Beyond RGB 1.5: Improvements to a free, opensource, spectral image processing software application for cultural heritage studio photography

Leah Humenuck and Susan P. Farnand; Rochester Institute of Technology; Rochester, NY/USA

Abstract

Beyond RGB is a free, opensource, software application providing colorimetric and spectral processing of a 6-channel spectral image. The software has an input of two sets of RAW RGB images, one set for each of two different lighting conditions. These sets include a dark current, flatfield, target, and item. The outputs are an RGB image that is color calibrated with data on the accuracy of the calibration and user-selected spectral reflectance estimations of regions of interest. The improvements created for this version of the software include an updated user interface, auto-sorting of files, improved color difference calculation and visualization, a user-friendly website, and the inclusion of various RAW file types.

Introduction

For color-accurate reproduction of cultural heritage items, traditional studio imaging, involving the single capture of an item under white light with an RGB camera, comes with challenges such as post-processing for color correction. This is because various materials and items are not always perceived by the camera in the same way as the human visual system. These challenges have been met with the inclusion of spectral imaging for cultural heritage documentation [1-2]. While spectral imaging is well known to provide the color accuracy that is desired for documentation and research, many of the spectral imaging systems used come with their own challenges. These challenges include requiring special training and equipment that is beyond the current budget. In response to these challenges, efforts have been made to minimize these challenges and create a lower cost solution with a lower barrier to entry [3]. One of these efforts was the development of a user-friendly, free, opensource software application, titled Beyond RGB, which utilizes a method of dual-condition capture and an RGB camera, and the development of a user-friendly, free, opensource software to perform the image processing, Beyond RGB [4].

Background: Beyond RGB 1.0

Beyond RGB inputs two sets of images from the dual-conditions, which include a dark current, flatfield, target, and item images, separately or together. This results in either 6 or 8 images, which move through the steps of pre-processing, and processing to produce an output of a color-calibrated RGB image of the item; information on the accuracy of the color-calibration; and user-selected spectral estimations of regions of interest on the item. The two-lighting conditions used are created by narrow band LEDs. The specific wavelengths are chosen depending on the calibration target and the spectral sensitivities of the camera to be used [5].

To summarize preprocessing, it consists of the rescaling all RAW input images to fill the 16-bit range of the resulting output TIFF, performing dark current correction, flatfielding, and registration [4]. Processing creates optimized colorimetric and spectral reflectance transformation matrices. These accurately associate the camera signals to the known colorimetric and spectral reflectance data of the chosen color target. The computational pipeline showing the flow of processing can be found in figure 1 The rows of colorimetric transformation matrix, $\mathbf{M_c}$, shown under the Colorimetric Transformation, correspond to the CIEXYZ tristimulus values, and the columns correspond to the 6-channel spectral stack camera signals. For the Spectral Reflectance Transformation, the matrix, $\mathbf{M_s}$, the rows correspond the measured spectral reflectance from 380-780nm at 10nm intervals for a total 36 samples per spectral reflectance measurement, with columns again corresponding to the 6-channel spectral stack camera signals [4].

$$\begin{bmatrix} X_{meas} \\ Y_{meas} \\ Z_{meas} \end{bmatrix} = M_c * \begin{bmatrix} R_{cam,1} \\ G_{cam,1} \\ B_{cam,1} \\ R_{cam,2} \\ G_{cam,2} \\ B_{cam,2} \end{bmatrix} \text{camera signals}$$

$$\begin{bmatrix} R_{meas,380nm} \\ R_{meas,390nm} \\ \vdots \\ R_{meas,730nm} \end{bmatrix} = M_s * \begin{bmatrix} R_{cam,1} \\ G_{cam,1} \\ B_{cam,1} \\ R_{cam,2} \\ G_{cam,2} \\ B_{cam,2} \end{bmatrix} \text{camera signals}$$

$$M_c = \begin{bmatrix} m_{1,1} & m_{1,2} & m_{1,3} & m_{1,4} & m_{1,5} & m_{1,6} \\ m_{2,1} & m_{2,2} & m_{2,3} & m_{2,4} & m_{2,5} & m_{2,6} \\ m_{3,1} & m_{3,2} & m_{3,3} & m_{3,4} & m_{3,5} & m_{3,6} \end{bmatrix}$$

$$M_s = \begin{bmatrix} m_{1,1} & m_{1,2} & m_{1,3} & m_{1,4} & m_{1,5} & m_{1,6} \\ m_{2,1} & m_{2,2} & m_{2,3} & m_{2,4} & m_{2,5} & m_{2,6} \\ \vdots & & \vdots & & \vdots & \vdots \\ m_{36,1} & m_{36,2} & m_{36,3} & m_{36,4} & m_{36,5} & m_{36,6} \end{bmatrix}$$
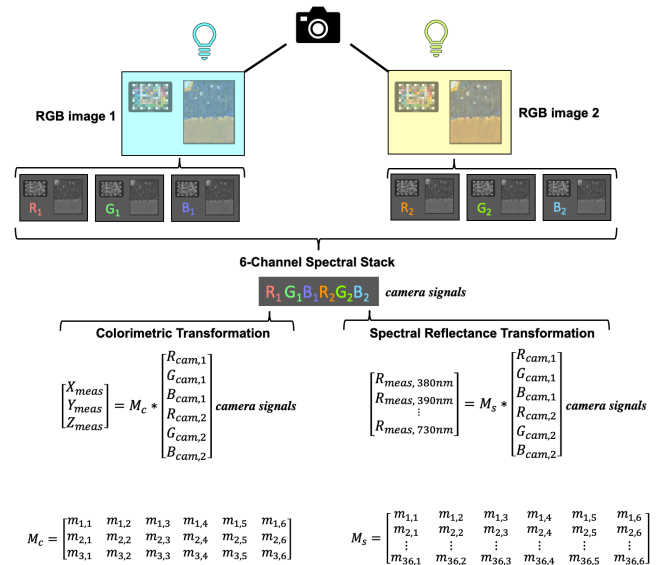
Figure 1. A visualization of the computational pipeline showing image capture under both lighting conditions, creating of the 6-channel spectral stack, the colorimetric transformation and the spectral reflectance transformation

Since the calibrations and optimization are based on the target data, the choice in target that best reflects the subject matter is important. Beyond RGB comes preloaded with the data from three well-known color targets, the Xrite ColorChecker Digital SG, the Xrite ColorChecker Passport, and the Avian Rochester Next Generation Target. Additionally, if a user has another color target, they wish to use, there is the option to upload that target's data into the software to use as the reference data. Beyond RGB supports image capture by RGB cameras which produce RAW images in the following file types: .ARW, .CR2, .NEF, .RAF, and .DNG. It also supports uncompressed linear TIFF files. The result from processing is a color calibrated image which has been transformed by the colorimetric transformation matrix, a calibration report which displays the global and individual patch ΔE_{00} of the chosen color target. In addition, spectral estimation can be performed on regions of interest and downloaded.

The first version of the software was demonstrated at various sized cultural heritage institutions to display its capabilities [5]. The software was met with a positive reception and a range of feedback regarding its attributes was provided. The suggestions regarding the software centered on the potential for incorporations into the standard workflow as well as general user experience options to ensure proper use of the software. Some of the suggestions for improvement included auto-sorting; a user-friendly site dedicated to download the software; general improvements on the user interface; and batch processing. The current version of the software has kept the key modular design while adding new improvements in order to ensure that the software can continue to be modified by users who wish to customize it to their purposes.

Software Improvements

Beyond RGB is structured through the following screens which direct the user to choose the appropriate path and process their images: Welcome, Import Images, Output Destination, Specify Image Roles, Optional Filtering, Target Patch Selection, Processing, Image Viewer, Calibration Reports. The process specific updates were created in Import Images, Specify Image Roles, Target Patch Selection, Calibration Reports, and Image View. Other updates were created that support the general use of the application.

Import Images

Drag and drop was added to the import images page to facilitate further intuitive use of the software. This is a common feature found in many applications to upload files and can save time. If the folder containing the images is open, the images can be immediately dragged into the load area for processing rather than retracing the pathway to the file and selecting the particular items by their names.
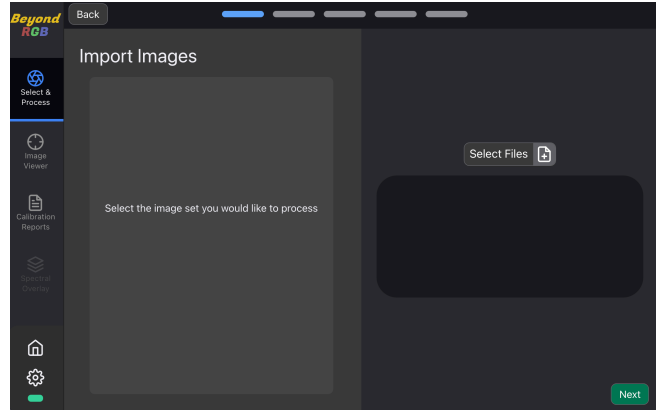

Figure 2. Import Images on Beyond RGB 1.0 where selection of images was only able to be performed by file name selection
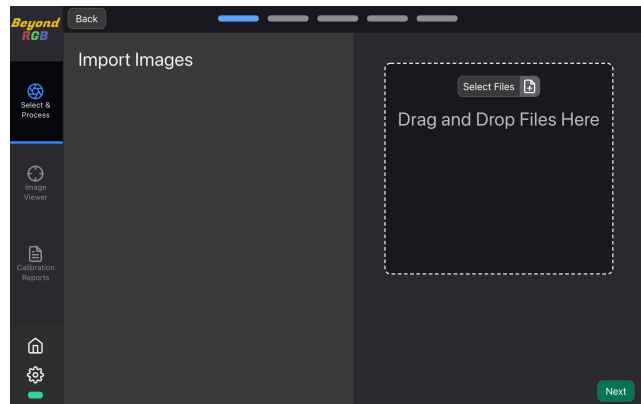

Figure 3. Import Images on Beyond RGB 2.0 where selection of images was only able to be performed by either drag and drop or file name selection

Specify Image Roles

Once the images are selected in the application, one of the bottlenecks for ease-of-use was sorting the two sets of images into their respective roles. This was solved by utilizing naming conventions where the software automatically assesses the names of the images and sorts them into two groups.

Another aspect on this page was clarified by having the application detect whether or not 6 (two dark current, two flatfields, and two targets) or 8 images (two dark current, two flatfields, two targets, and two items) were to be processed by the application. This is now performed automatically by the application through counting how many images were uploaded rather than the user manually selecting that option.
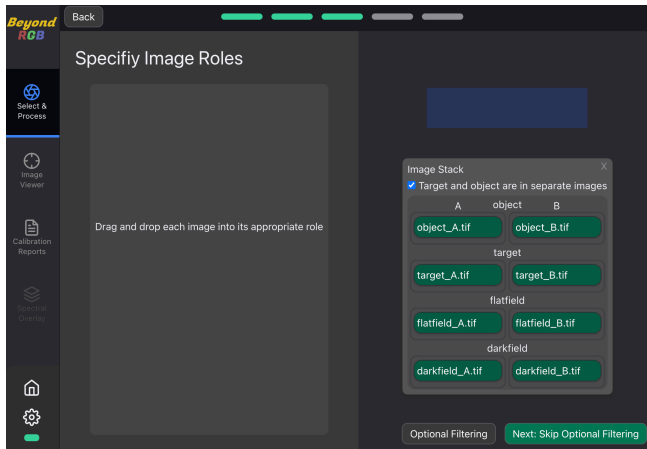
Figure 4. Specify Image Roles on Beyond RGB 1.0 where sorting of the images was to be performed manually and the option needed to be selected if 6 or 8 images are to be processed
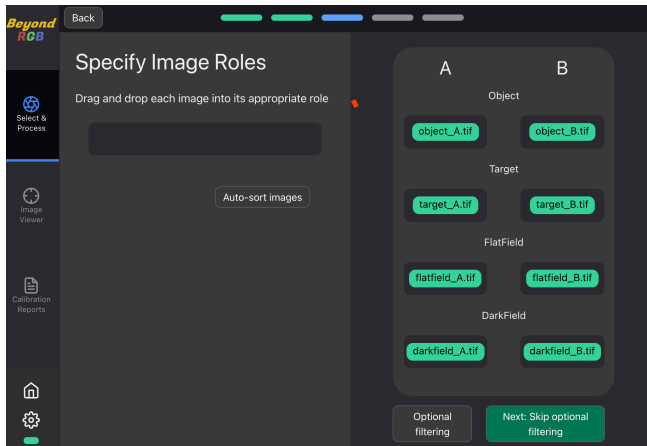

Figure 5. Specify Image Roles on Beyond RGB 2.0 where sorting of the images can be performed automatically and the application automatically detects if 6 or 8 images are to be processed

Target Patch Selection

Within the target patch selection, on this version of the software the zoom feature to position the selection grid was given a smoother response. This now allows a better user experience, more precision, and control in placing the selection grid over the areas of the chosen target to calibrate the image.

Image Viewer

Once the final color-calibrated image is produced in the Image Viewer, the zoom feature shows the percentage the image is zoomed in. This feature was incorporated from feedback to help orient the user on how close they are to detail and to assist with repetitive selection of details.

The estimated reflectance spectra can now be compared with one another. The user may enable this feature, use the spectral picker by clicking on a region of interest, and compare two or more reflectance spectra against each other from various areas of the painting. This feature may help in performing initial

assessments of various regions of the painting and aid in advocating for further material identification techniques.
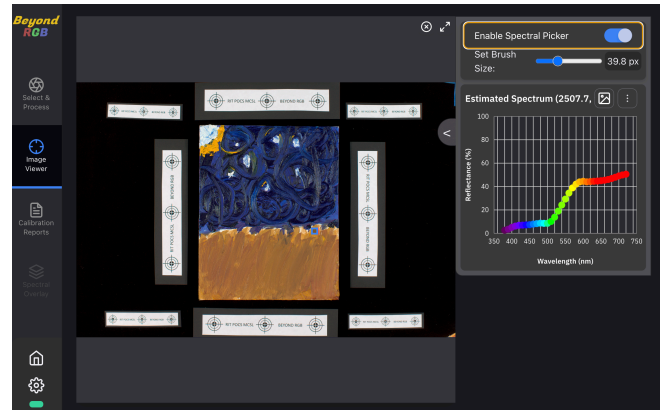

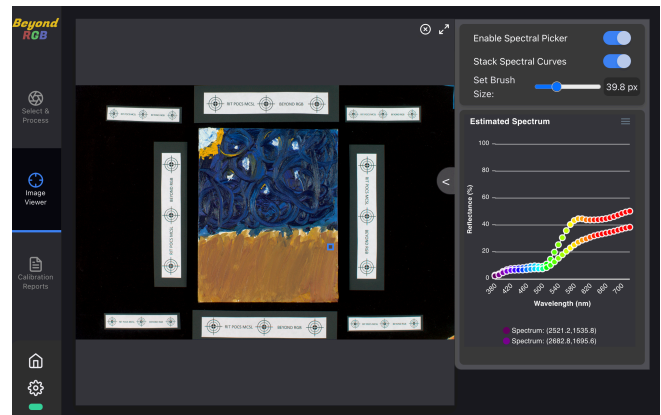Figure 6. Image Viewer on Beyond RGB 1.0, this enabled a single area to be selected for spectral estimation

Figure 7. Image Viewer on Beyond RGB 2.0, this enabled multiple areas to be selected and compared for spectral estimation

Calibration Reports

Under this section, a color difference heat map is created. This heatmap displays the CIEDE2000 color difference between the reference target patches and the estimated color of each of the imaged target patches. The color scales have now been proportioned to better reflect variation in color differences. On the first version of the software, by default the largest color difference would appear as a red even if the color difference was less than 1. The improved version shows only color differences of 5 or larger to appear as a red hue.

For the color difference heat map, another feature was added to take into consideration users with color anomalous vision. This was to change the color difference heat map to a gray scale, where instead of red, black was used to indicate color differences of 5 or larger.

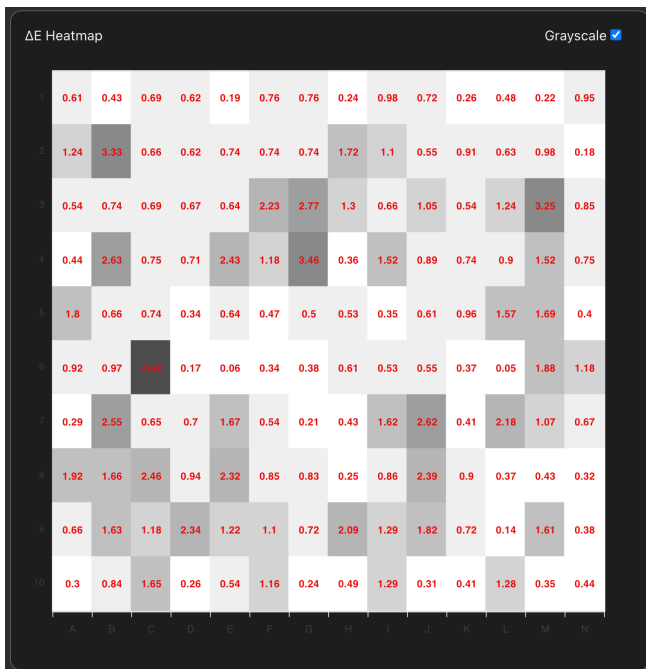*Figure 8. Calibration Report on Beyond RGB 2.0, showing the improved heat map*

Figure 9. Calibration Report on Beyond RGB 2.0, showing the improved heat map in Grayscale mode

Other aspects

With this version of Beyond RGB, the ability to move forward and backward in the application before processing has been improved. Now users are able to return to previous steps and adjust settings or inputs before processing their image. Additionally, there have been improvements to the speed of the backend processing to produce color-calibrated images in a shorter period of time than before.

Dedicated Website

The repository to download the application and obtain other information such as a user guide and software requirements is now found on a more approachable, dedicated webpage hosted by GitHub. This was done to assist users who may not be familiar with navigating GitHub, which includes other aspects of the application that might not be relevant to their needs. Should a user wish to know more about the application, the GitHub repository continues to be a free, open access space to retrieve this information.
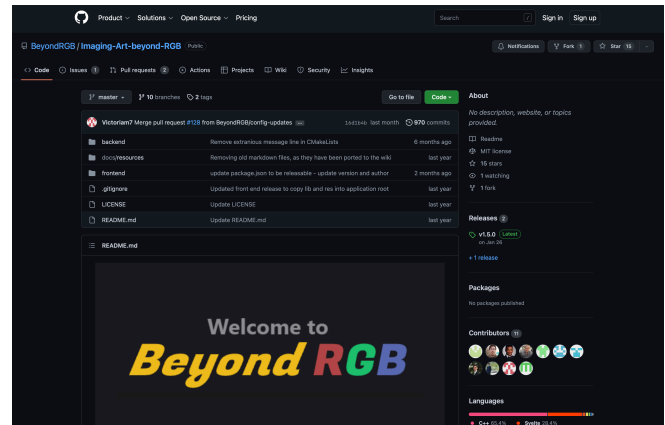

Figure 10. Beyond RGB GitHub repository

Figure 11. Beyond RGB dedicated website hosted by GitHub

Conclusion

These improvements to Beyond RGB enable it to be more readily utilized by cultural heritage professionals to create color-calibrated documentation of their items. Further, it provides not just a low-barrier to entry spectral system to encourage the adoption of this powerful technology, but also intuitive and easy-to-use applications to perform the image analysis as well. These two aspects work in tandem to create a space for the adoption of these

techniques to empower the documentation of items for cultural heritage institutions.

References

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Author Biography

Leah Humenuck is a PhD candidate in Color Science at the Munsell Color Science Laboratory at Rochester Institute of Technology. Leah's research interests are in imaging, reproduction, and lighting for cultural heritage. She is also a book and paper conservator which informs her color science research of archival items. Leah holds a BS in Chemistry from Sweet Briar College and an MA with honors in Conservation from West Dean College of Arts and Conservation.

Susan Farnand is the Graduate Program Director of, and an Associate Professor in, the Program of Color Science at the Rochester Institute of Technology (RIT). Her research interests center around human color vision and perception including individual color vision differences, visual attention, color imaging, image quality metrics, 3D printing, and archiving. Prior to joining RIT in 2006, Dr. Farnand was a Senior Research Scientist at Eastman Kodak Co. working primarily on projects in perceptual image quality measurement and modeling. She holds a BS in Engineering from Cornell University, an MS in Imaging Science, and a PhD in Color Science from RIT. Dr. Farnand is the current IS&T President.