

Live Stacking using a Mallicam Skyraider video camera : a vocabulary

The concept of capturing and stacking astronomy images "on-the-fly" in order to increase the signal to noise ratio by progressively cancelling random noise during an observing / imaging session is well established. A number of software packages offer this ability. However, most are exclusively concerned with the stacking of frames by *within* the computer *after* the camera has downloaded the frames that will comprise the Stack. This is because these software packages are designed to work with all types of digital imaging cameras.

However, Mallincam Skyraider cameras are *video cameras* and the Live Stacking process between the photons entering the camera's sensor and arriving at the computer screen is quite different from that of imaging cameras, in terms of both technique and quality of the resulting image. It is essential to understand this difference if we are to be able to fully utilise the abilities of Mallincam Skyraider cameras and the MallincamSky software that we use to control them. To understand this we need to be able to communicate, and to communicate we need an unequivocal vocabulary. This brief text will offer an overview of the Live Stacking process in Mallincam Skyraider cameras in terms that are as accessible as possible to the average reader. A more technical perspective is beyond the purview of this contribution.

First we need to understand the difference between frames and fields. A *frame* is an assembly of data that can be represented directly as an image or picture. In astronomical terms, you could simplistically represent a frame as stars and a uniform background sky. Identifying the presence of stars is generally enough to identify the image : you don't need to analyse the uniform background itself. You can think of this as a short-cut approach. A *field* is something quite different : it is an assembly of data. In essence it is a 2D (x,y) field of values that can be visualised as tables, or as a set of algorithms. You can write out the algorithms, or you can look up data in tables, but you cannot represent the field as a "picture". To analyse a field, one has to examine every value at every location (x,y) in the field : there are no simple short cuts. A field is therefore less "tangible" than a frame, and its analysis takes a lot more work..

Dedicated imaging cameras work with frames. Hence, for example, one speaks of *Dark Frame Subtraction* when processing images (frames) to increase the signal to noise ratio. However, in the video world, we work with fields. For example, we speak of *Dark Field Correction* (see my detailed explanation in your camera manual) when processing to achieve a similar effect (think also Flat Field Correction). In addition, frame rate plays a critical role in video astronomy (see below).

In the Live Stacking module window of the MallincamSky software there are three numbers : *Input* and *Output* numbers associated with a *Status indicator* at the bottom of the module window, and a user controlled *Number box* (located to the right of the Align Frames check box).

What do these numbers represent, and what do they do ? To answer this question we must first understand what happens to photons when they are captured by the camera. First the camera takes a user-determined exposure and downloads the noisy result to the computer where it shows up as an frame / image on the computer screen. At this point the user can adjust various parameters (*gain, exposure, gamma, contrast, histogram etc*) to obtain a more satisfactory initial image.

Now, when Live Stacking is enabled, by checking the Enable box, the circuitry within the video camera begins the Live Stacking process by generating and compiling a number of fields on-board. The number of fields to be compiled is user-determined by setting the value in the *Number box*. Let's

say we set the Number box to 5 : the camera circuitry will compile 5 fields to form a "master" field, commonly referred to as group.

So, let's be clear : the digit in the Number box is the number of fields that then constitute a "master" field or group, compiled within the camera before being downloaded to the computer.

What are these fields ? Here's a very approximate analogy (*don't take it literally !*). If you are old enough to remember early TV sets with cathode ray tubes (CRT), you know that the on-screen image had a slight flicker. The CRT rapidly drew a series of horizontal lines (~400 or so) on the screen and did so several times to generate fields that our brains interpreted ("compiled") as images (frames). With enough frames coming at us quickly, our brains "saw" the impression of smooth motion. The flickering on screen reflects the fields before our brains compiled them into steady images. Now, how does this apply to MallinCam Skyraider cameras, MallinCam Sky software and your computer ?

What happens during compiling within the camera circuitry ?

Again, let's set the Number box to 5. First, the camera circuitry saves 5 fields to its internal memory. This occurs so quickly that the user doesn't see it happen (think of the CRT analogy) : *it is independent of the user-determined exposure time*. The camera circuitry then compiles the 5 fields to make a "master" field. What does this mean ? First, these fields are progressive scans, not interline scans, so they come "warts and all". In addition, as mentioned above, frame rate is an important consideration when the camera is generating and compiling fields because the rate can vary between consecutive fields (think of the CRT flicker analogy). Hence the need to compile more than one field to smooth out intrinsic variations in and between fields. Compilation involves either the addition or the averaging of the 5 fields, according to the mode selected by the user prior to enabling Live Stacking. Also, if the user has checked Align Frames, an alignment is performed on the 5 fields during the on-board compilation within the camera circuitry. Be aware that this alignment process is **NOT** an alignment of stars : the latter occur in frames or images. Here we are dealing with intangible fields wherein every pixel in every field must be evaluated : this requires a lot of processing work. In addition, if Dark Frame Correction and/or Flat Field Correction have been selected by the user, these corrections will be performed within the camera's circuitry. The result is the generation of the "master" field / group.

So, let's be clear : the compilation process within the camera, prior to downloading the result to the computer, involves the creation of a "master" field / group by the averaging or adding of the selected number of fields, plus the alignment of those fields and the performance of field corrections (*if selected*).

How does the user know this is happening ?

First, the user will notice a distinct delay after initially enabling Live Stacking, even after the camera has taken its user-determined exposure. *In part*, this delay reflects the fact that the camera circuitry is performing the compilation of the fields : 5 in our example. It must determine whether the data in the 5 fields is of sufficient quality for the compilation of the "master" field or group to be successful. Remember, to analyse a group of fields, the computer must evaluate the values at every location in every field in the group : it must even interrogate every dark pixel, even if the pixel doesn't say anything particularly interesting about that location in the field. This is why we want to keep the value in the Number box at a low value (e.g. 5) so as to minimize the amount of field processing required.

When the Input number is incremented from 0 to 1, it means that a "master" field, or group has been successfully compiled within the camera and downloaded to the computer. **This constitutes an Input**. Note that the Output number is still 0, and the Status indicator remains blank. Note that the "master"

field is also stored in the camera memory as a reference group for comparison with successive compiled groups of 5 fields during the ongoing Live Stacking run.

What happens in the computer ?

When the compilation process within the camera's circuitry is completed, the camera downloads the resulting group to the computer, and the computer's software will attempt to stack the group with the original noisy image that was visible on the computer's screen prior to enabling Live Stacking.

Stacking here means averaging (or adding) and maybe aligning the group with the original noisy image. Note, this involves processing frames or images : i.e. the alignment process does use stars, which is quite different from the processing of fields in the camera (*see above*). This initial computer-based processing accounts for the other part of the initial delay perceived by the user at the beginning of Live Stacking (*see above*).

If the computer software determines that alignment and averaging was successful, it will now place the result in the Stack. **This constitutes an Output** : the Output number is incremented from 0 to 1, and the Status indicator is set to OK. Sometimes the computer will reject the attempted first Output (*maybe not enough good stars for an alignment*) and will wait for the camera to download a fresh group, hopefully with better quality data. In this case, the Input number will continue to increment until the computer software accepts the first Output and sets the Output number to 1. A new image that represents the processed Stack is then sent to the computer screen where the user will note a significant decrease in the random noise.

The camera now takes another exposure, captures, compiles and processes a new group of 5 fields in its internal circuitry, then downloads the resulting group to the computer where it will be treated as a frame and processed (averaged or added, and maybe aligned) as part of the growing Stack. The cycle repeats and the Stack continues to grow (see Output number) until the user disables Live Stacking.

Within a given Live Stacking run, because the "master" field is already stored in the camera, the compilation process is significantly faster than during the generation of the initial reference group. As the camera downloads successive groups to the computer, the computer's software will process and stack them, and increment the Output number without perceptible delay after each new exposure.

So, let's be clear on our vocabulary :

- the digit in the Number box is the number of fields that constitute a group, compiled within the camera before being downloaded to the computer.
- the Input number is the number of groups that the camera has downloaded to the computer for evaluation. Some of these groups are not acceptable to the computer, and that is reflected in ongoing incrementing of the Input number with no corresponding change in the Output number.
- the Output number is the number of groups that have been accepted by the computer, converted to frames, aligned and averaged or added in the Stack by the computer's software.
- the Stack will continue to grow until the user disables Live Stacking.

Post Script : *I have taken this overview of Skyraider Live Stacking about as far as my limited technical knowledge will allow. I know it's not "bedside reading", but I think it is necessary to establish a standard vocabulary so that we can all understand what the variables in the MallincamSky software refer to and how to better use them and our cameras.*

I thank Rock Mallin for his patience in explaining things to me, multiple times ! I hope I understood it all, at least in principle. Nonetheless, all errors or understanding remain mine ... and corrections are most welcome.

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