Image Tiling

Alastair Reed, Fred Cao, Larry Hsu, Daryl James, Kevin Macarthur, Wenny Macura, Derek Montgomery, John Nelson, Stephen Pavelick, Gary Pringle, Matt Rektor, Horst Schaaf. and Con Verburg*

Cymbolic Sciences Ltd. and *DMI

Richmond, British Columbia, Canada

Abstract

Output of images to photographic material within an internal drum machine, implies the maximum image size is limited by the dimensions of the internal drum architecture. To overcome this problem we have created a blend algorithm, that enables us to tile several images into 1 large mural of size limited only by the input roll of photographic material. Image tiling consists of the process of splitting a large image into 2 or more parts which are output in sections that correspond to the maximum imaging area or frame within the drum. The photographic material, which is on an input roll, is then advanced by a frame length and the next image section is output. To create a seamless joint between these sections of the image and reduce the need for accurate registration, an overlap region is created in which the left hand image is ramped off and the right hand image is ramped on. Software has been written to create and place these blended images.

1. Introduction

Tiling consists of the process of splitting a large image into 2 or more parts for output to a frame based continuous tone silver halide photographic material. To create a seamless join between these sections of the image and reduce the need for accurate registration, an overlap region is created in which the left hand frame is ramped off and the right hand frame is ramped on.

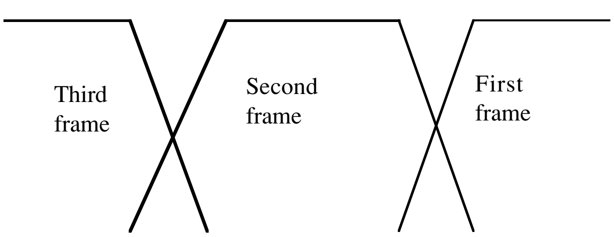

Figure 1: Image Blend Region

In the overlap region a double exposure is used versus single exposure in the remainder of the image area. Reciprocity failure and image latency in the photographic material, cause density differences in the overlap region resulting in objectionable image artifacts.

To produce a seamless tiled image, two corrections are required.
The first frame must be aligned to the nearest pixel, to the second frame using an overlap region to avoid the need for sub-pixel registration.
The reciprocity failure and image latency effects in the overlap region are measured and correction applied.

2. Image Alignment

For a frame based device the first frame must be aligned to the nearest pixel, to the second frame. This is accomplished using a positive feedback system where a hole is punched in the photographic material, and that hole is then detected after a frame has been moved. The second image is then shifted in x and y to align within 1 pixel to the first image.

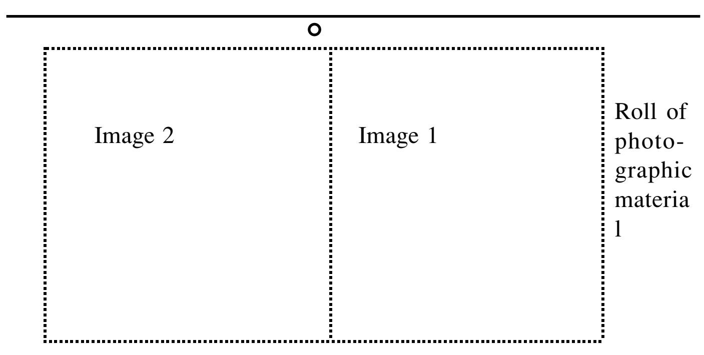

Figure 2: Image Alignment

In practice image 2 can have an angular displacement compared to image 1. To measure this an edge or hole is detected on the other side of the media (bold solid line below). The angular correction is applied by shifting image 2 by a corresponding angle in the opposite direction (light solid line below). Image 2 will then align as shown by the dotted line.

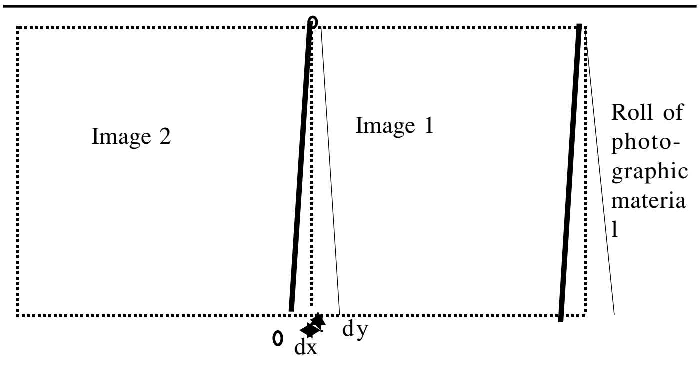

Figure 3: Image Alignment with Rotation

3. Blend Algorithm

In the overlap region a double exposure is used versus single exposure in the rest of the image area. This results in density differences primarily due to reciprocity failure and latency effects in the photographic material. For an exposure

$$E = I*t$$

where E is the total exposure on the photographic material
I is the peak light intensity
and t is the exposure time

The density produced on a photographic material for a given exposure E, is not independent of the exposure time t. This effect is known as reciprocity failure (see Ref. 1). There are two types of reciprocity failure - at a high light intensity known as High Intensity Reciprocity Failure (HIRF), and a low light intensity known as Low Intensity Reciprocity Failure *LIRF).

The latent image produced in a photographic material changes with elapsed time before it is processed (see Ref 2). The change in density due to latent image stability and reciprocity failure is measured and compensated for as described in Section 3.2 below.

Since the measured density correction varies with light level - a method of smoothly going from the LIRF to HIRF correction is used as follows:

$$CC = x*HIRF\_correction + (1-x)*LIRF\_correction$$

where,
CC is the combined correction
HIRF_correction is the High Intensity Reciprocity Failure correction
LIRF_correction is the Low Intensity Reciprocity Failure correction
x is the proportion of HIRF_correction.

Since the latent image on the photographic material decays with time before it is processed, the density correction required needs to be measured with the same time interval as used when imaging frame 1 and frame 2.

The calculation of the double exposure correction in the blend region, can be accomplished in 2 stages:
First order correction - so blend occurs in light exposure space since two light levels add approximately linearly on a photographic material.
Second order correction - to compensate for the measured density error after the first order correction has been applied. This density error is caused by reciprocity failure and latency effects in the photographic material.
Or,
Applying the second order correction directly to compensate for the measured density error, when ramping the input image data. This density error is caused by reciprocity failure and latency effects in the photographic material.

3.1 First Order Correction

To calculate the light intensity in the blend region, image data in the blend region is converted to light using the following method.

$$\boxed{I\ G\ E^{-1} * B(x)\ E\ G^{-1}}\ \boxed{G\ E^{-1}}$$

where,
I is the image data
G is the grey balance table in the LJ5000
E is the look-up table to obtain linear light ramp from LJ5000
B(x) is the blend shape as a function of position
E^{-1} is video DAC response of LJ5000
G^{-1} is the inverse of the grey balance table in the LJ5000

$\boxed{I\ G\ E^{-1} * B(x)\ E\ G^{-1}}$ happens within the host,

and the final $\boxed{G\ E^{-1}}$ occurs in the LJ5000.

The host processing, for first order correction, consists of the steps shown below in Figure 4:

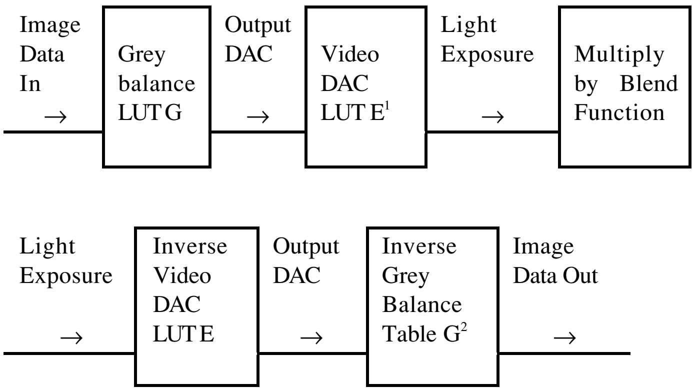

Figure 4: Image Data in Blend Region

A blend shape is used, such that the total exposure in the blend region is:

$$E_{total} = E_{left} + E_{right}$$

where,
E_{total} is total material exposure within the blend region
E_{left} is material exposure within the blend region due to left hand image

E_{right} is material exposure within the blend region due to right hand image

The exposure is split between the left hand and right hand images so that the total adds to the original image exposure value. Therefore, since to a first approximation light adds linearly on the photographic material, the required density will be achieved.

3.2 Second Order Correction

When the densities obtained across the blend are measured, instead of a perfectly uniform density the following results are seen, as shown in Figure 5.

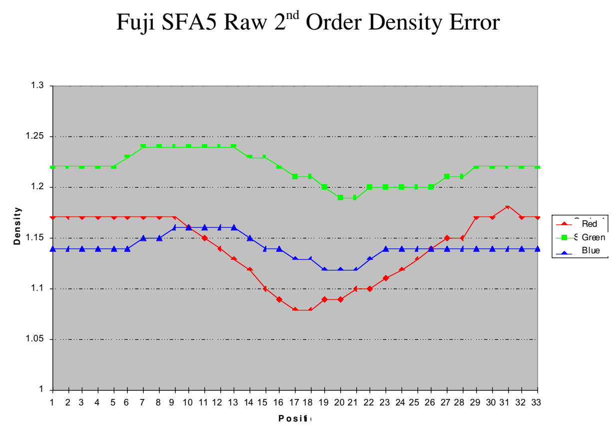

Figure 5: Measured Densities Across Grey Blend for Fuji

This density error, is caused by a combination of high intensity reciprocity failure (HIRF) and low intensity reciprocity failure (LIRF).

The density error shown in Figure 5 for Fuji SFA5 Type C, is of a low magnitude, and is typical for materials which have been designed for short exposure times. A similar error was also measured for Kodak PX 2976. A density error of this magnitude can be reduced to densitometer noise levels in 1-2 iterations by the method described below. More than 1 iteration is required due to dye cross-talk.

A second order density correction is applied iteratively as follows:

In general for iteration n:

$$Br0(x) + CBln{+}1(x) = Br0(x) + (Bl0(x) + Bln{+}1(x)) + CBln(x)$$

where,
$Bl_0(x)$ is the zero iteration left blend function
$Br_0(x)$ is the zero iteration right blend function
$CBl_{n+1}(x)$ is the (n+1)th iteration combined left hand blend correction to compensate for the measured density error after the nth iteration calculated as a percentage of light.
$Bl_{n+1}(x)$ is the (n+1)th iteration left hand blend correction to compensate for the measured density error after the nth iteration calculated as a percentage of light.
$CBl_n(x)$ is the nth iteration combined left hand blend correction to compensate for the measured density error after the (n-1)th iteration calculated as a percentage of light.

Conclusions

The feasibility of outputting mural size images using a plotter with internal drum architecture has been demonstrated. The blend algorithm, enables us to tile several images into 1 large mural of size limited only by the input roll of photographic material. Software has been written to create and place these blended images, and is being successfully used at about 150 customer sites.

References

1. W.F.Berg, ‘Exposure Theory and Practice’, Amphoto, New York, New York, 1971, p.190.
2. T.H.James, ‘The Theory of the Photographic Process’, Eastman Kodak Co, Rochester, New York, 1977, p.167.