Axis 206 Camera Green Lamp Imaging

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Introduction

The Axis 206 Network Camera can be used to image the green cold-cathode lamp used in the 2006 and 2007 FRC games, but the default camera settings do not work well for that application. To complicate matters, the camera interface does not provide a method to directly set the camera to work well with the FRC green lamp. This article explains why the default settings do not work well and how to indirectly change the settings for excellent green lamp imaging.

Two software tools were used in working with the Axis 206 camera. The camera's web server interface was used to change camera settings and to capture images. The National Instruments Vision Assistant was used to process the captured images.

Phil Malone (Mentor: Team 1629) has further developed the procedure by adapting the LabVIEW FRC "Locate Colored Object" example, and he describes his easy-to-use method in another Think Tank article.

Once the FRC green lamp has been turned on for a period of time, its light level and color properties stay relatively constant, even under differing lighting conditions. It is these constant properties of the green lamp – it's hue, saturation and luminance – that can be used in identifying and locating the lamp.

Introduction

By default, the Axis 206 exposure and white balance are set to automatically adjust to compensate for differing lighting conditions. Automatic adjustment may work well when capturing images of reflected light of variable level and color temperature. However, it is better to use fixed exposure level and white balance settings to capture an image of a light source whose brightness and color temperature remains relatively constant under variable lighting conditions.

If the camera is allowed to automatically vary exposure and white balance when imaging the green lamp under variable lighting conditions, the apparent properties of the lamp will vary from image to image as the camera auto-adjusts to the lighting conditions. In order to obtain consistent imaging of the lamp, the exposure and white balance settings can be fixed at the optimum "green-lamp" level. Achieving that optimum level is the trick.

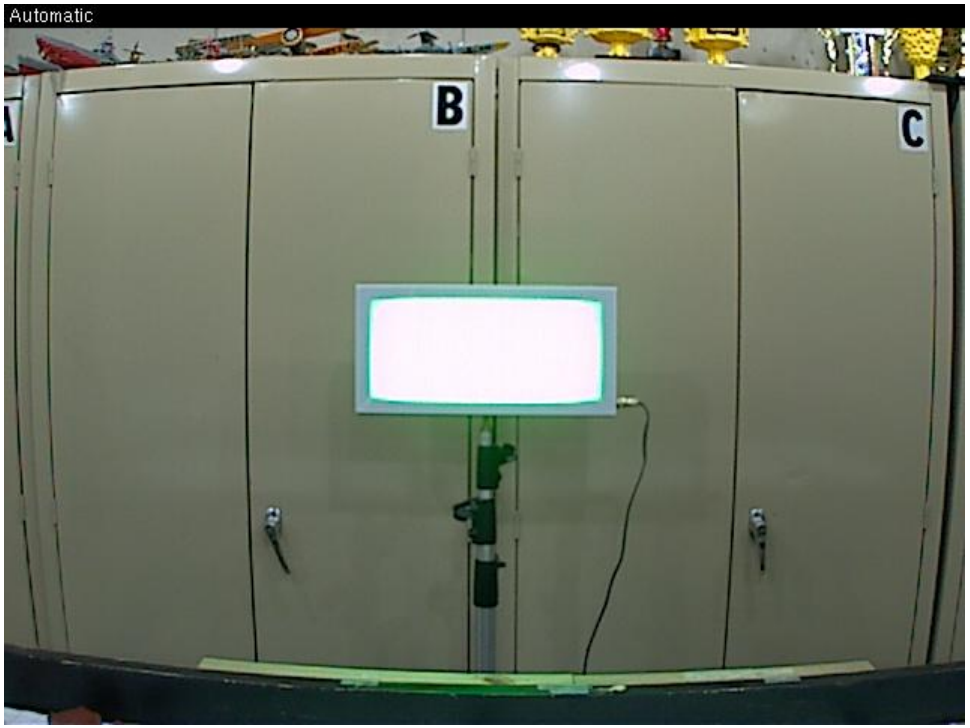
When auto-adjusting for exposure, the Axis camera seems to adjust for average brightness of the image. If the green lamp fills the entire image, auto-adjustment will achieve the correct exposure for the lamp. The camera exposure can then be held fixed. The camera will retain its settings even if powered off and then on again.

Contents

- Exposure Problem at Camera Default Setting
- Solving the Exposure Problem
- Accessing the Camera Web Server
- Adjusting Camera Settings
- Develop Image Processing
- Identifying the Green Lamp

Over-Exposure

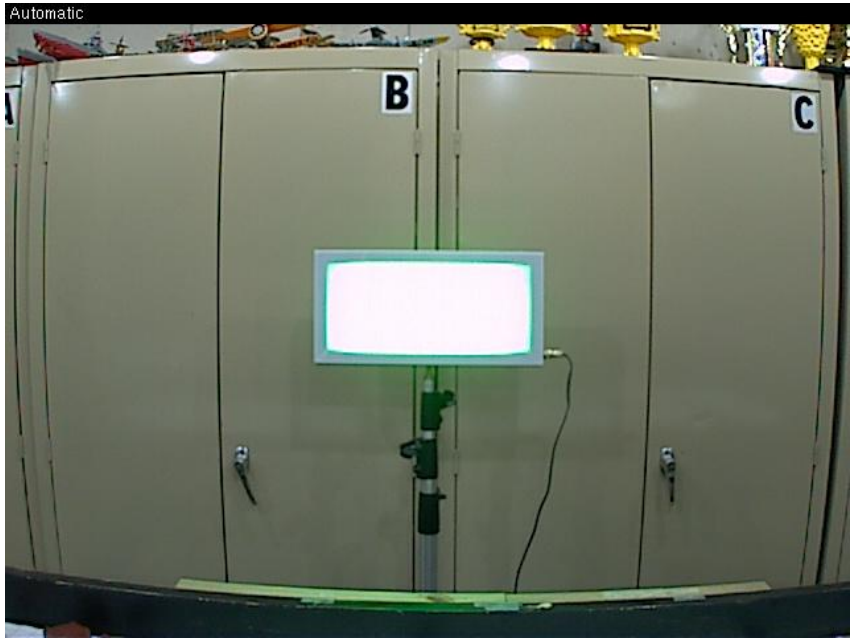
If the green lamp is one of the brightest components of a scene and the camera exposure is allowed to auto-adjust, the lamp will likely end up overexposed. Each of the red, green and blue components of that part of the image containing the lamp will saturate so that each RGB component will have the same value: maximum! Since the RGB component values are all about equal, the light source will appear white in color.



Inconsistent Exposure

If the camera is allowed to auto adjust and the green lamp appears in scenes of differing lighting conditions, the camera image of the light source may vary from scene to scene. The camera seems to auto-adjust to the average brightness of the scene.

In a dimly-lit scene, the green lamp may appear over-exposed.



In a brightly-lit scene, the green lamp may appear less-exposed

Inconsistent Exposure

In a very bright scene, the camera auto-adjusts the exposure for a very high brightness level. The green lamp is correctly exposed.

Solving the Exposure Problem

- One solution to the problem of over-exposure and inconsistent-exposure is to hold the camera exposure and white balance at a fixed level that will work for all conditions under which the camera will be used.

- For the camera to correctly image the green lamp everywhere on the field, the exposure level should be set to work with the camera positioned closer to the lamp than it will ever be on the field. That way, overexposure will never occur.

- The Axis 206 exposure level and white balance cannot be set directly by the user, but can only be set by the camera while the camera automatically adjusts to current lighting conditions. To set and hold a desired exposure level, the camera should be exposed to a lighting condition that will cause it to automatically adjust to the desired level. Then, after the camera has been given time to stabilize, the exposure level can be held fixed.

- White balance level does not appear to be as critical as exposure level for good green-lamp imaging. The author has found that the **`Fixed Fluorescent 2`** setting works well. The **`Fixed Indoor`** setting is not recommended.

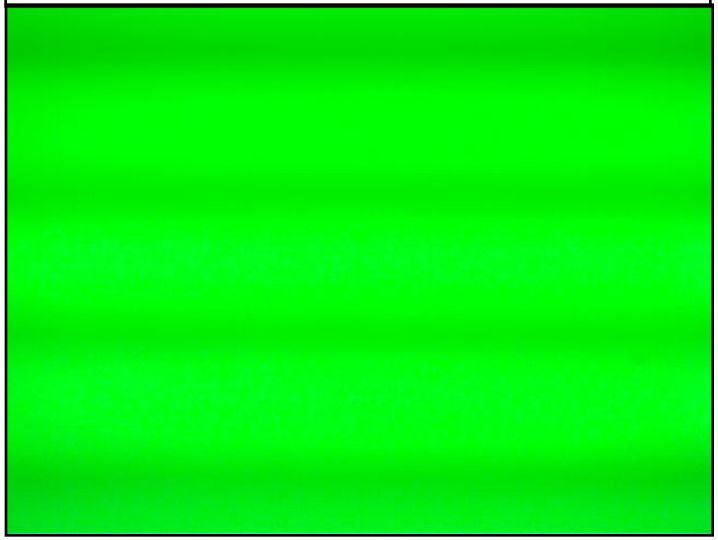
Setting the Camera Exposure

1. Allow the lamp to warm up for 15 minutes or longer.
2. Place the camera facing the lamp so the lit portion of the lamp fills the entire camera image.
3. Set the camera exposure to “Automatic” and allow the exposure to stabilize for 30 seconds or longer.
4. Set the exposure to “Hold current”

   The camera will retain its exposure setting even if power-cycled.

Relative Lamp-Camera Position for Setting the Exposure

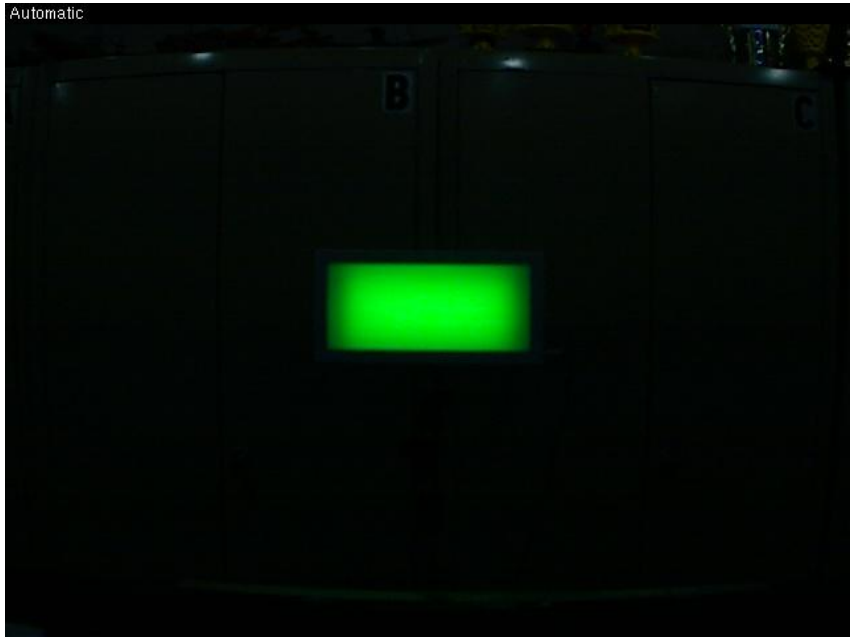
Camera Image of Green Lamp with Correctly-Set Exposure



Consistent Exposure

If the camera settings are fixed and the light source appears in scenes of differing lighting conditions, the camera image of the light source will remain consistent even while the lighting conditions change.

In a dimly-lit scene, the light source appears correctly-exposed



In a brightly-lit scene, the light source appears correctly-exposed

Accessing the Camera Web Server

Camera settings can be changed and camera images can be captured by accessing the camera web server from a PC. The simplest and most direct way to access the web server is:

1. Set the PC network interface IP address to 192.168.0.n (n ≠ 90)
2. Leave the camera IP address set to 192.168.0.90 (factory default)
3. Connect the camera to the PC using an ethernet crossover cable. The orange ethernet cable supplied with the 2009 FRC Control System, part 219153-3, can be used.

OR

3. Connect the camera to the PC using standard (straight-through) ethernet cables through a hub or router.

Accessing the Camera Web Server

192.168.0.n

Crossover cable

192.168.0.90

OR

Standard cable

Standard cable

192.168.0.m

m ≠ n ≠ 90

Accessing the Camera Web Server

Access the camera from the PC by entering 192.168.0.90 in the web browser address field.

Enter the root or FRC user name and password:

(User name: FRC, Password: FRC)

Adjusting Camera Settings

After accessing the camera web server, the exposure and white balance settings can be adjusted:

1. Allow the green lamp to warm up.
2. Place the camera near and facing the lamp so the lit portion fills the entire image. Check the image on the Live View page.
3. Go to Setup >> Video & Image >> Advanced
4. Allow the image to stabilize for 30 seconds on automatic exposure.
3. Select “Fixed Fluorescent 2” in the White balance drop-down box.
4. Select “Hold current” in the Exposure control drop-down box.
5. Click “Save” to save the new exposure and white balance settings.

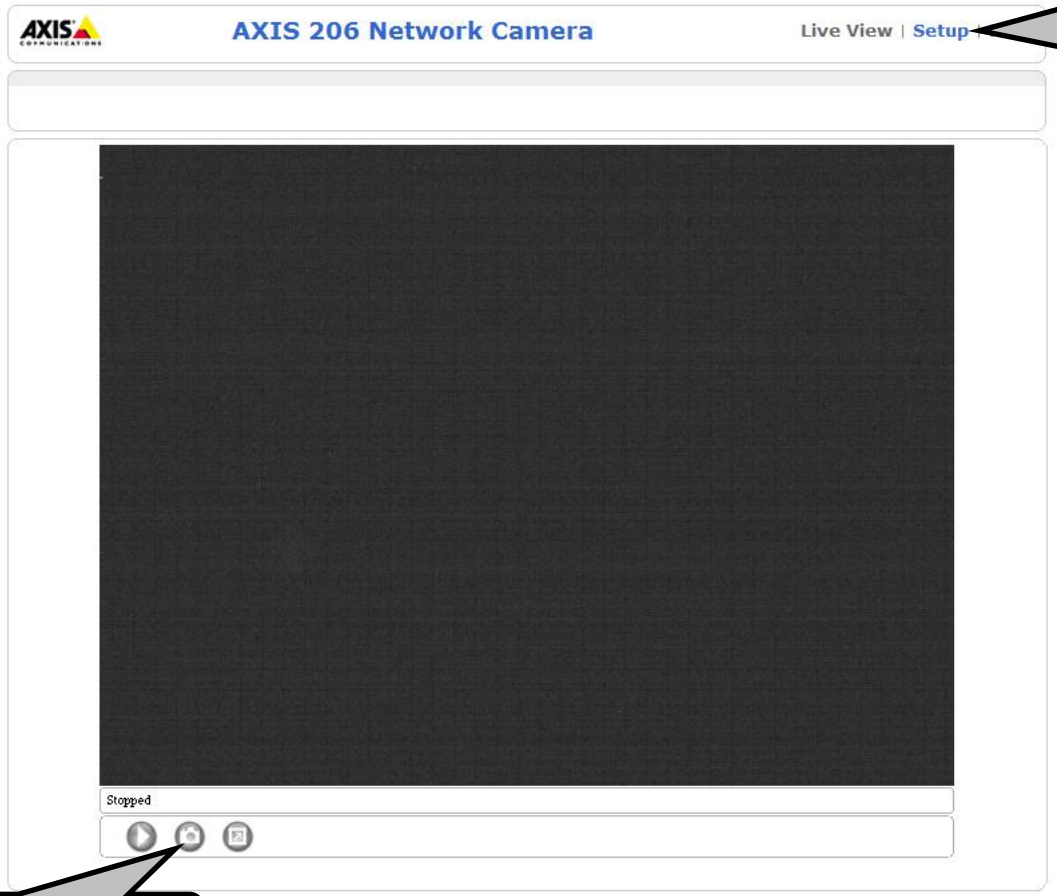
The Live View Page

Go to Setup Pages

Once logged on to the camera web server, the Live View page is visible. To adjust camera settings, click “Setup” to go to the camera setup pages.

An image may be visible in the window. To save a copy of the image, click the snapshot button.

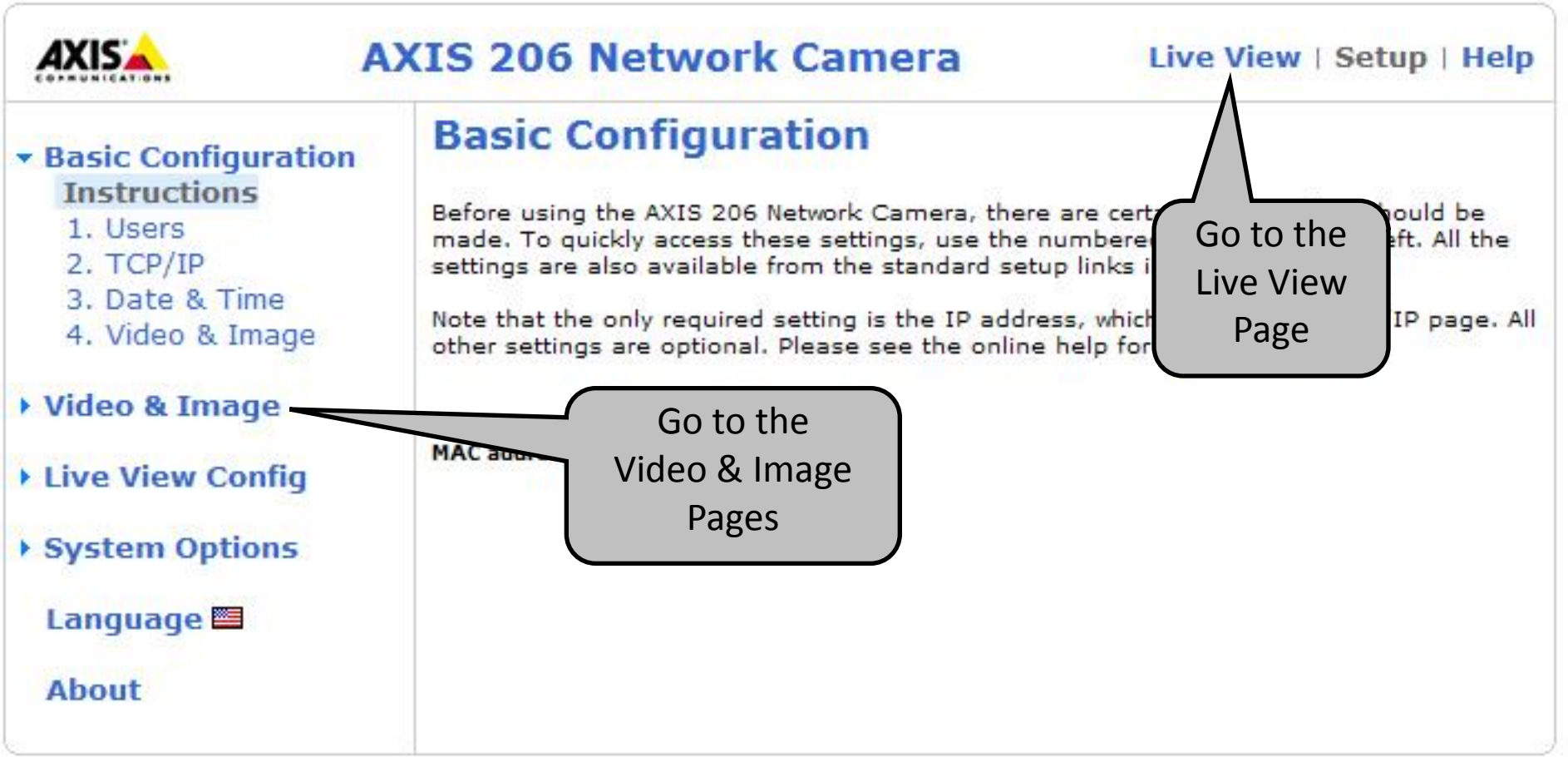
The camera position relative to the green lamp can be adjusted by observing the image in the Live View window.



The Basic Configuration Page

Go to Video & Image Pages

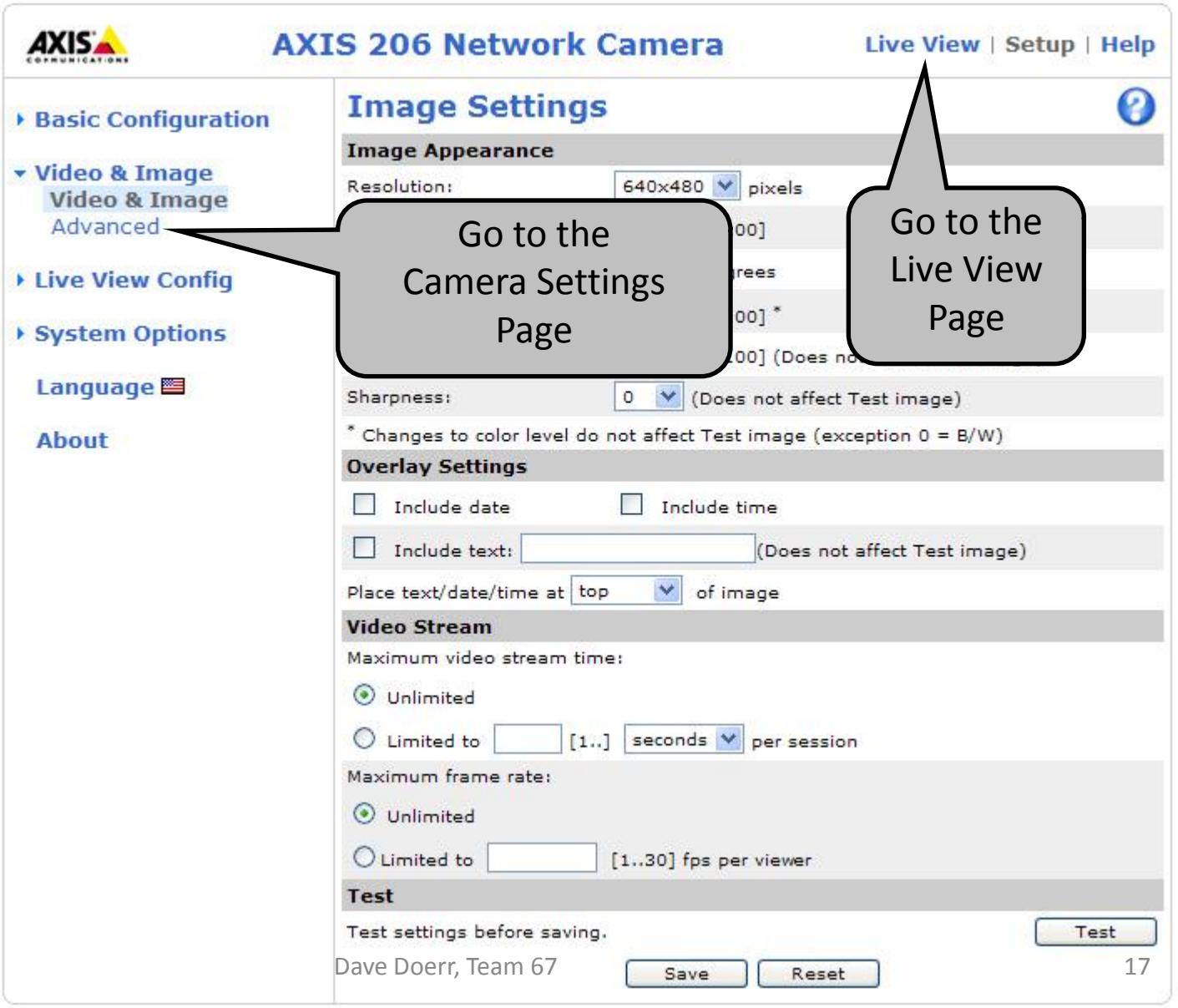
To navigate to the Image and Camera settings pages, click “Video & Image”.



The Image Settings Page

Go to Camera Settings

From the Image Settings page, click “Advanced” to navigate to Camera Settings to adjust the exposure and white balance.



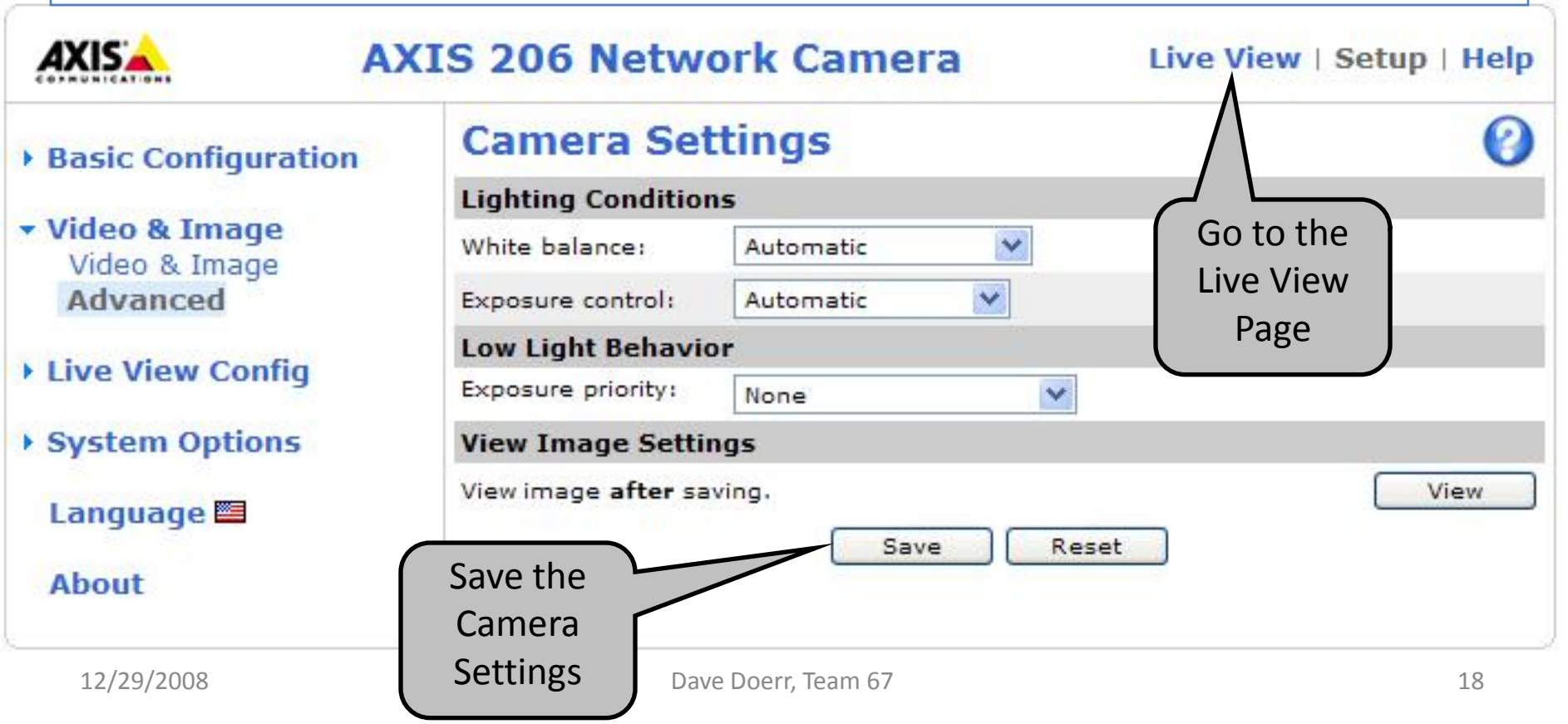
The Camera Settings Page

Set White Balance and Exposure Control

White balance and exposure control can both be set from the Camera Settings page by making the desired selection from the drop-down box and clicking “Save”.

To set the exposure control for correct green-lamp imaging, the camera should first be placed directly in front of the lamp so the camera “sees” nothing but the green light source. The correct position can be checked on the Live View page.

After stabilizing on the “Automatic” setting for about 30 seconds, the exposure control should be set to “Hold current”.



Set the Exposure Control

Axis 206 Exposure Control Settings	
Automatic	Automatically adjust for current lighting conditions (Factory Default)
Flicker-free 50 Hz	Correct for 50 Hz Fluorescent Lamp Flicker (Automatic, Video)
Flicker-free 60 Hz	Correct for 60 Hz Fluorescent Lamp Flicker (Automatic, Video)
Hold Current	Hold the currently-adjusted setting

Set the White Balance

Axis 206 White Balance Settings	
Automatic	Automatically adjust for current lighting conditions (Factory Default)
Fixed Indoor	2600K Color Temperature
Fixed Fluorescent 1	4000K Color Temperature
Fixed Fluorescent 2	5000K Color Temperature
Fixed Outdoor 1	5500K Color Temperature
Fixed Outdoor 2	6500K Color Temperature
Hold Current	Hold the currently-adjusted setting.

Develop Image Processing

Once the camera exposure and white balance settings have been set, the next step is to develop image processing to identify the green lamp.

First, an array of images of the green lamp can be analyzed for color content parameters such as hue, saturation and luminance. Then a color threshold application can utilize the parameter information to identify and locate the position of the green lamp in a scene.

The Vision Assistant is a tool for prototyping image processing applications, such as might be used on a robot. Scripts can be developed and saved that implement processing algorithms, and the scripts can be tested on multiple images.

Image processing could utilize the following steps:

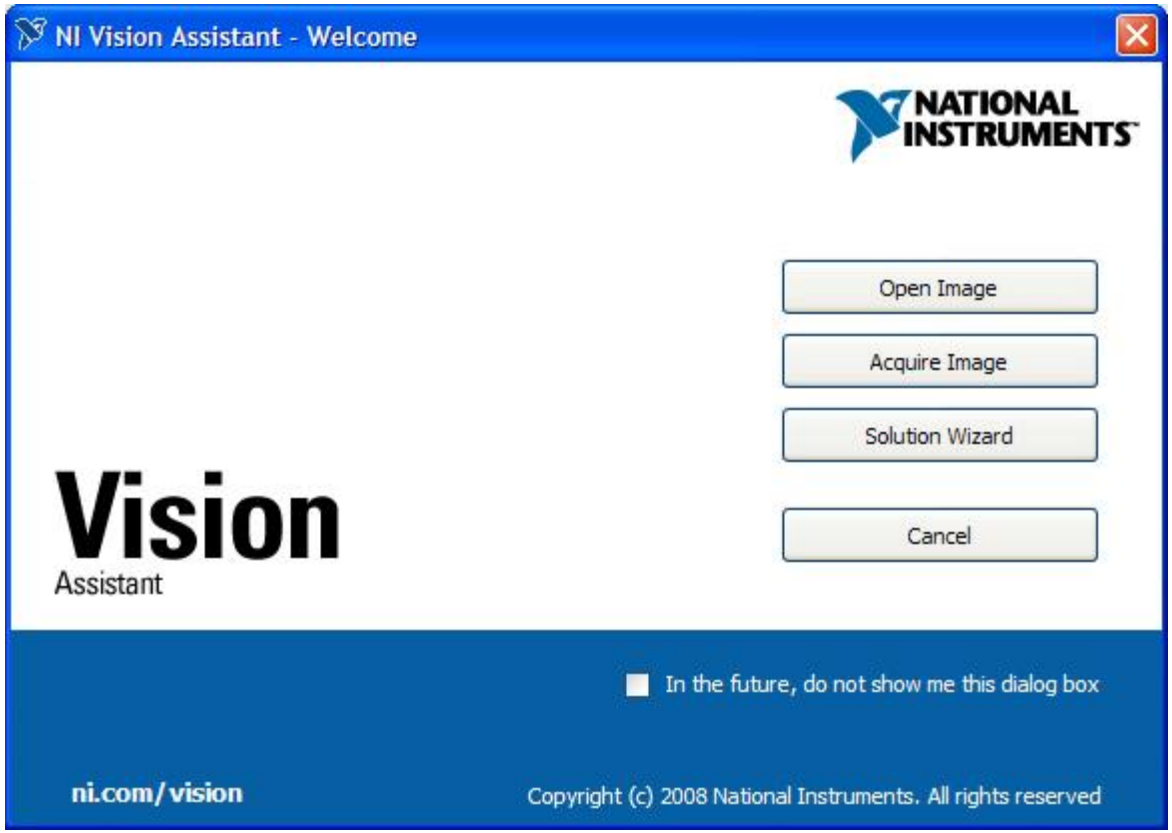
1. Mask an image to pass only the part containing the green lamp
2. Separate out the color information: Hue, Saturation, Luminance or Red, Green, Blue
3. Analyze the level of each color component
4. Repeat with enough images to cover all operating conditions
5. Choose min-max threshold levels for each color component

Using the NI Vision Assistant

Startup of Vision Assistant

On startup of the Vision Assistant, you can open existing images, acquire images from the Axis 206 camera, or proceed to a solution wizard.

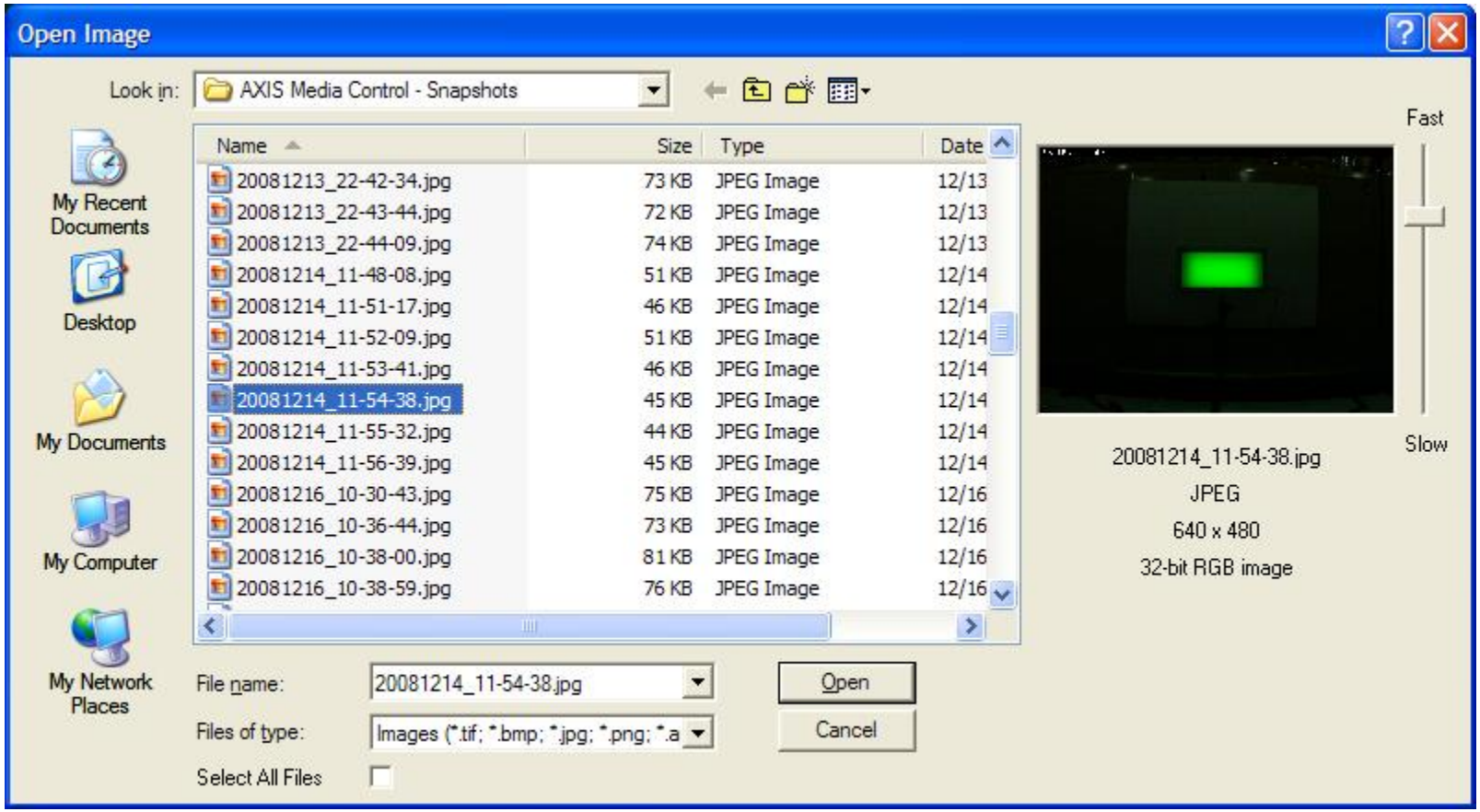
Although, camera settings can be made and images can be acquired directly from the camera by the Vision Assistant, the author does not recommend using this capability at this writing because not all of the camera setting features appear to be correctly implemented. It is less convenient but safer to adjust camera settings using the Axis 206 web server.



Using the NI Vision Assistant

Opening Images in Vision Assistant

If you choose to “Open Image”, you will be presented with a file selection box. Browse to the correct folder, select either a single image or a set of images and click “Open”.

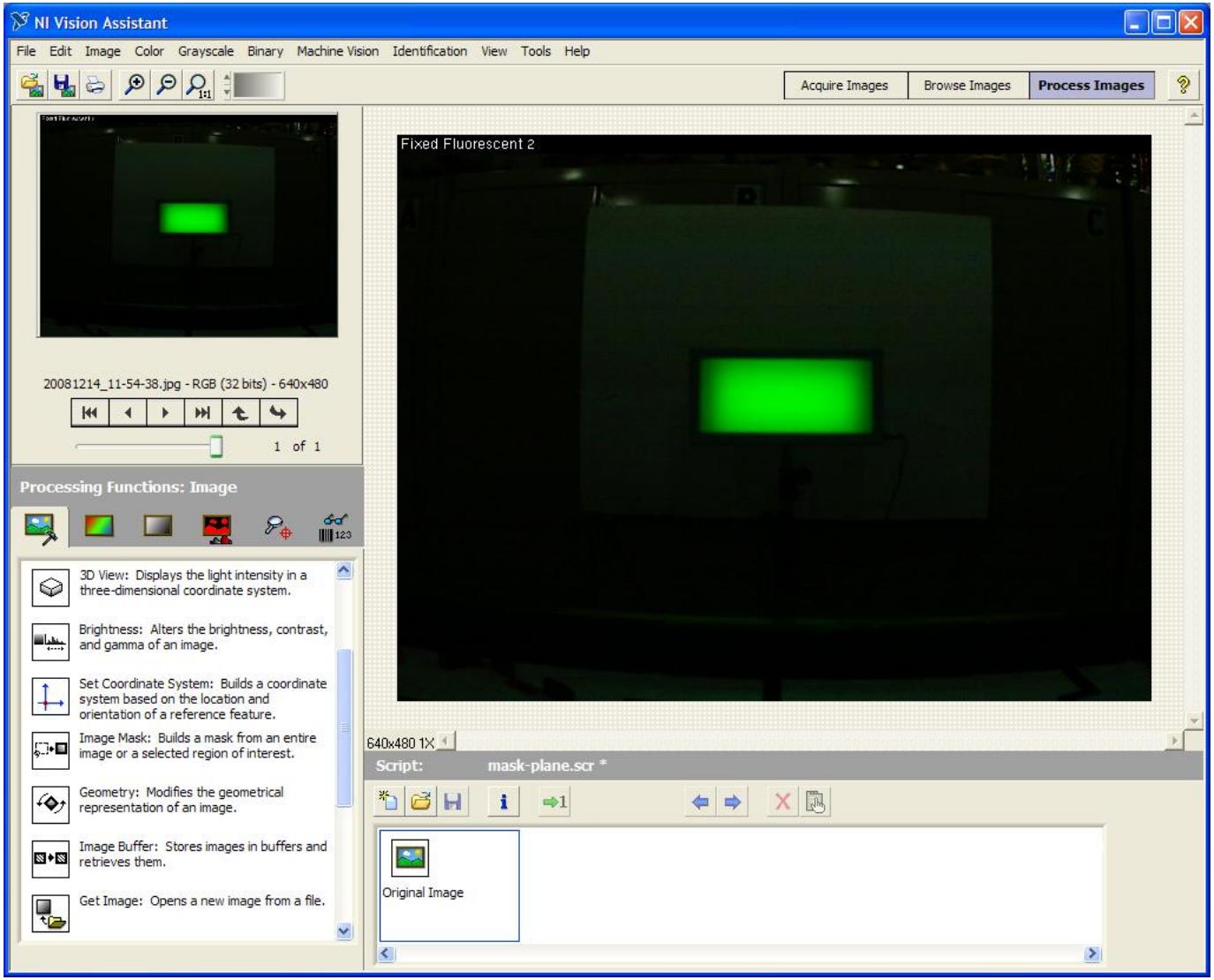


NI Vision Assistant: Color Analysis

Green Lamp Color Analysis

The goal is to analyze the color parameters of the green lamp in the image. First, mask the image so that only the green lamp part of the image is processed.

Choose the "Processing Functions: Image" tab in the acquisition palette of the Vision Assistant. Next, choose "Image Mask" from the set of available processing functions.



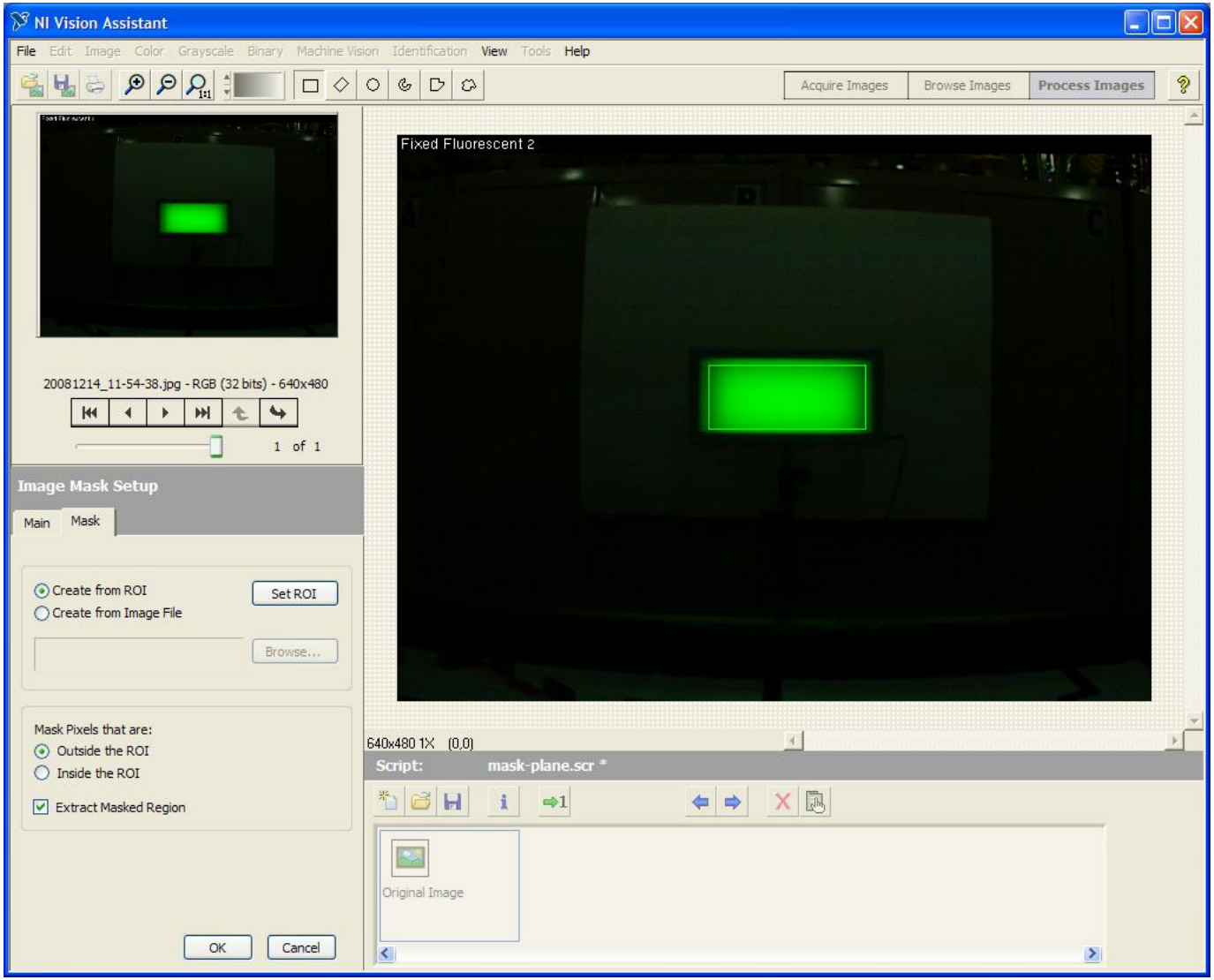
NI Vision Assistant: Color Analysis

Masking the Image

Click and drag a rectangle over the green lamp to form a mask.

Make sure “Create from ROI”, “Outside the ROI”, and “Extract Masked Region” are selected as shown. (ROI = Region Of Interest)

Then, click “Set ROI” to build a mask from the region of interest.

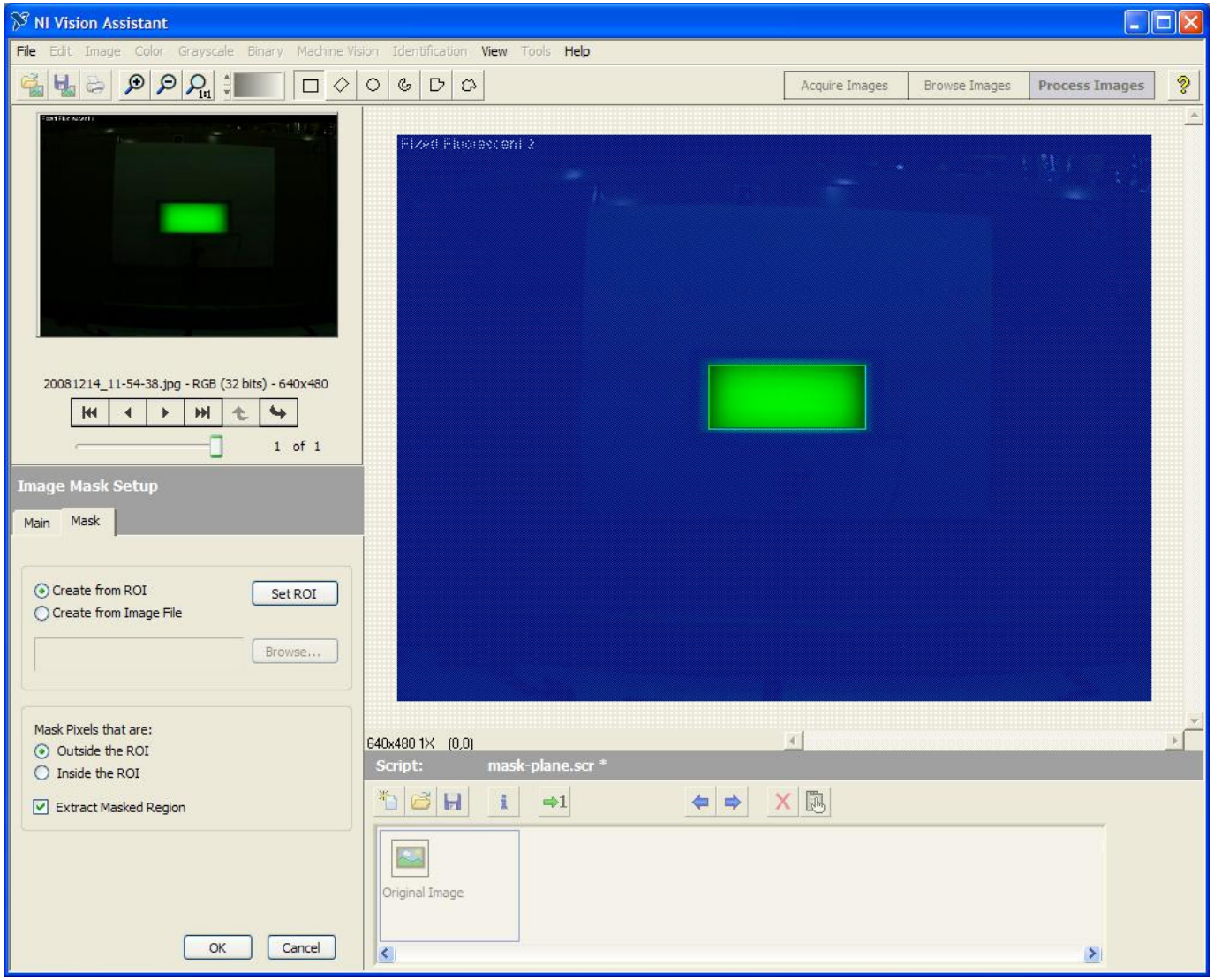


NI Vision Assistant: Color Analysis

Building a Script

Masked pixels will show as blue. Only unmasked pixels will be passed through the mask.

Click “OK” to add the processing function to the script and close the Image Mask Setup parameter panel.

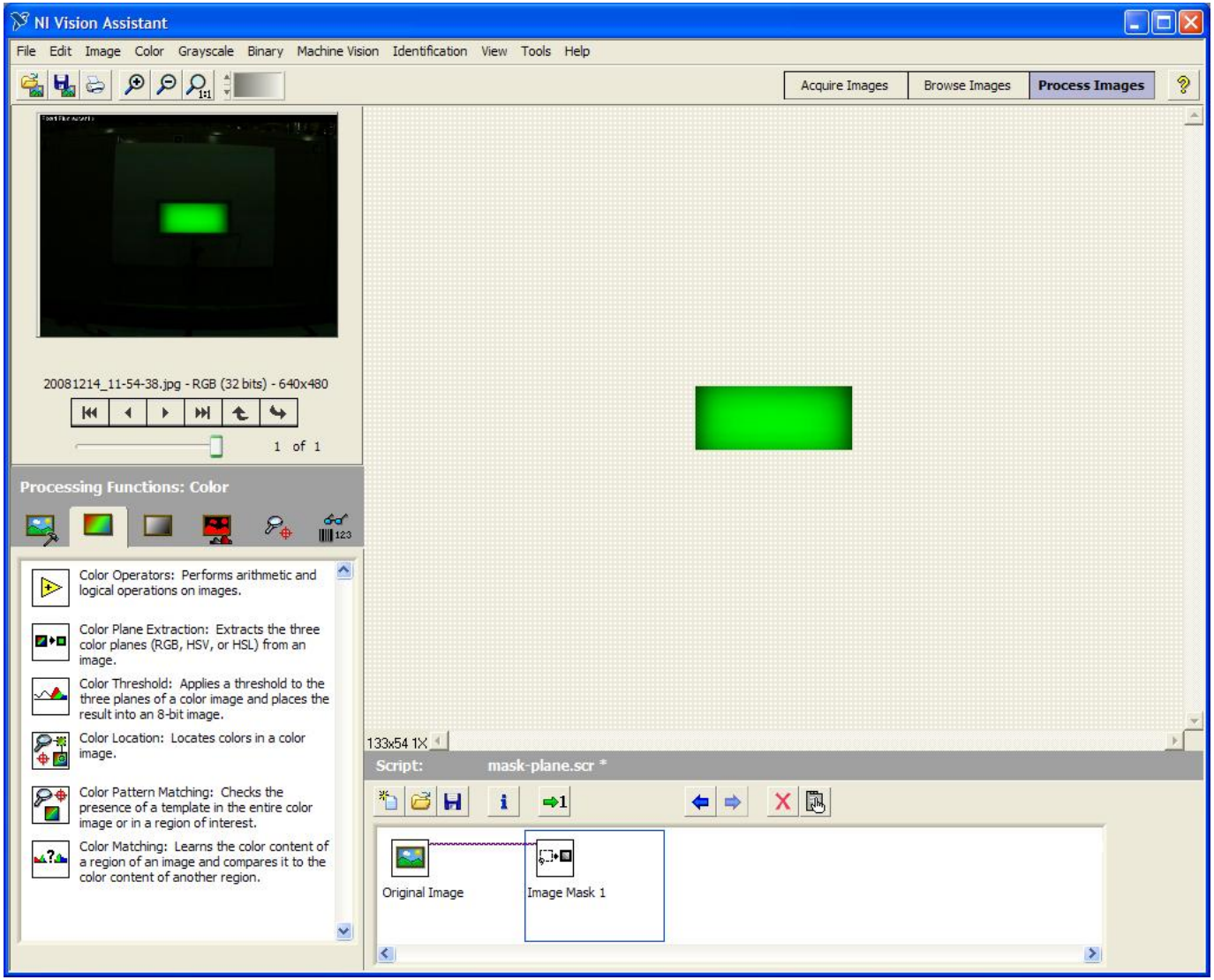


NI Vision Assistant: Color Analysis

Color Plane Extraction

The Image Mask processing function is added to the script. Only the unmasked pixels show in the Vision Assistant main window.

Continue analyzing the color parameters of the green lamp. Select the "Processing Functions: Color" tab in the acquisition palette. Then choose the "Color Plane Extraction" processing function.

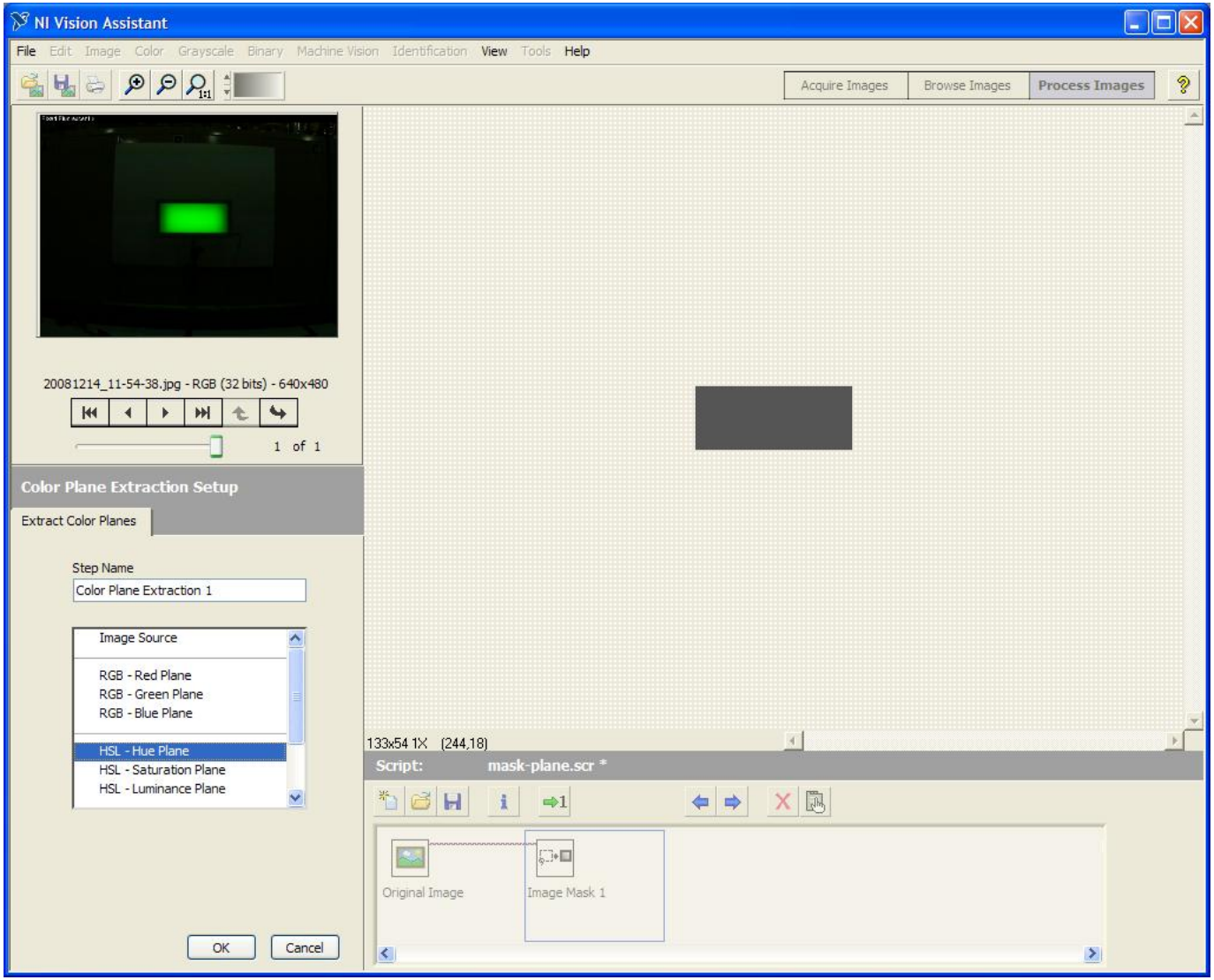


NI Vision Assistant: Color Analysis

Color Plane Extraction

Choose “HSL - Hue Plane” in the selection box. (HSL = Hue, Saturation, Luminance)

Click “OK” to add the processing function to the script and close the Color Plane Extraction Setup parameter panel.

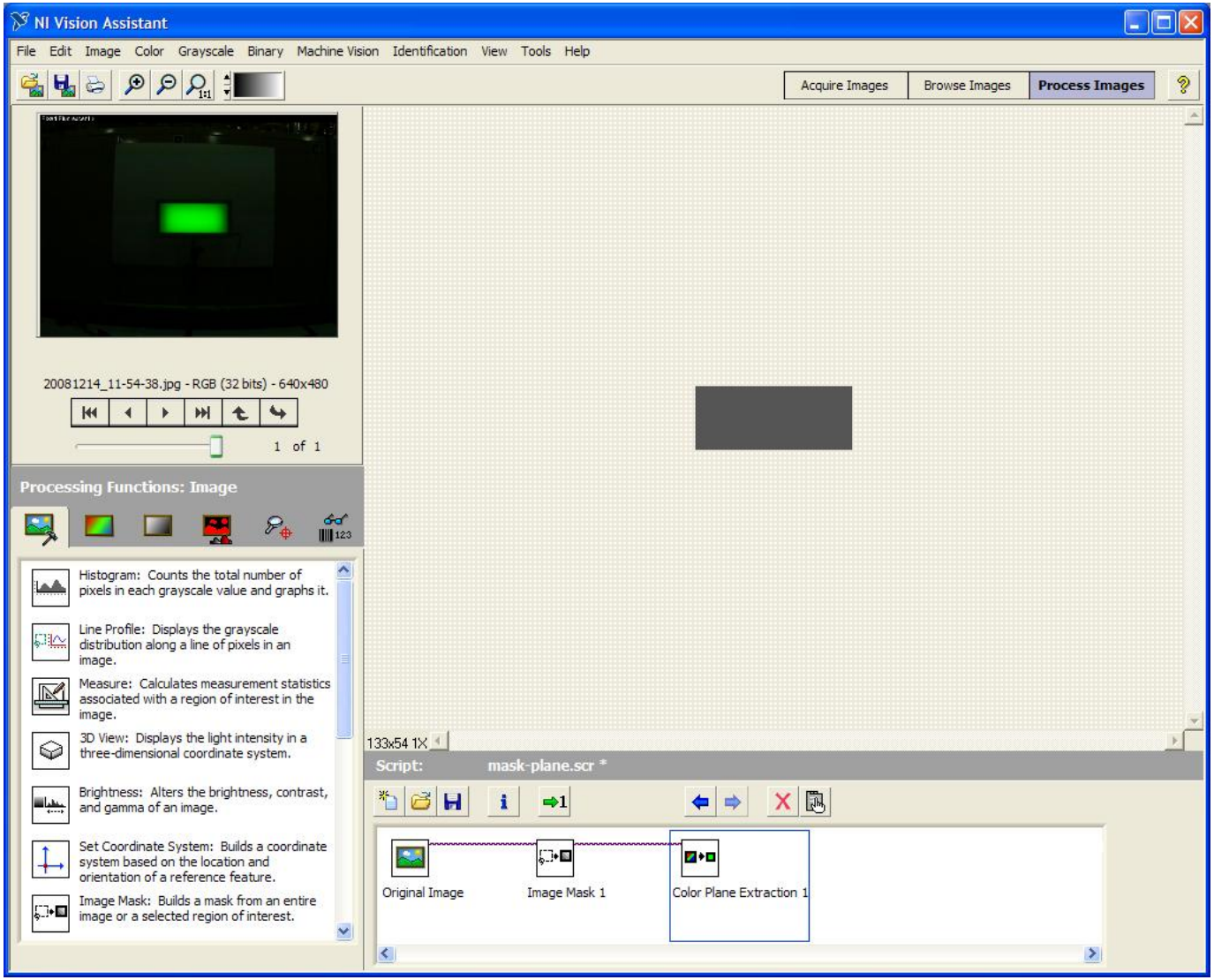


NI Vision Assistant: Color Analysis

Color Plane Extraction

The Color Plane Extraction processing function is added to the script. The hue value for each pixel shows in the Vision Assistant main window.

Continue analyzing the color parameters of the green lamp. Select the "Processing Functions: Image" tab in the acquisition palette. Then choose the "Histogram" processing function.



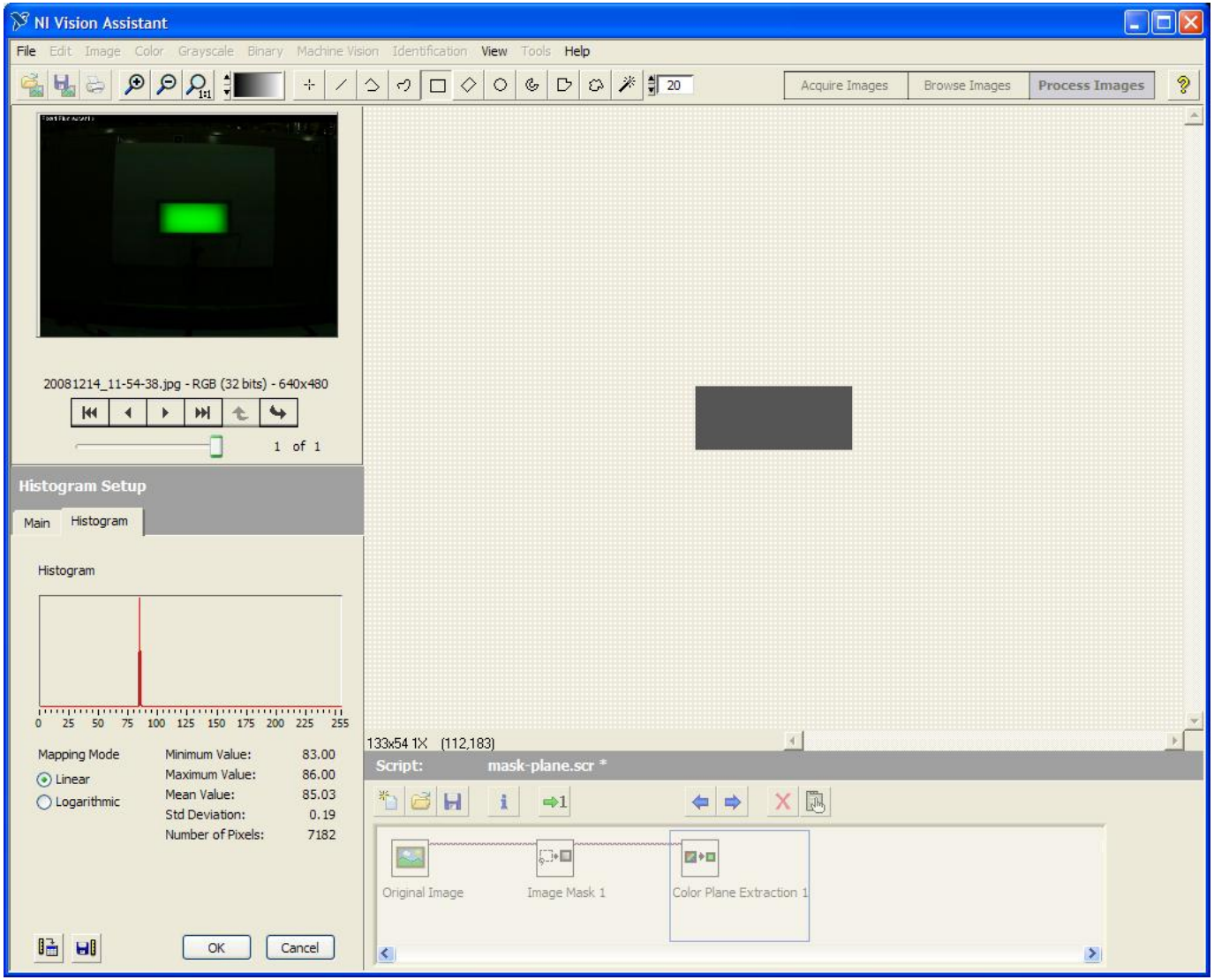
NI Vision Assistant: Color Analysis

Statistical Analysis

Measurement statistics for the hue plane of the green lamp show in the Histogram Setup display in the lower left pane of the Vision Assistant. The Mean Value is the average value of all pixels passed by the mask. The Std Deviation is a measure of the variation in value of the pixels.

In this example a mean of 85 corresponds to a hue of 120 degrees, or pure green.

Click “OK” to add the processing function to the script and close the Histogram Setup parameter panel.



NI Vision Assistant: Color Analysis

Running the Script

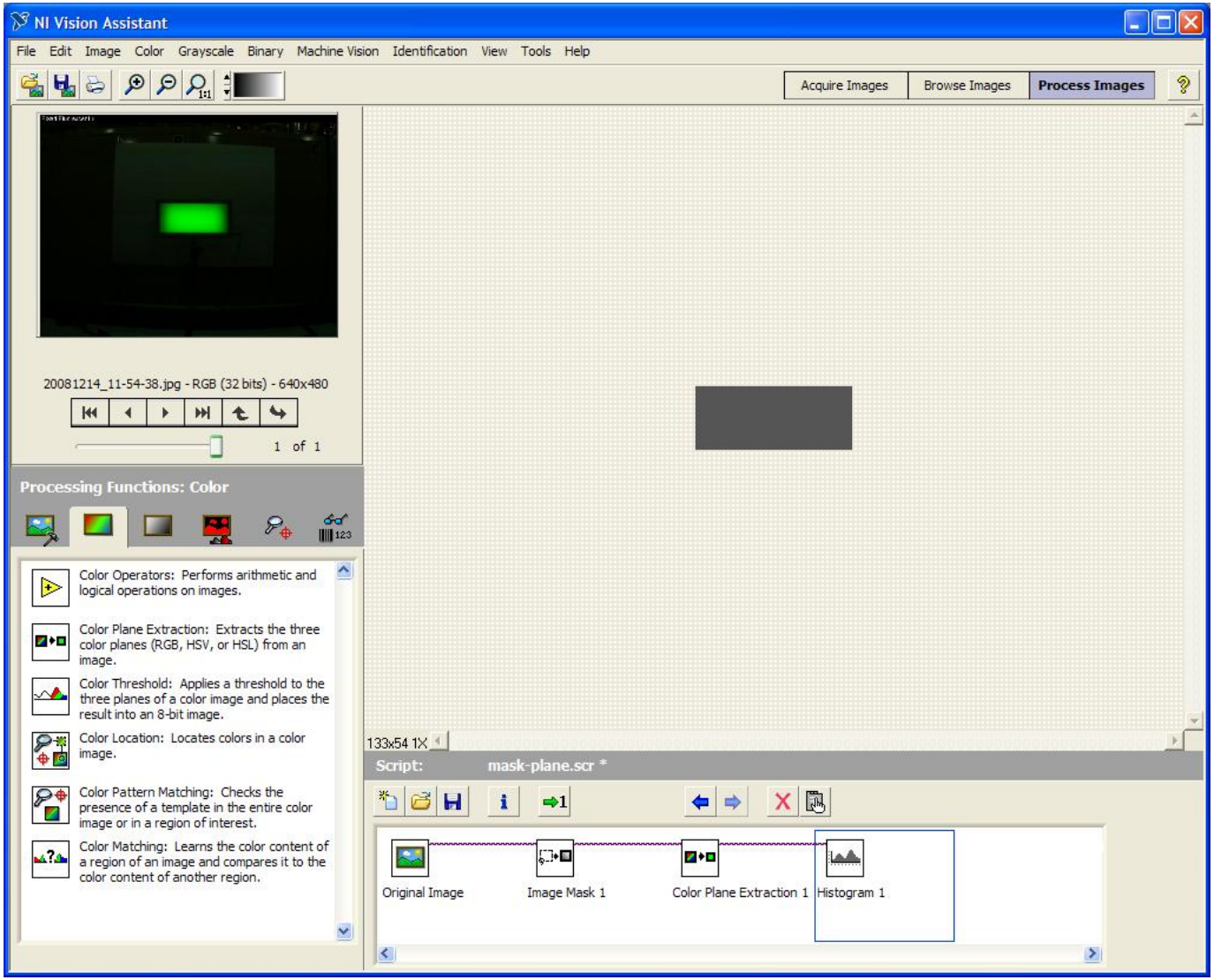
The Histogram processing function is added to the script.

Save the script by using File >> Save script As… or the Save Script button.

Run the script by using the Run Once button.

Image can be loaded and processed using the script by clicking the Run 1 button.

Additional color planes – saturation, luminance, red, green, blue -- can be extracted and analyzed.

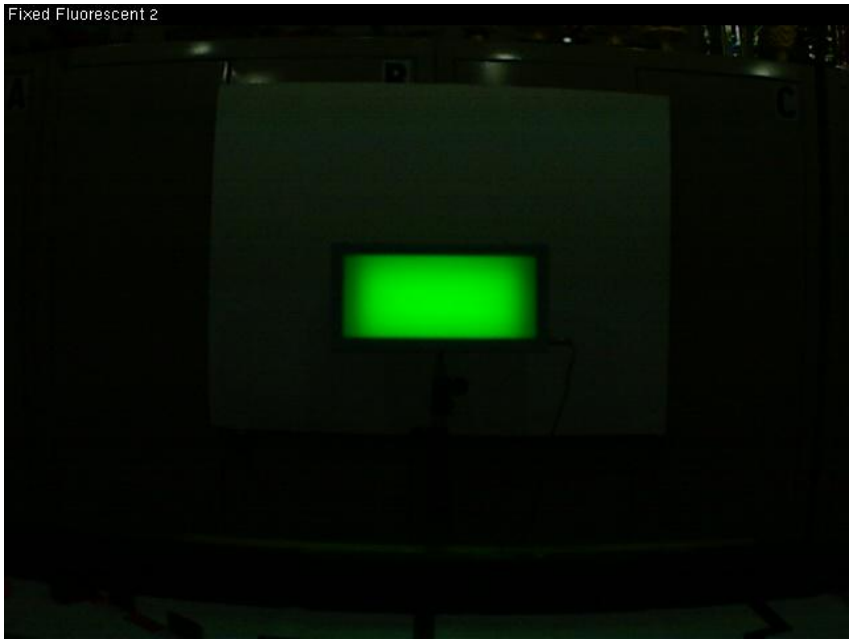


NI Vision Assistant: Color Analysis

Example HSL Analysis

The color analysis script should be run on images of the green lamp under as many different field conditions as possible to find the range of variation in hue, saturation and luminance to be encountered on the field. The example below shows the means of hue, saturation and luminance for the previously-shown example.

Vision Assistant HSL values range from 0 to 255. The Vision Assistant Hue value of 85 corresponds to 120°, or pure green.



Fluorescent Lighting
Hue = 85 = 120
Saturation = 255
Luminance = 118

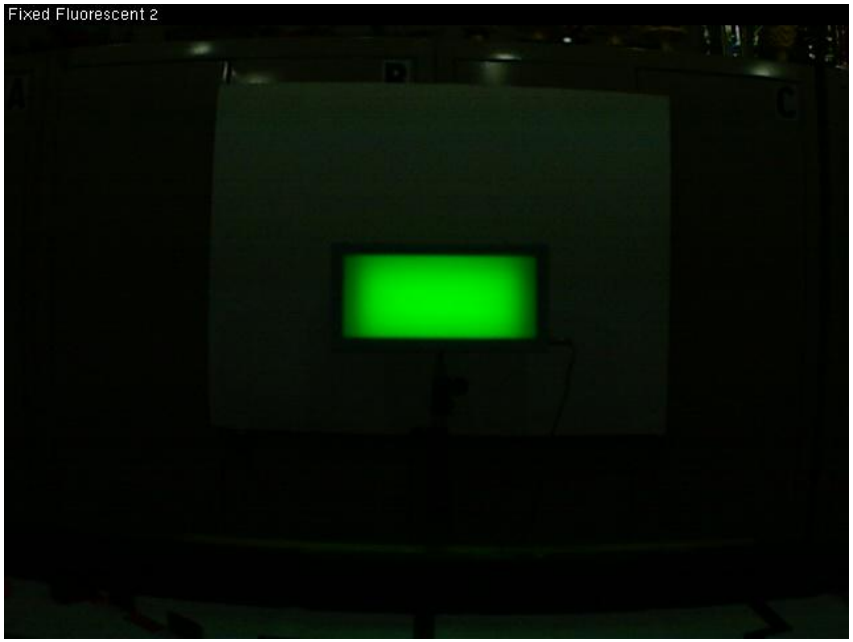
Bright, Natural Lighting
Hue = 85 = 120
Saturation = 255
Luminance = 115

NI Vision Assistant: Color Analysis

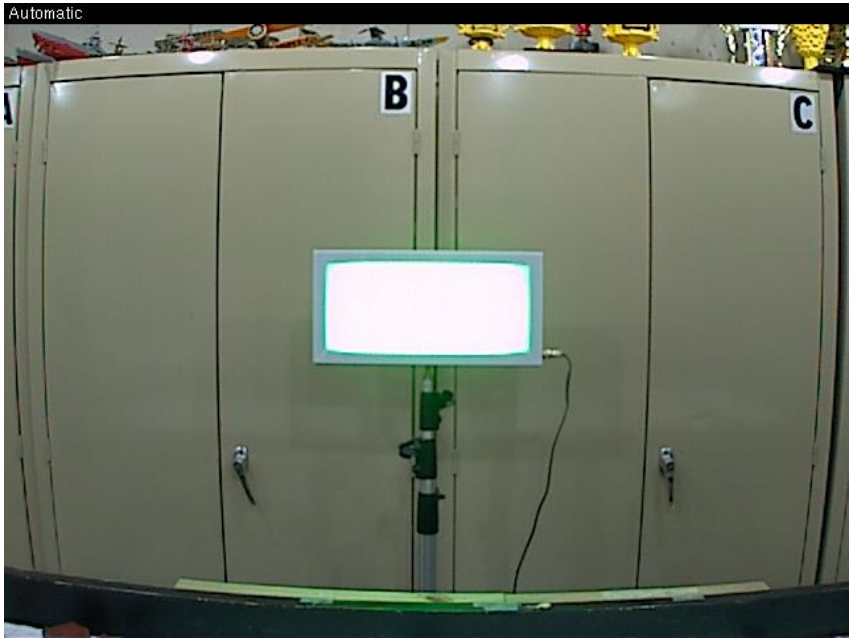
Example RGB Analysis

If an RGB analysis is done on the original overexposed example of the green lamp, it can be seen that each of the RGB component values lie near-saturated or 255, indicating a near-white lamp color.

In a similar RGB analysis of a correctly-exposed green lamp the red and blue component values are 0 -- indicating that the lamp has no red or blue color content – while the green component value is high, indicating a high level of green color content.



Fluorescent Lighting
Red = 0
Green = 220
Blue = 0



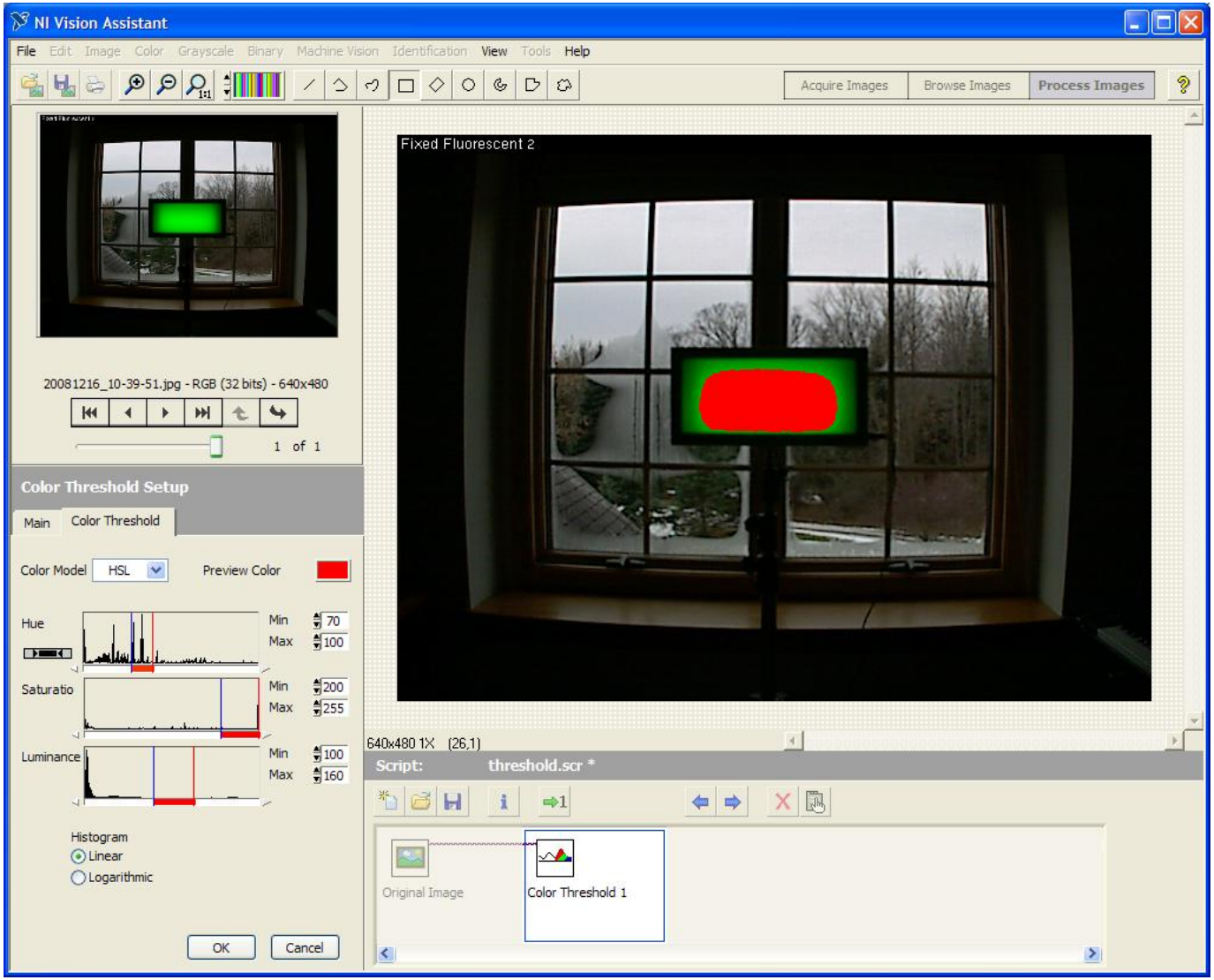
Fluorescent Lighting
Red = 254
Green = 246
Blue = 254

NI Vision Assistant: Color Threshold

Color-threshold processing can be used to detect the presence and location of the green lamp. To do so, a set of high and low threshold values should be found by analyzing representative images of the green lamp that the robot will "see" around the FRC field. For color-threshold analysis to work in detecting the green lamp, the the high-low threshold ranges should include all images of the lamp and exclude everything else.

Threshold ranges used for the example:

Hue: 70 – 100
Sat: 200 – 255
Lum: 100 – 160

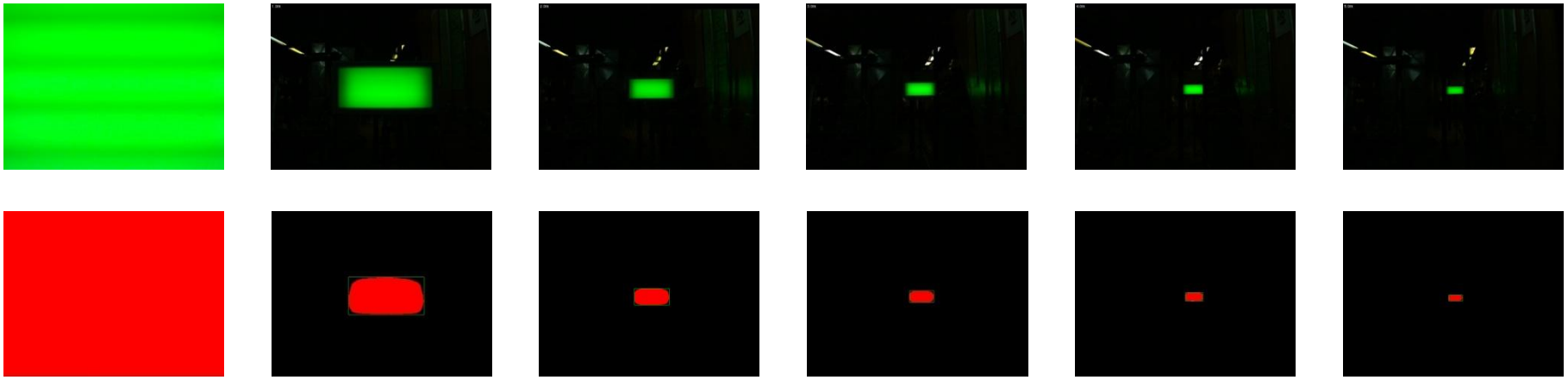


NI Vision Assistant: Color Threshold

Example Color-Threshold Analysis

Color-threshold processing was done on images of the green lamp positioned at distances from a few inches to 8 meters from the Axis 206. Original images are in the top row. Processed images are in the bottom row, showing color-threshold detection of the green lamp in red. Fluorescent lamps in the original image, even though very bright, are not detected by color-threshold processing.

Set Exposure 6.7 inches	1 meter	2 meters	3 meters	4 meters	5 meters



NI Vision Assistant: Color Threshold

Example Color-Threshold Analysis

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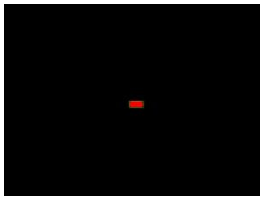
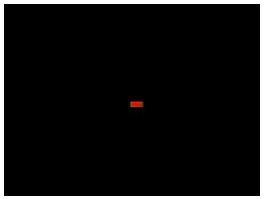
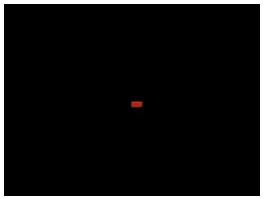
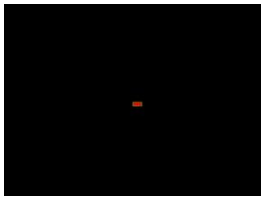
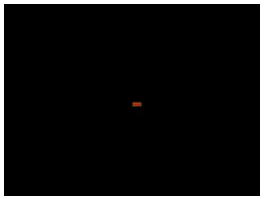
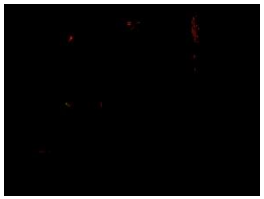
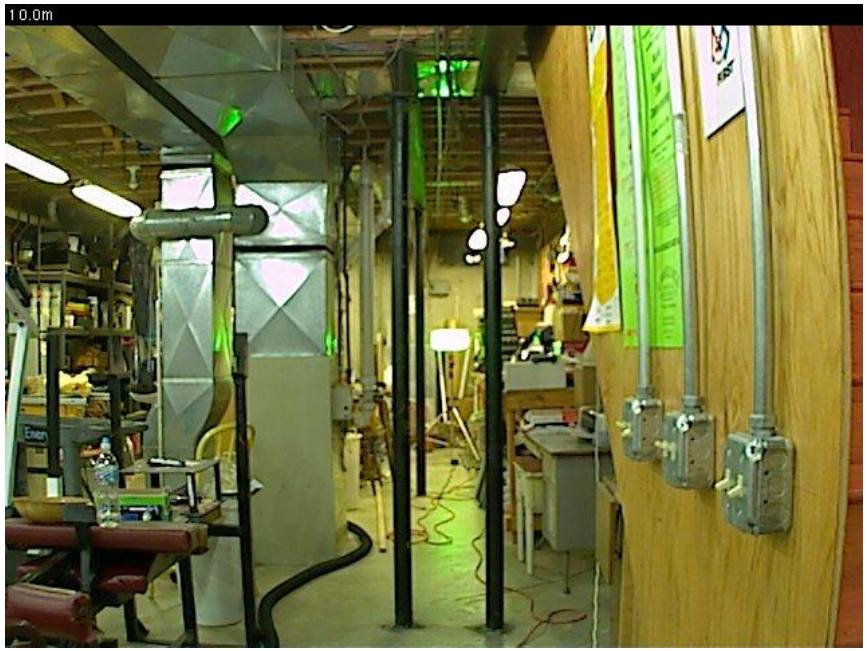
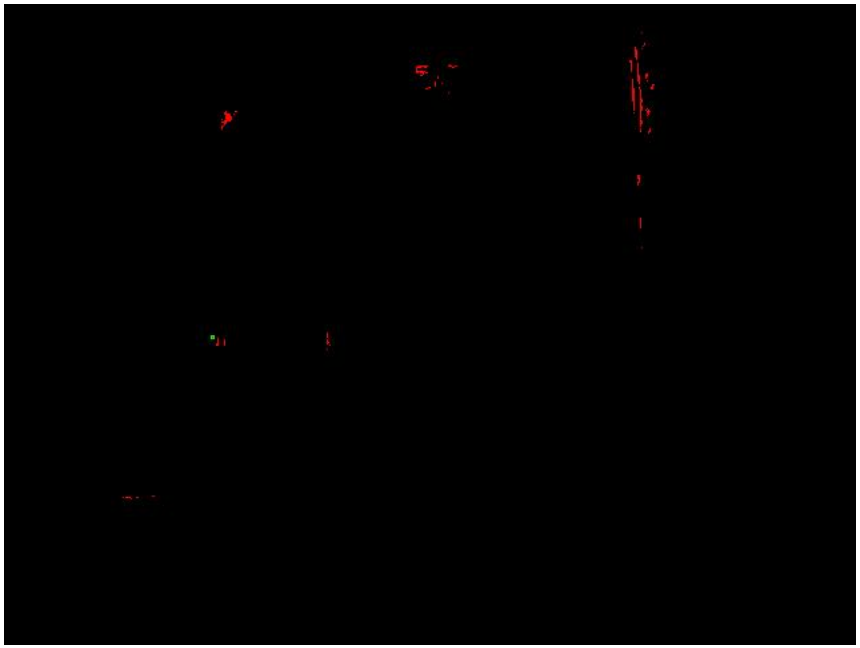
6 meters	7 meters	8 meters	9 meters	10 meters	Auto Exposure 10 meters
					
					

NI Vision Assistant: Color Analysis

Example Color-Threshold Analysis

For the example image below, the exposure control was set to automatic. The green lamp is overexposed and appears white in the original image. Color-threshold processing does not detect the overexposed green lamp, but does detect a number of green reflections in the image. The green reflections are from the green lamp, but are not bright enough to result in overexposure.



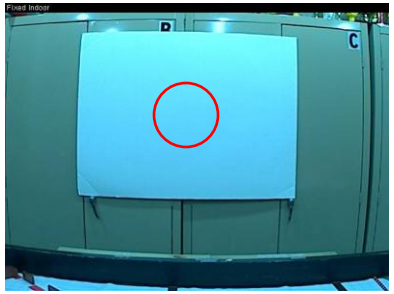


Appendix

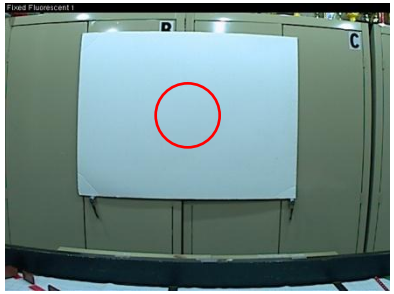
The following pages contain images captured at the various white balance settings of the Axis 206. The images show the effect of differing white balance settings on HSL and RGB color components.

White Balance – Fluorescent Lighting

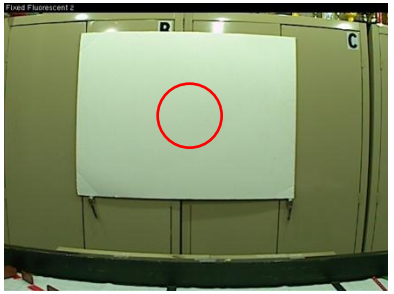
The images of a white board below were captured at differing white balance settings under fluorescent lighting. Indoor white balance subtracts a significant amount of red, to compensate for the warm color of most incandescent indoor lighting. The automatic setting produces the most natural white color. Automatic exposure control was used.



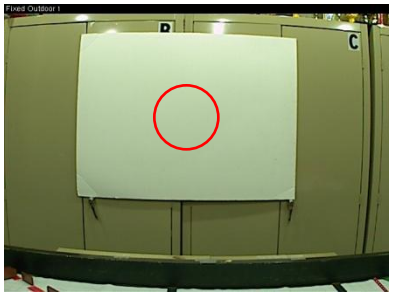
Fixed Indoor
H = 137 / S = 131 / L = 182
R = 091 / G = 214 / B = 254



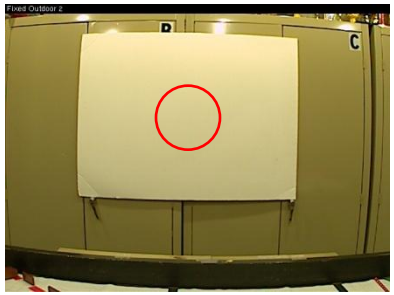
Fixed Fluorescent 1
H = 138 / S = 45 / L = 187
R = 157 / G = 200 / B = 214



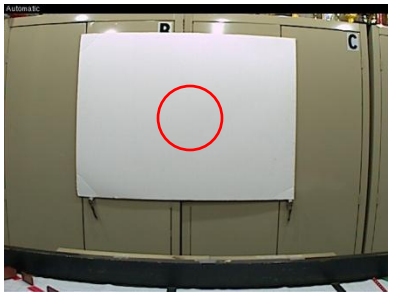
Fixed Fluorescent 2
H = 73 / S = 22 / L = 192
R = 179 / G = 204 / B = 168



Fixed Outdoor 1
H = 65 / S = 27 / L = 191
R = 182 / G = 202 / B = 163



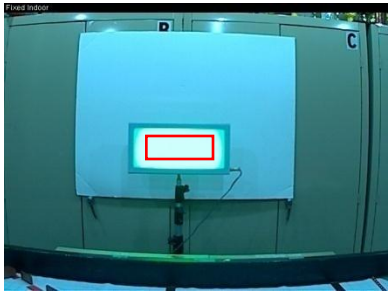
Fixed Outdoor 2
H = 36 / S = 61 / L = 197
R = 213 / G = 200 / B = 141



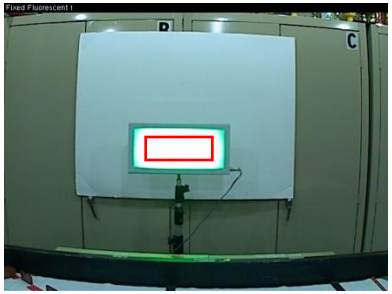
Automatic
H = --- / S = 2 / L = 195
R = 192 / G = 192 / B = 195

White Balance – Fluorescent Lighting

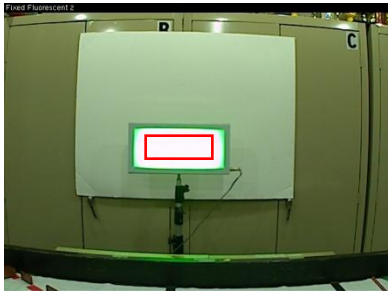
The images of the green lamp below were captured at differing white balance settings under fluorescent lighting. Automatic exposure control was used.



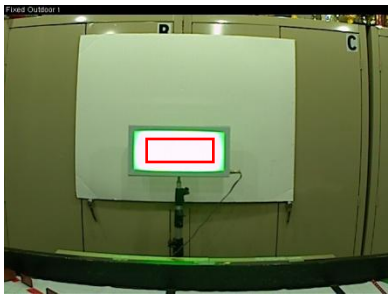
Fixed Indoor
H = 126 / S = 34 / L = 240
R = 207 / G = 245 / B = 253



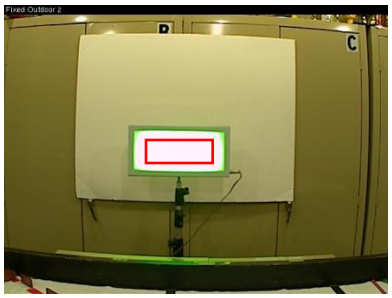
Fixed Fluorescent 1
H = --- / S = 1 / L = 253
R = 254 / G = 252 / B = 254



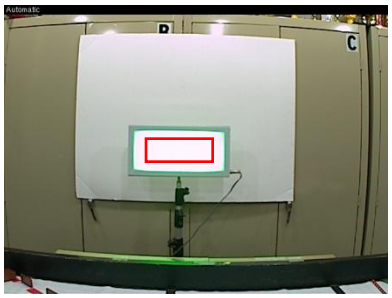
Fixed Fluorescent 2
H = 212 / S = 5 / L = 250
R = 254 / G = 248 / B = 245



Fixed Outdoor 1
H = 212 / S = 6 / L = 250
R = 254 / G = 243 / B = 254



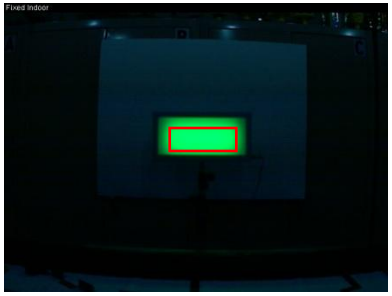
Fixed Outdoor 2
H = 214 / S = 8 / L = 248
R = 254 / G = 243 / B = 254



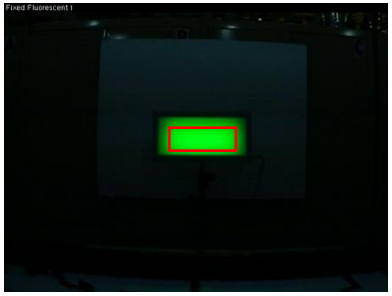
Automatic
H = 215 / S = 7 / L = 249
R = 254 / G = 245 / B = 254

White Balance – Fluorescent Lighting

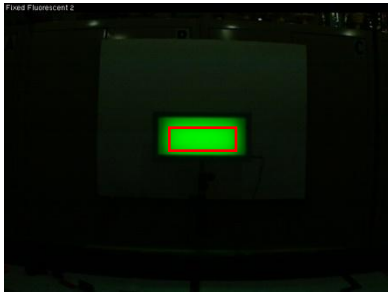
The images of the green lamp below were captured at differing white balance settings under fluorescent lighting. Exposure control was held current after stabilizing at about 6 to 7 inches from the lamp.



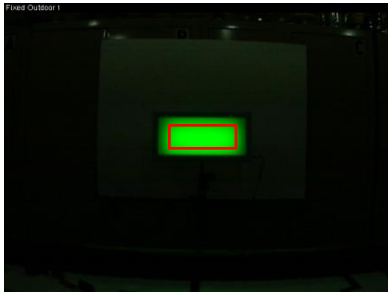
Fixed Indoor
H = 101 / S = 255 / L = 155
R = 0 / G = 246 / B = 99



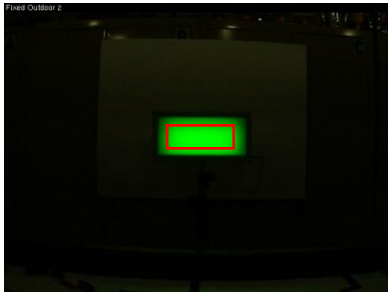
Fixed Fluorescent 1
H = 87 / S = 254 / L = 133
R = 0 / G = 224 / B = 12



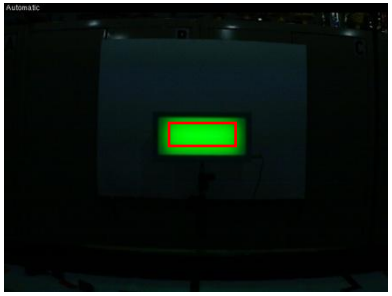
Fixed Fluorescent 2
H = 85 / S = 254 / L = 128
R = 0 / G = 217 / B = 0



Fixed Outdoor 1
H = 85 / S = 255 / L = 135
R = 0 / G = 230 / B = 0



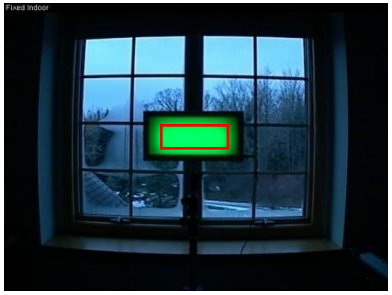
Fixed Outdoor 2
H = 85 / S = 255 / L = 132
R = 0 / G = 225 / B = 0



Automatic
H = 86 / S = 254 / L = 132
R = 0 / G = 224 / B = 5

White Balance – Natural Lighting

The images of the green lamp below were captured at differing white balance settings under natural lighting. Exposure control was held current after stabilizing at about 6 to 7 inches from the lamp.



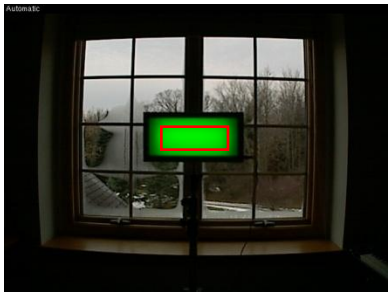
Fixed Indoor
H = 100 / S = 255 / L = 153
R = 0 / G = 243 / B = 89

Fixed Fluorescent 1
H = 85 / S = 255 / L = 125
R = 0 / G = 213 / B = 0

Fixed Fluorescent 2
H = 85 / S = 255 / L = 125
R = 0 / G = 212 / B = 0

Fixed Outdoor 1
H = 85 / S = 255 / L = 134
R = 0 / G = 228 / B = 0

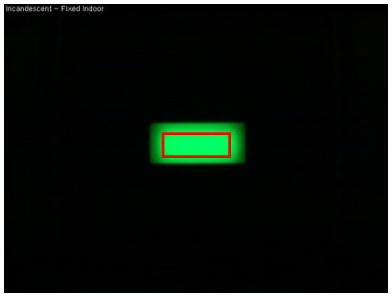
Fixed Outdoor 2
H = 85 / S = 255 / L = 119
R = 0 / G = 203 / B = 0



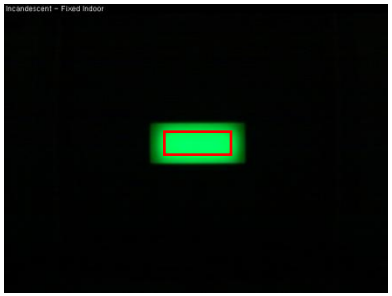
Automatic
H = 85 / S = 255 / L = 126
R = 0 / G = 214 / B = 0

White Balance – Incandescent Lighting

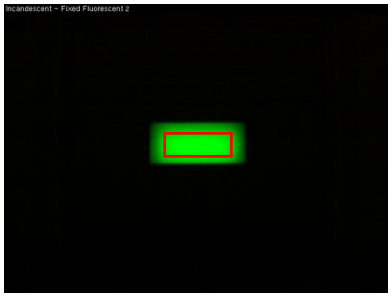
The images of the green lamp below were captured at differing white balance settings under incandescent lighting. Exposure control was held current after stabilizing at about 6 to 7 inches from the lamp.



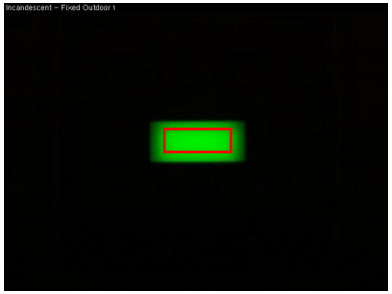
Fixed Indoor
H = 100 / S = 255 / L = 157
R = 0 / G = 249 / B = 89



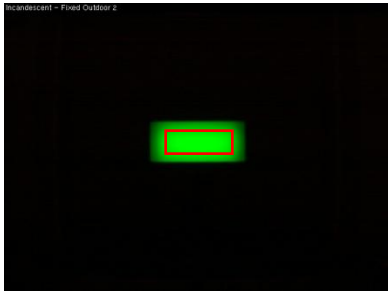
Fixed Fluorescent 1
H = 86 / S = 255 / L = 137
R = 0 / G = 232 / B = 3



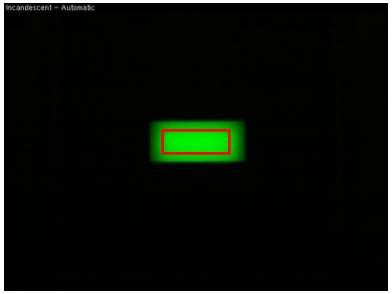
Fixed Fluorescent 2
H = 85 / S = 255 / L = 138
R = 0 / G = 234 / B = 0



Fixed Outdoor 1
H = 85 / S = 255 / L = 128
R = 0 / G = 218 / B = 0



Fixed Outdoor 2
H = 85 / S = 255 / L = 138
R = 0 / G = 235 / B = 0



Automatic
H = 85 / S = 255 / L = 131
R = 0 / G = 224 / B = 0