer in the early twentieth century).

What happened? The camera was moving horizontally during the image “grab” to follow the car. Due to the irregular camera movement, the static subjects seem to lean over while the wheel in motion still reflects a geometric distortion (the camera should have been moving slower). Comparatively drivers are well grabbed with no distortion at all.

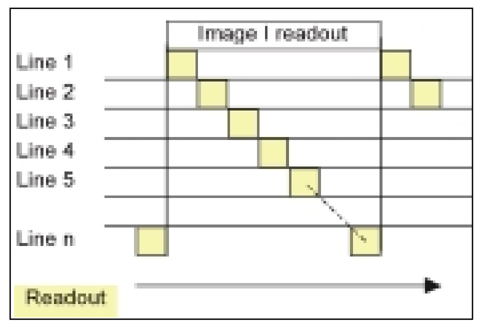
When grabbing images a shutter is required in particular with objects in the scene moving too fast compared to the integration time. The effect of the blur obtained is well known when the speed is too slow during the shooting of pictures with moving objects.

The camera speed or, for industrial camera users, the integration time must be chosen so that the image of the object may not move more than one pixel (for example) during the exposure time.

The blur is easy to explain, but what about distortion effect? This article describes the advantages and drawbacks of two existing solutions in the progressing scan sensor area: the rolling shutter and the global shutter.

Image Readout

In progressive sensor areas, each line is read one after the other.



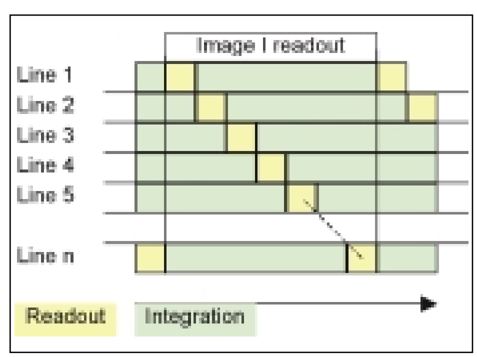
Rolling Shutter Description

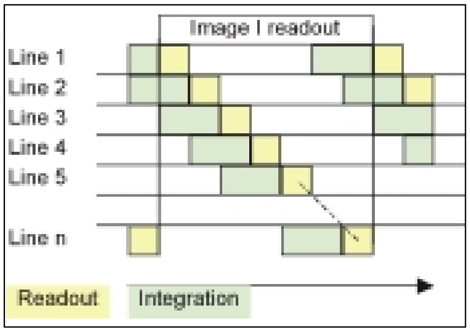
With a rolling shutter sensor:

- Integration time occurs just before the readout of each line
- The readout resets the pixel content

Therefore the integration time for each line is not done at the same time.

Depending on the required speed, the chosen integration time might be longer or shorter than the frame readout time.

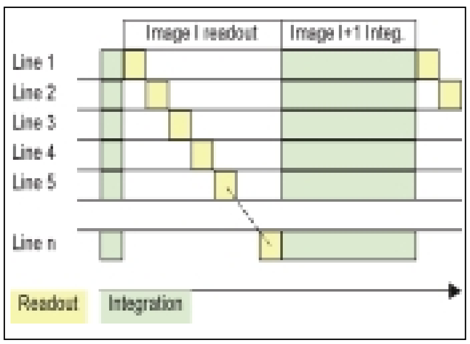


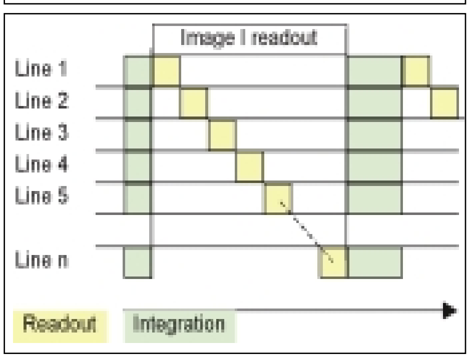


Global Shutter Description

With a global shutter, all lines have their integration time simultaneously.

- A global reset is done just before starting the readout
- At the end of integration the pixel content is stored in memory
- Then the readout may start





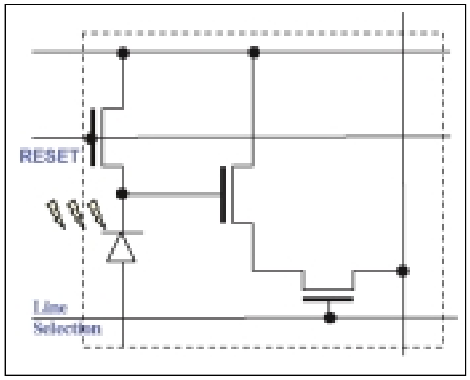
Characteristics of Each Solution

Rolling Shutter Characteristics

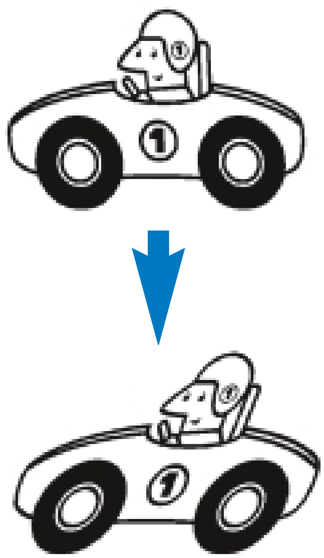
The rolling shutter pixel structure is the easiest solution to implement. Only three transistors are needed at pixel level. This allows a good signal-to-noise ratio. Micro lenses used to optimize the fill factor (% of the pixel array sensitive to light) are much easier and more tolerant when using wide aperture lens.

The main drawback of the rolling shutter is the image distortion when an image of a moving object is grabbed and if the integration time is too short in comparison with the readout time.

Next an example of image distortion of a moving object analyzed with a rolling shutter fixed camera.



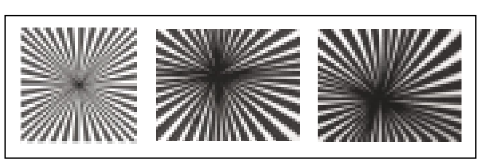
As shown below, the helmet at the above part of the image will be integrated first and then the bottom part at the last time. Therefore between these two exposure times the object has moved.



This will cause a distortion on the grabbed image.

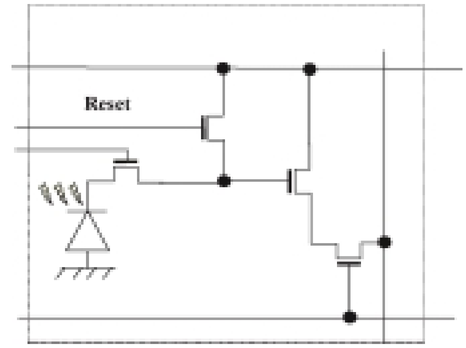
We can notice that in order to reach this distortion this picture is shot at full field with a square sensor. The speed of this object is approximately 1 m in 20 ms (resulting from a maximum frame rate of 50 image per second), or 180 km/h /112 miles/h.

An other example on a "sun" pattern grabbed with the Atmos camera with a speed rotation of 85T/mn and 1ms integration time/20ms readout time:
After the pattern drawing on the left, the first image with no rolling shutter effect shows that the lines are straight. On the second image, with the rolling shutter effect and the same integration time we can notice that the lines are bent.



Global Shutter Characteristics

To perform the global shutter function, a memory "area" must be used beside each pixel. Here below an example with an additional single transistor.

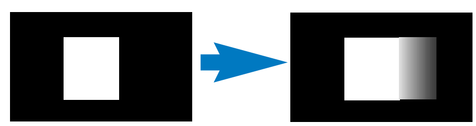


This memory zone must be non-sensitive, which means there is no light leak.

In fact, on the available components nowadays, this memory zone is always sensitive to light and sometime "very" sensitive. We may find global shutter with the worst ratio of 1/15, while standard ratio ranks from 1/200 to1/500 and last best ratio announced today is 1/5000.

For "family pictures" this may be acceptable. However this is not sufficient in most high demanding industrial applications. Therefore an electrical shutter seems to be a very good solution. In the case of a global shutter the user does not have to take care of light conditions

The effect of a bad shutter efficiency level is shown in the following pictures. A bright white point is moving from left to right during readout. On the right of the white point an ghost image may be visible. Contrast and size of the ghost image will depend of the speed and of the shutter efficiency itself.



When working with a 12-bit resolution, the global shutter at a ratio better than 1/4000 is necessary as to avoid any wrong information that might be generated. During the image readout the light of path continues to move illuminating the memory zone of the sensor thus creating a brighter light intensity.

This ratio should be divided as follows:

- By the over-saturation factor you may have on the image (x 100 even x 1000) when metallic reflections occur
- And also by the ratio between the integration time to the longest memory time as an example with a 10 ratio

Meaning a $1/(4\ 10^6)$ ratio, which is not feasible today.

The memory zone is built using room at pixel level (by adding one to three transistors) which results in decreasing the pixel aperture ratio and therefore requiring micro lenses of higher efficiency. This often means that micro lenses are less tolerant to telecentricity errors of the image side of lens. These additional transistors may also induce noise. In fact it is a compromise between shutter efficiency (increase of number of transistors) and pixel aperture (decrease of the number of transistors)

A Solution?

The unique solution is to pulse the light. But if there is a need for pulsing the light why not choosing the rolling shutter with its better signal-to-noise ratio and its better pixel aperture without micro lenses?

Conclusion

There are already many applications where a type of rolling shutter is used. Often this parameter is not taking into consideration by end users:

Example 1:

Roller blind cameras (24 x 36 film camera, for example) are still used without any complaint from users.

Example 2:

All the old vacuum tube cameras were using a readout that reset the pixel.

Example 3:

All line scan cameras are also using different integration times for each line. To prevent any distortion in this case, the object speed to the camera speed should be adjusted.

Before buying or building a vision system the image quality required must be defined. If no ghost image and no distortion is allowed the light will have to be pulsed.

Therefore the shutter type is not a key feature. The user needs to be able to synchronize the light pulse. Therefore the camera must offer either a light output signal or an input trigger.

Atmel cameras provide these two possibilities. Both the Atmos 1M30/1M60 and Atmos 2M30/2M60 offer high resolution, high speed with a Camera Link® interface able to work at 8-10 or 12-bit.

Based on a rolling shutter sensor these cameras allow excellent dynamic range. The Atmos 2.5M can capture 48 fps at full resolution, 60 fps at 2M, and 160 fps in VGA format for the 2M60 thanks to the region of interest function. With a 44 mm square section design, plus a C-mount adapter, Atmos cameras are among the smallest in the market.

The Atmos cameras features are particularly suited for typical machine vision tasks: Inspection (glass, Flat Panel Display, PCB) robot-guidance, metrology, as well as various applications such as microscopy or surveillance.