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DIP-Toolbox: A Matlab Toolbox for Automated Image Band Registration and RGB Composition from Multispectral Images Obtained Using UAVs

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Abstract. This work presents the DIP-Toolbox - an open toolbox, developed in Matlab for automated processing of multispectral images. In this paper, we introduce two tools - DIP-align and DIP-RGB, that perform automatic registration of misaligned bands of multispectral images and generate RGB compositions. The aim of the toolbox is to present a quick and easy tool for processing multispectral images that could be easily embedded in image processing workflows or other Matlab applications. The samples used in the development and testing of the toolbox have been obtained using UAVs flying at different altitudes, in the margins of a freshwater reservoir. We developed and calibrated the tools using images containing different proportions of water, land and vegetation.

Keywords: Multispectral images, image registration, image processing, matlab toolbox, UAV.

1 Introduction

UAV multispectral sensors have been used for many purposes and applied on different scales. Studies including [1, 2] have stressed that the capacity to capture data at exceptional spatial and temporal resolutions increases the range of solutions and opportunities for environmental research and remote sensing applications. Following, [1] compared to traditional airborne systems and satellites, UAVs offer high flexibility and versatility, and can be rapidly adapted to changing flight plans and/or schedules. Moreover, the quality and quantity of spatial data gathered in this fashion lead the decision-making process to be faster and more accurate. This is a great advantage for quick-responses to time-crucial applications, e. g., water pollution, invasive macrophytes (aquatic plants) and algae bloom monitoring [3, 4].

Multispectral images captured by drones or other autonomous devices are usually composed of several bands, or scenes, each captured in a by a sensor and covering the same area. These scenes can be combined into RGB compositions or processed to generate indexes such as Normalized Difference Vegetation Index (NDVI), Visible Atmospherically Resistant Index (VARI), Green Atmospherically Resistant Index (GARI), Surface Algal Bloom Index (SABI), among many others [4-7]. Because they are captured by physically separate sensors, the bands of these images are offset relative to one another and need to be aligned before the generation of multiband compositions. The misalignment between bands generally varies according to the physical distance between the sensors and the distance between the camera and the photographed objects [8-10].

Processing images from either hyper or multispectral cameras coupled with drones can often be time consuming. When considering the time reduction for each stage essential in obtaining the final product, the benefits become clear, since the time reduction also culminates in cost reduction. Currently, the mechanisms used for the precise alignment of the spectral bands can be rudimentary and/or often rely on manual techniques or in the use of tools that are specific for each camera model or brand, when these exist. This scenario can be quite limiting for certain camera models or when batch processing is required. The automation of this step can make the processing more viable, resulting in a gain for the community that needs to deal with a large volume of images.

When processing images composed entirely of land, the correct alignment and orientation of the models occurs by obtaining precise coordinates where the connection between the support points registered in the field and the control information stored by the equipment is determined. This process is called phototriangulation or aero triangulation [11]. However, in images composed of various surfaces or composed entirely of water, this procedure can be conflicting and should be avoided due to the difficulty in detecting marked points that can be identified on the image [12].

A long drone flight (around 30 minutes) at 120m (height), with overlap and sidelap values of 80 and 70%, using a camera such as the MicaSense Altum can result in approximately 600 multispectral images, composed of 3600 files. It can be of great use to have the ability to quickly visualize RGB compositions of a certain area, without the need of advanced software, this could even be achieved whilst in the field to check areas which could merit further imaging.

DIP Toolbox (Available at: <github.com/gabrielarabelo/DIP/>) was created in order to provide tools for initial processing of images obtained by multispectral cameras, especially those commonly used in Drones. Toolbox was developed in Objective-C language in Matlab software and is freely available on the GitHub repository. A step-by-step video can also be seen on <youtu.be/9N0O5Os6J78>.

The registration of the images is done using the intensity-based image registration technique and the optimization parameters were adjusted from training images obtained in mixed areas on the edge of a lake, containing different proportions of water, land and vegetation. The optimized parameters were set as the program's default, but these can be changed by the user to adapt to any particular image set.

In this article, we will present the DIP_align tool, part of the Toolbox, which performs the following actions:

- Import all bands.
- Perform intensity-based image registration for all the bands.
- Crop image edges where not all bands overlap.
- Save files of the aligned bands.
- Generates RGB compositions from the selected bands using the encapsulated tool DIP_RGB.
- Enhances RGB compositions with the use of histogram correction, haze elimination and gamma correction tools.
- Save enhanced RGB composition files.

The main techniques used in the tool will be presented over the next sections.

2 Materials and Methods

2.1 Sample Images

The camera we use (MicaSense Altum) has 6 sensors which capture 6 16-bit monochromatic images of the same region, in different bands of the spectrum. For each shot, 6 files will generate - each with the information captured by a band (see Fig. 1).

The images used for calibration were obtained near the Três Marias Reservoir, in Brazil (-18.604158, -45.233450), using a multirotor NuvemUAV Spectral. The samples have been obtained during two field campaigns, and along eight days with variating atmospheric conditions.

The flights varied in duration (12 to 30 minutes), and in height (80m and 200m). After these two field campaigns we acquired over 9,000 images (over 56,000 files). From this set, we selected 50 samples, containing diverse features (land, trees, ground, water) in different proportions (varying from water only to land only), among other images such as those in which our boat could be seen or those with features of interest, such as aquatic plants or fish farms (see Fig. 2).

State of the Art Technique

In order to perform a comparison with state-of-the-art techniques, in this section we utilized one of the most traditional software in the field to register the bands of one of the images.

When processing is performed in ArcGIS on raw images, the method can be performed using the Georeferencing tool (ArcGIS v.10.5).

Initially, it is necessary to identify some reference points between the images and add control points that will guide the alignment. When choosing which layer to align, the points must be selected, one by one, in the first image and related according to the reference of the second image. After this process it is necessary to save the updates.

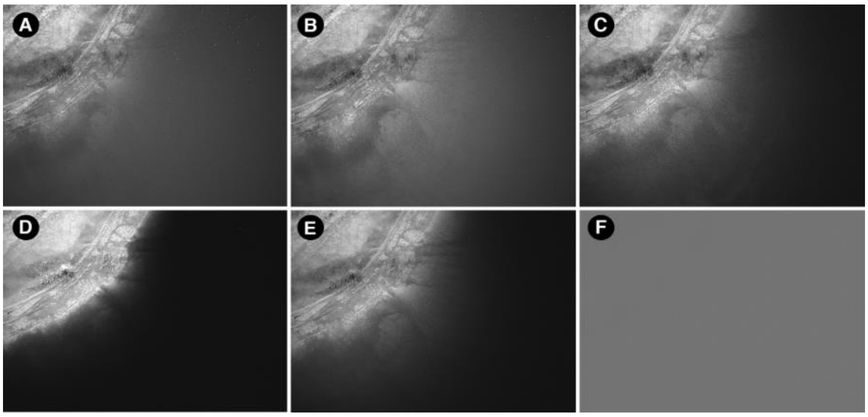

Fig. 1. Six bands of the same image captured by the camera MicaSense Altum, taken in a flight at a height of 120m. (A) Blue (475 nm center, 32 nm bandwidth), (B) Green (560 nm center, 27 nm bandwidth), (C) Red (668 nm center, 14 nm bandwidth), (D) Red Edge (717 nm center, 12 nm bandwidth), (E) Near-IR (842 nm center, 57 nm bandwidth), (F) LWIR thermal infrared 8-14um.

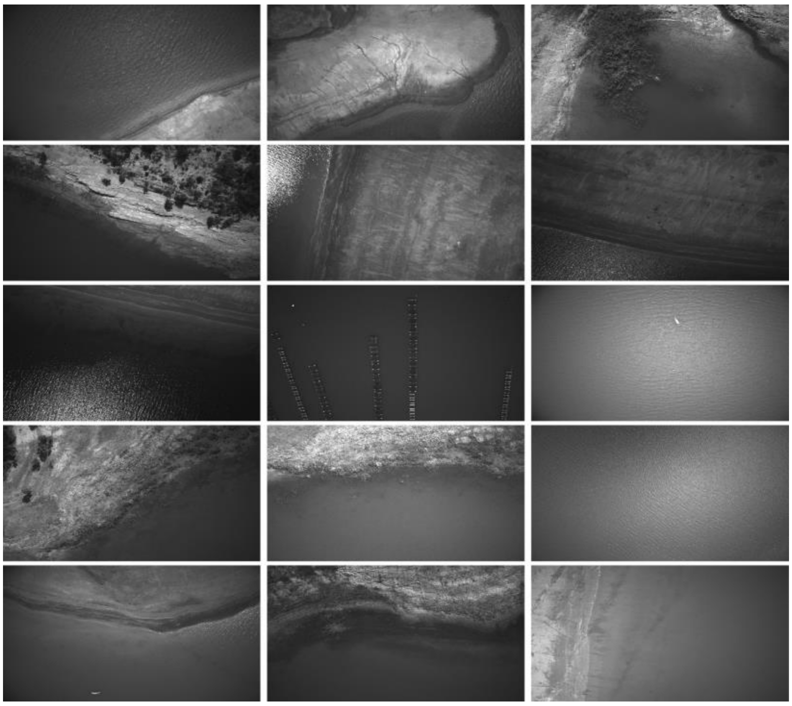

Fig. 2. Selected bands of some of the samples used in the calibration step.

Aligned, it is possible to perform the RGB composition using the tool available in *ArcToolbox* called *Composite Bands* and, thus, obtain the colored composition (see **¡Error! No se encuentra el origen de la referencia.**).

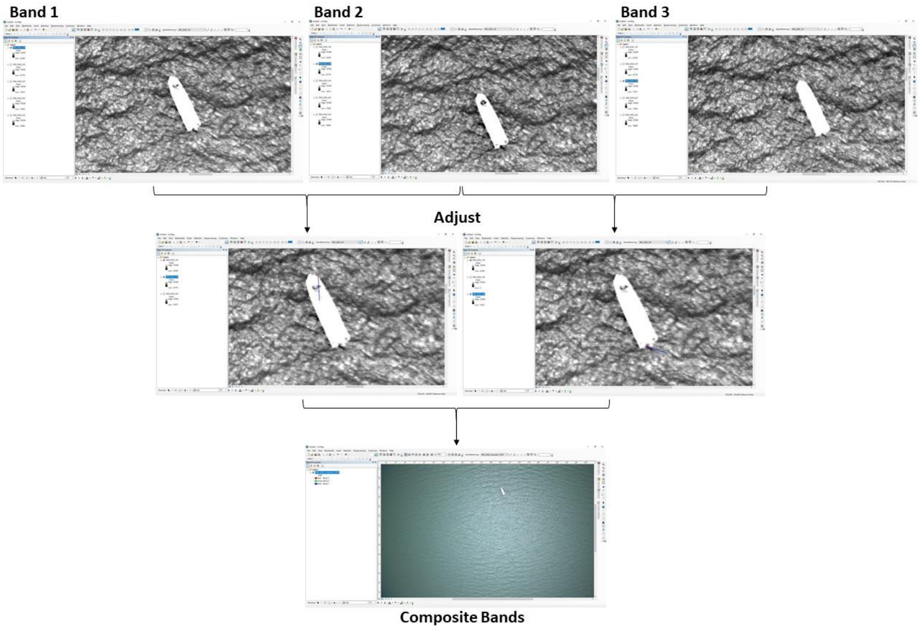

Fig. 3. Image Registration process using ArcGIS and the Georeferencing tool (ArcGIS v.10.5).

2.2 Band Register Alignment

The optimization methods and parameters were defined after a sequence of tests with images obtained in different areas, under different atmospheric conditions and through flights at different altitudes (see Fig. 2).

To align the bands obtained by different sensors, we used the intensity-based image registration technique, implemented through the function *imregister*, introduced in R2012a. The function *imregister* uses the optimizer, a metric, and a transformation type to find the search and find the best fit for each two images. The best results were achieved with the transformation of type 'rigid' and the optimizer and metric configures according to the following parameters:

```
InitialRadius = 0.0002

Epsilon         = 0.0000015

GrowthFactor     = 1,002

MaximumIterations = 500
```

The alignment is done two by two, from a band of reference. The best results for our calibration dataset were obtained using Band 2 (Green, 560 nm center and 27 nm bandwidth) as a reference for the alignment of the other bands (see Fig. 4).

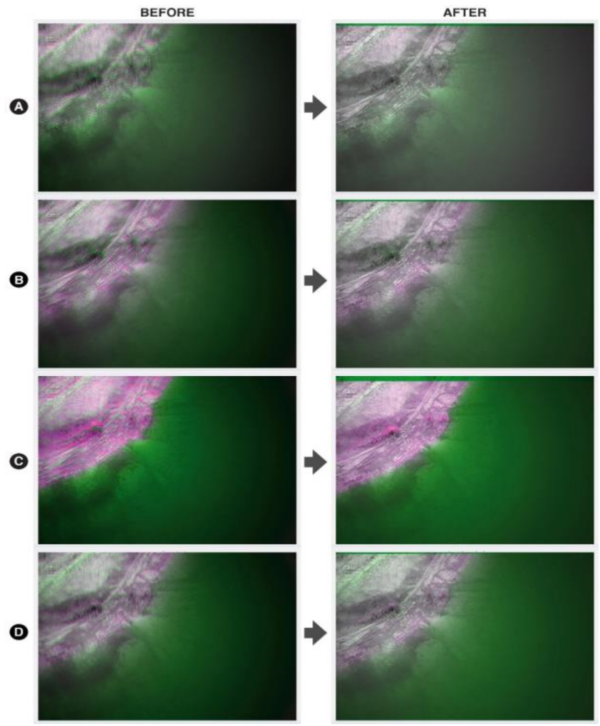

Fig. 4. Alignment of each band according to the reference band (band 2). (A) Bands 1 and 2. (B) Bands 3 and 2. (C) Bands 4 and 2. (D) Bands 5 and 2. As for MicaSense Altum the sixth band has a size much smaller than the others (160x120px, whereas the other bands are 2064x1544px), the alignment is not necessary.

Figure Fig**. 5** shows the example of an RGB image (generated from bands 3-2-1) before and after the alignment. As a last step after all the bands have been aligned, the program will crop the edges of the image that are missing one or more bands.

2.3 Image Color Enhancement

For each RGB composition, the program will plot and save extra images with enhanced colors. The color enhancement usually provides a better visualization of the spectral features, and it is especially useful for multispectral images. At its current stage, the program applies three different color enhancement transformations, coupled in two presets:

– Haze & Gamma Adjustment: this preset performs a combination of reducing Atmospheric Haze and Gamma correction (see Fig. 6A).

– Stretching Contrast Limits: this preset computes the lower and upper limits of each band and uses the values obtained for contrast stretching the RGB image (see Fig. **6**B).

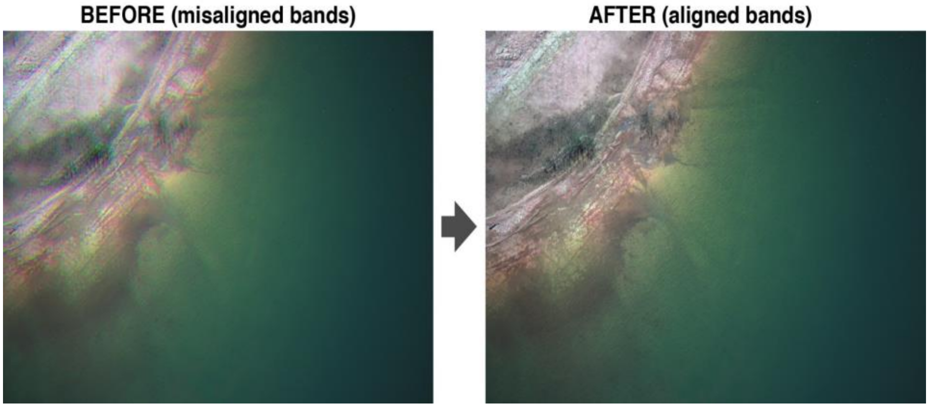

Fig. 5. RGB composition using bands 3-2-1 before and after the alignment of the bands.

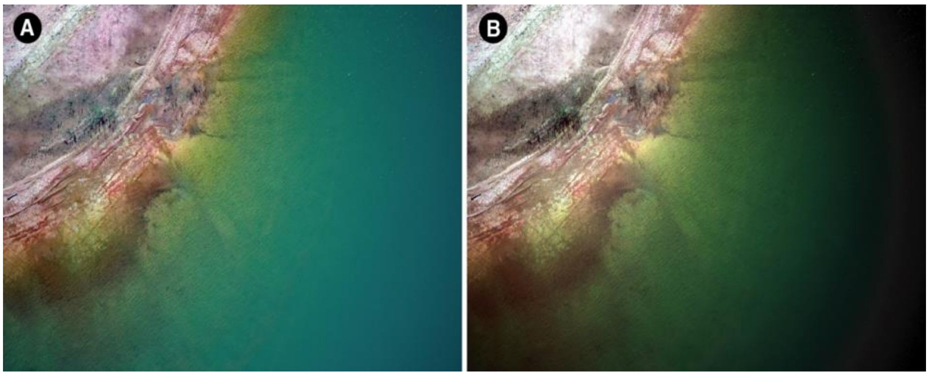

Fig. 6. Enhanced RGB (3-2-1) compositions using (A) Default Haze reduction and Gamma correction and (B) Stretching Contrast Limits.

2.4 Custom RGB Compositions

Once the bands have been aligned, the program proceeds to generate custom RGB images, composed from bands other than the corresponding Red, Green and Blue (see Fig. 7).

The band combinations can be inputted before calling the program function or after the initial RGB processing there will be a prompt for further custom combinations. For each composition, the program will automatically apply the color enhancement methods described in the previous section and save both images.

Custom RGB compositions can be useful for highlighting certain objects or features in images that may appear similar on the visible spectrum. In Fig. 8, a default RGB (3-2-1) composition is compared to a custom RGB composition (4-2-1). The latter highlights the contrast between the aquatic plants and the water.

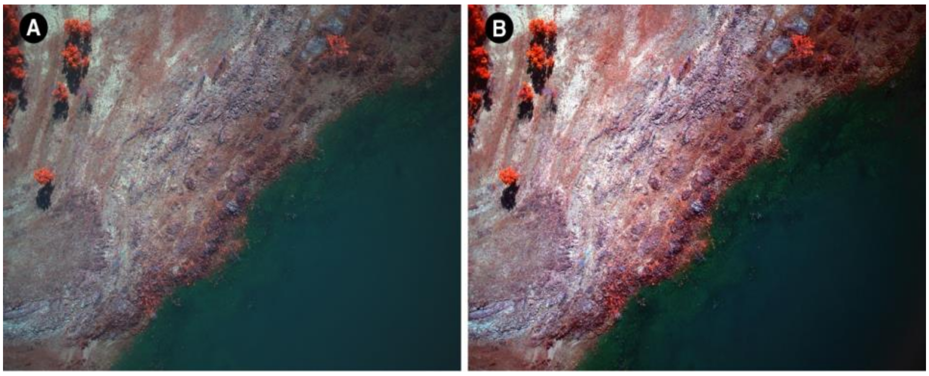

Fig. 7. Two RGB (4-2-1) compositions. (A) RGB (4-2-1) before enhancement. (B) Enhanced RGB (4-2-1) after using Stretching Contrast Limits.

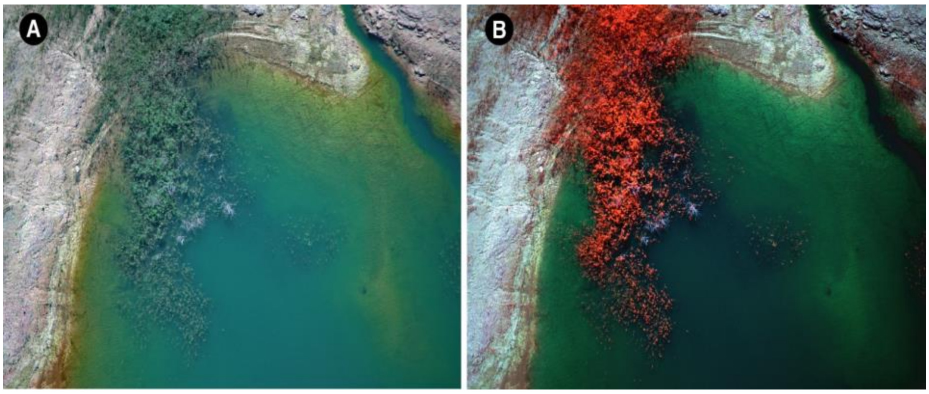

Fig. 8. Two RGB compositions from the same multispectral image. (A) Visible RGB (3-2-1) enhanced composition. (B) RGB (4-2-1) enhanced composition highlighting the presence of aquatic plants.

2.5 User Commands, Function Calling and Program Routine

The DIP_align tool can be used by calling the DIP_align function. This function has 1 optional input (parameters), which is a variable of type struct containing information about the camera, number of image bands, optimization parameters for image registration, and for image enhancement:

```
DIP_align
DIP_align(parameters)
```

The optional variables of the current version are presented in Table 1.

Each parameter presented in Table 1 should be declared as a field of the input variable parameters, as in the following example:

Table 1. Optional Input Parameters for DIP_align.

Parameter	**Type**	**Description**
nband	number (double)	Number of bands captured by the camera
camera	string	Camera model
band_specs	cell array	Cell array containing the specification of each band of the camera (automatically generated for Altum and RedEdge)
RGB_bands	3-column vector	Band sequence for traditional RGB composition. Default is 321.
customRGB	3-column vector or matrix	Band sequence for RGB prompt compositions that will be generated without user
customMode	logical	Opens a dialog box so the user can enter custom RGB compositions
InitialRadius	number (double)	Optimization parameter for *imregister*
Epsilon	number (double)	Optimization parameter for *imregister*
GrowthFactor	number (double)	Optimization parameter for *imregister*
MaximumIterations	number (double)	Optimization parameter for *imregister*
TransformType	string	Optimization parameter for *imregister*
ref_band_align	number (double)	Band to be taken as reference for the image registration
scale	number (double)	Factor to scale images (useful for images that are too big or for using orthomosaics)
skip_bands	vector (double)	Bands to be ignored during the image alignment (to be used with bands which the size is too different from the other bands)
haze_adj	number (double)	Number between 0 and 1 as input for *imreducehaze*
haze_adj_method	string	Method for *imreducehaze*
gamma_adj	number (double)	Number between 0 and 1 as input for gamma correction using *imadjust*

```
parameters            = struct;
parameters.camera     = 'altum';
parameters.customRGB  = [4 5 2; 4 2 1];
parameters.customMode = true;
```

After calling the function *DIP_align*, or *DIP_align(parameters)*, the program will start to run.

The user will first be prompted to select one band of the multispectral image to be aligned. Selecting only one band is enough and the program will automatically identify and import the other band files (as long as the file names follow the pattern *"_<band-number>"*).

The user will then be prompted to select a folder to save the output files.

The user will then be prompted to enter a custom name prefix for the output images that will be exported.

After that, the program will perform the image registration alignment and the program will plot the following:

– RGB image before the image registration.

– Before and After of the bands of the image being aligned.

– RGB image after the image registration.

The program will then plot and save high-resolution images of the RGB Compositions in the following sequence: Regular RGB; Haze & Gamma Adjusted RGB; Stretch Limits Adjusted RGB.

After that, in case the user selected the Custom Mode, the user will be prompted to enter any band combinations to generate other custom RGB compositions.

Finally, all the high-resolution images will be saved in the output folder.

3 Results and Conclusion

After the calibration step, the program managed to successfully align 40 of the 50 multispectral images of the sample set (see Fig. 9) using the default image registry optimization parameters of the program. However, in 10 of the sample images, one or more bands did not align correctly; these 10 images did not have any land in them. In all of the cases, the alignment of the band 4 (Red-Edge) was the most persistent issue. All 10 issues were resolved by either adjusting the *InitialRadius* to 0.00025 and or, changing the Reference Band (*ref_band_align*) to Band 5.

Although all of the image samples for this work were aerial images obtained with UAVs, it is very likely that the tools presented would work for other types of images obtained with multispectral cameras.

The computational toolbox resulting from this work is fully automated, which means it requires very little or no programming background, but still allows custom parameters, which means that it can be adapted to different areas and purposes. As the program relies on the visual information of the images it works with different camera models and manufacturers with consistent results. In the current version, the program requires a Matlab license to run but the program itself is open access.

4 Future Work

We are currently working on the improvement and expansion of the Toolbox and soon it will come equipped with tools for obtaining RGB compositions and some of the most common algorithms (such as NDVI, VARI, GARI, SABI) from multispectral orthomosaics, alongside other Tools. The tools presented will also be updated in order to automatically display band information from images obtained with other multispectral cameras and brands available on the market.

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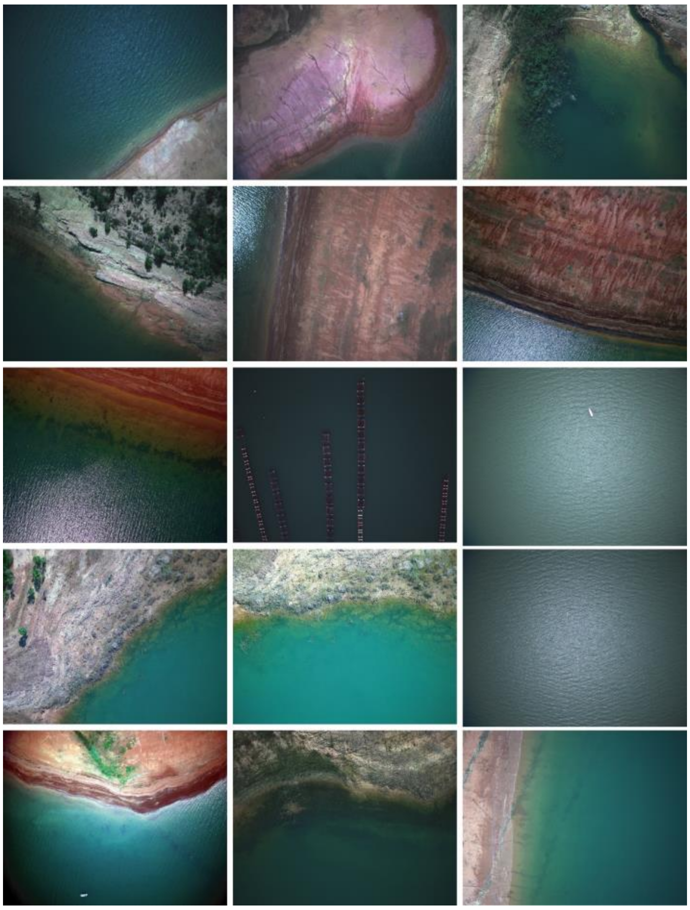

Fig. 9. A selection of some of the RGB (3-2-1) compositions obtained from the samples used for calibrating and testing the program.

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