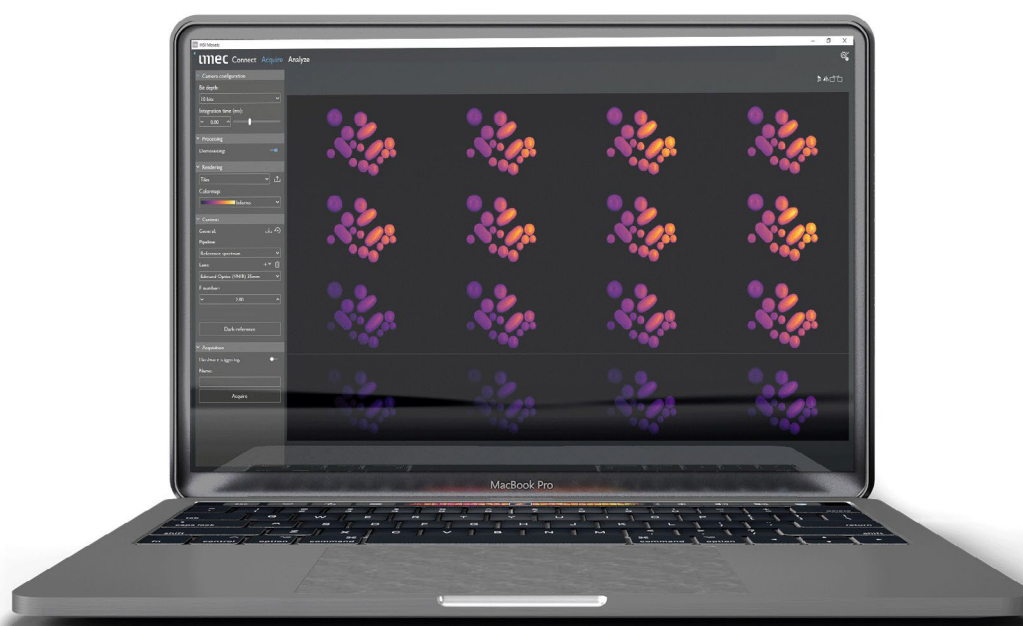


HSI MOSAIC

SOFTWARE MANUAL

Dear Customer,

We are currently updating the HSI Mosaic software manual. Until the official release of the new manual, please use the current document for general background information and basic functionalities, together with the engineering document “User Journeys.pdf” to guide you during the use of HSI Mosaic V2. Please do not hesitate to contact us at hsisupport@imec.be if you have any questions.



User manual update of February 21, 2022

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This document is the original English user manual.

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1. Introduction

1.1 Introduction

Dear customer, thank you for choosing imec's hyperspectral imaging solutions.

HSI Mosaic is an advanced hyperspectral imaging software for cameras with an imec snapshot spectral imaging sensor. The main purpose of the software is acquiring and processing data into high quality hypercube data sets. The snapshot sensor at the camera's core is equipped with an integrated array of narrow band filters, patterned in a mosaic layout. This enables video rate acquisition of spectral image data with the ease of use of a regular machine vision camera.



Figure 1: Snapshot sensor

The software enables acquisition, processing and analysis of hyperspectral image data. It offers you the flexibility to configure a range of acquisition parameters to tailor the data acquisition and helps you to acquire good quality irradiance, reflectance and transmittance data. It also provides several useful visualization tools and a built-in classifier to quickly visualize and analyze the acquired data.

1.2 The HSI Mosaic workflow

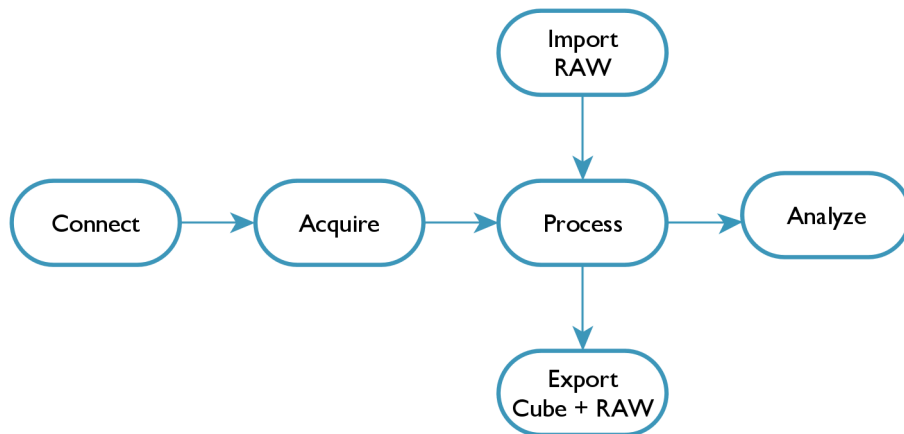


Figure 2: The HSI Mosaic workflow

HSI Mosaic was designed to get the maximum performance out of the imec hyperspectral sensor. For this reason, the software first acquires raw data with minimum overhead after which the user can process them to maximum quality hyperspectral data cubes.

These raw data can also be exported to disk and imported at a later stage to reprocess with different processing settings.

1.3 The manual's objectives

The HSI Mosaic user documentation aims to:

- Familiarize you with the user interface and utilities, addressed in the first chapter [General HSI Mosaic functionalities and utilities](#) on page 9.
- Provide you with correct workflows and accompanying instructions to efficiently acquire and analyze images. This goal is tackled in three phases, each covered in a chapter:
 - [Connecting the camera](#) on page 16
 - [Acquiring images](#) on page 20
 - [Data processing, viewing and exporting](#) on page 31

2. General HSI Mosaic functionalities and utilities

2.1 The HSI Mosaic user interface

Status colors in the HSI Mosaic user interface

Text and graphic elements such as lines, frames and icons can change color depending on their status.

A look at icons in the Selection panel in the Analyze tab explains in a simple way how colors are used to indicate the status of a user interface element.

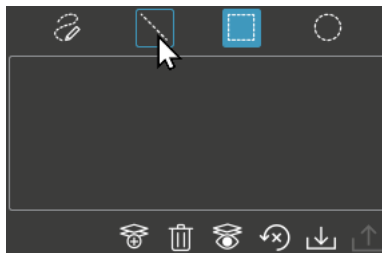


Figure 3: Color use in the user interface

Color	Example	Description
Permanent blue		Selected
Blue at mouseover		Selectable
Greyed out		Non-selectable

User interface elements

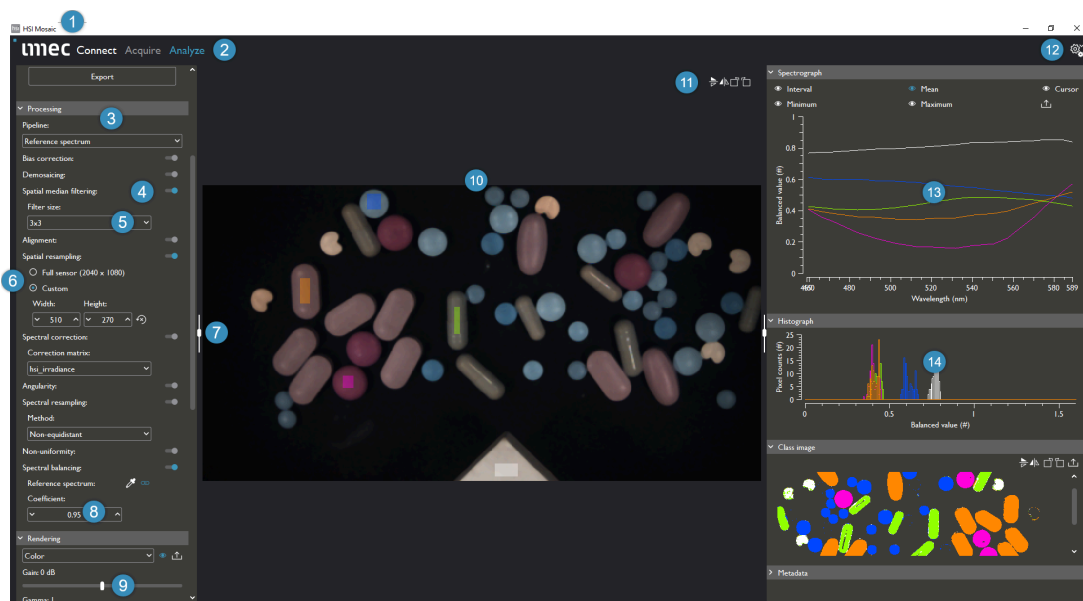


Figure 4: User interface elements

Nº	UI Element	Description
1	Title bar	Software title Minimize, maximize and close window
2	Tabs	Navigate to the different tabs. The Analyze tab is selected.
3	Panel	Expandable/collapsible grouped software functionality, for example, the Processing panel
4	Toggle button	Enable/disable button (or just showing the enabled/disabled state of the according functionality)
5	Drop-down list	To select an option from a list
6	Radio button	To select functionality options
7	Handle bar	To change width of a user interface element
8	Text field	To enter a text or a value
9	Slider	To adjust parameter settings
10	Image window	Displays the current camera view or acquired image
11	Icon	General user interface element function
12	Utility menu	Access to utilities as language, view, logs, help.
13	Spectrograph panel	Shows the spectra of the selections on the image
14	Histogram panel	Shows the histogram of the selections on the image

Table 1: User interface elements (Analyze tab)

See also

[The utility menu](#) on page 13

[General user interface functionality](#) on page 11

2.2 General user interface functionality

2.2.1 Change the width of the image window and the panels

In the Analyze tab, the width of the image window and accordingly the left or right panels can be changed.



Figure 5: Vertical handle bar

1. Grab the vertical handle bar or a vertical edge of the image window.
2. Steer left or right.
3. Release the handle bar or the edge of the image window.

2.2.2 Expand/collapse a panel

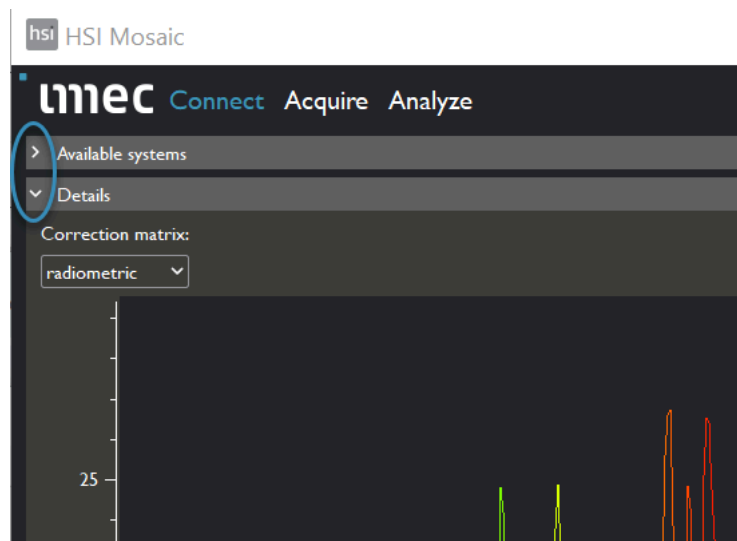


Figure 6: Expand and collapse arrows

Click the panel title, for example in the **Connect** tab, click **Available systems**. You can also click the arrows to expand or to collapse the panel.

See also

[Zoom in/out on an image](#) on page 12

2.2.3 Flip or rotate an image

Click one of the following icons:

-  **Flip vertically**
-  **Flip horizontally**
-  **Rotate clockwise**
-  **Rotate anticlockwise**

See also

[Zoom in/out on an image](#) on page 12

2.2.4 Zoom in/out on an image

You can zoom in or out on an image in for example the image window or the class image panel.

1. Move the mouse pointer to the image window or panel.
2. Scroll up/down.

See also

[Flip or rotate an image](#) on page 11

[Expand/collapse a panel](#) on page 11

2.2.5 Show/hide an item or selection

An item can be set to visible or hidden.

Click or double click one of the following icons to change its status:

Icon	Status
	• Blue: Visible item • White: Hidden
	• Blue: Visible selection • White: Hidden selection

2.2.6 Export/import: overview

Exports are performed with the  icon.

Imports are performed with the  icon.

Detailed export/import dialog box instructions can be found in each specific topic (see topic references in the table below).

Tab	Panel	Topic reference
Analyze Acquire	Rendering	Export the current rendered image on page 23

Tab	Panel	Topic reference
Acquire	Context	Export/import a context on page 29
Analyze	IO	Export collections and/or context on page 33 Import an unprocessed collection to analyze on page 34
Analyze	Selection	Export the selection information and/or mask for reuse on page 45 Import the selection information and/or mask for reuse on page 45
Analyze	Classification	Export the classifier on page 51 Export the classifier on page 51
Analyze	Spectrograph	Export spectrograph data on page 46
Analyze	Class image	Export the class image on page 52
Analyze	Metadata	Export metadata on page 53

Table 2: Export/import instruction references

2.3 The utility menu

The utility menu  allows you to view software info, set preferences, get help, ...

Option	Description
 Languages	Select one of the available languages, close and restart the software.
View	Select a view: • Default: high-quality workflow with optimal default settings; complex settings are hidden in the user interface. • Extended: all processing and settings information and functionality for in depth comprehension. This allows you to have a better control over the hyperspectral imaging process. See Extended view information in the Analyze tab on page 38.

Option	Description
Logs > Verbosity	The verbosity level of a log message reflects the amount of information the log message provides. The available levels; in ascending order of the amount of info, are: • Error • Warning (default) • Info • Verbose • Debug NOTE The higher the amount of info is logged, the more disk space will be consumed. It is therefore recommended to only use the levels Info, Verbose and Debug as long as required and then switch back to Error or Warning. NOTE Logs are stored in ... \AppData \Roaming\imec\HSI Mosaic \logs of your user folder, for example; C:\Users\<userName> \AppData \Roaming\imec\HSI Mosaic\logs
Help > Contact us	For support, questions and remarks, fill in and send the Contact us form that appears. You can also send an email to hsisupport@imec.be.
Help > About.	Version information is shown and you can click Visit us to open the Hyperspectral imaging website (https://www.imec-int.com/en/hyperspectral-imaging).

Table 3: Utility menu options

See also

The HSI Mosaic user interface on page 9

General user interface functionality on page 11

2.4 Extended view functionality

Extended view functionality
Select the bit depth of the camera on page 22
Enable/disable spatial median filtering on page 35
Enable/disable the angularity correction on page 36
Extended view information in the Analyze tab on page 38: • Bias correction: • Demosaicing: • Alignment:

Table 4: Extended view functionality

2.5 System requirements

Requirement	Minimum	Recommended
OS	Windows 10 64 bit	Windows 10 64 bit
Processor	Intel i5 7th gen or AMD Zen 2 GHz 64 bit support	Intel i7th gen or AMD Zen + or better 4 GHz or faster 64 bit support
RAM	8 GB	32 GB or more
Disk		SSD SATA III 500MB/s write speed > 5 GB free storage

Table 5: System requirements

3. Connecting the camera

3.1 Authenticate a camera in HSI Mosaic

When you connect a camera for the first time, it is not yet recognized in the HSI Mosaic software. A system/camera card will be shown for the new camera, indicating the sensor data is not found.

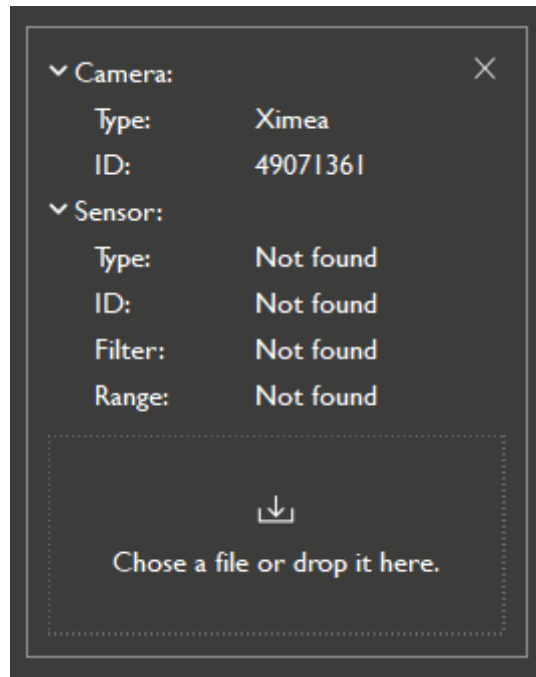


Figure 7: System/camera card of a non-authenticated camera

To authenticate the camera, you will have to add the calibration file to HSI Mosaic. The calibration file name contains the serial number of the sensor; for example the file name CMV2K-SSM4x4-595_860-13.10.5.4 with 13.10.5.4 being the sensor serial number.

1. Connect the camera to the computer and turn the camera on.
2. Open the **Connect** tab.
3. At the **Available systems** panel, click .
The system/camera cards of cameras that are turned on and connected to your computer are shown.

4. In the system/camera card of the camera that you want to authenticate, click , browse to the calibration file and click **Open** or drag and drop your file to the card.
The camera is now recognized and the sensor data in the system/camera card are filled in.

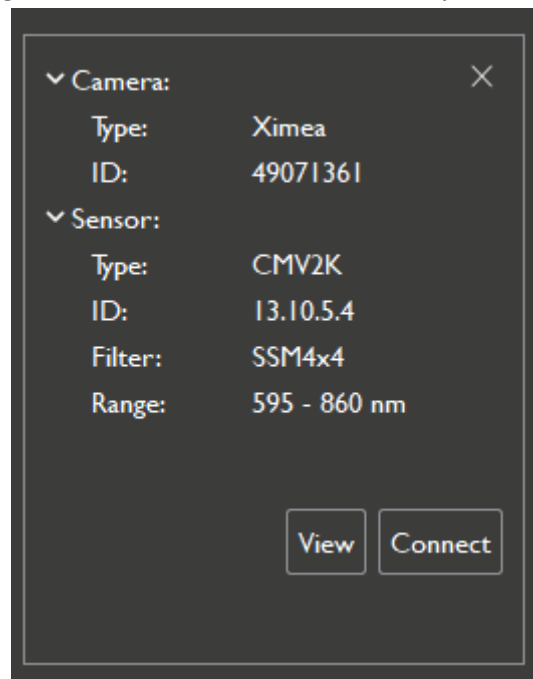


Figure 8: System/camera card of an authenticated camera

See also

- [Connect a camera to HSI Mosaic](#) on page 17
- [Find cameras connected to your computer](#) on page 18
- [Connecting the camera](#) on page 16

3.2 Connect a camera to HSI Mosaic

To connect a camera to HSI Mosaic it has to be authenticated.

1. Connect the camera to the computer and turn the camera on.
2. Open the **Connect** tab.
3. At the **Available systems** panel, click .
The system/camera cards of cameras that are turned on and connected to your computer are shown.
4. In the system/camera card of the camera that you want to connect, click **Connect**. When a dialog box appears, confirm if you want to use your last optical setup.
The camera connects to HSI Mosaic and the **Acquire** tab opens.

See also

- [Authenticate a camera in HSI Mosaic](#) on page 16
- [Find cameras connected to your computer](#) on page 18
- [Determine context and non-uniformity \(irradiance pipeline\)](#) on page 25
- [Connecting the camera](#) on page 16

3.3 Find cameras connected to your computer

When opening HSI Mosaic, it checks for cameras that are connected to your computer to show them in the **Available systems** panel. However, if the system/camera card of your camera isn't shown because, for example, you connected a camera to your computer after opening HSI Mosaic, you have to refresh the **Available systems** panel.

NOTE

HSI Mosaic will only find cameras that are switched on.

1. Make sure your camera is connected to the computer and the camera is turned on.
2. Open the **Connect** tab.
3. At the **Available systems** panel, click ↻.

See also

[Connect a camera to HSI Mosaic](#) on page 17

[Authenticate a camera in HSI Mosaic](#) on page 16

[Connecting the camera](#) on page 16

3.4 Show the spectral response of a system

The system's spectral response reflects the sensitivity of the system per spectral band to light at different wavelengths. The system response is a combination of the following factors:

- The sensor quantum efficiency at each wavelength (i.e., how efficiently photons are converted to electrons).
- The transmission efficiency of the narrow-band Fabry-Pérot filters on the sensor.
- The attenuation through other components in the system, such as the system level band pass filter.

Multiple system variants may be possible depending on the sensor type and other system level filters added in the optical path to select a specific spectral range. When available, you can select them in the Correction matrix drop-down list (step 3 of this procedure).

NOTE

This selection is purely visual and does not impact the software. It is important to select the appropriate matrix in the pipeline in the Analyze phase.

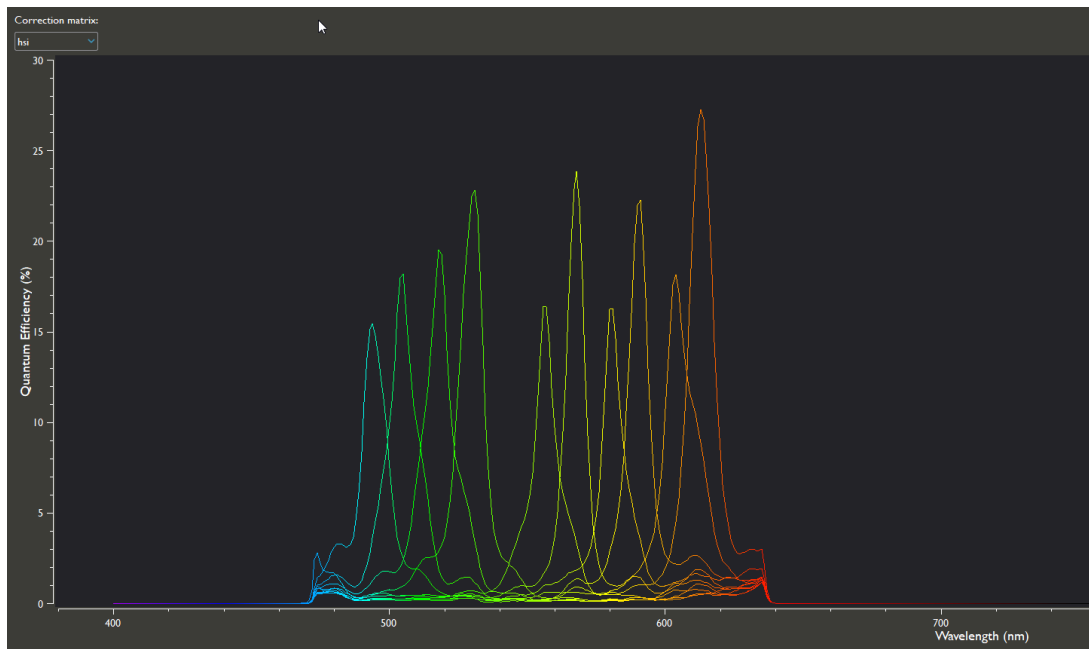


Figure 9: The spectral response

1. Open the **Connect** tab.
2. At the **Available systems** panel, in the system card, click **View**.
In the **Details** panel the quantum efficiency-wavelength graph, representing the spectral response, is shown for the system.
3. Select the **Correction matrix:** from the drop-down list.

See also

[Show or hide the camera information](#)

[Show or hide the sensor information](#)

[Connecting the camera on page 16](#)

4. Acquiring images

4.1 Acquire workflow

Acquiring images of the highest possible quality is by far the most crucial step in your workflow. HSI Mosaic's irradiance pipeline (reference spectrum pipeline) is a method to acquire top quality images in all conditions and in any environment.

In addition to the irradiance pipeline, HSI Mosaic still offers the classic but much less widely applicable reflectance pipeline (full coverage pipeline).

1. The first step to achieve a quality image is the accurate configuration of the camera:
 1. We recommend to turn **Demosaicing**: on (default), see [Enable/disable demosaicing](#) on page 22. This allows you to optimally set the integration time and to focus the lens properly in the next steps. You can select **Tiles** (all bands are shown side by side in the image window) or **Single band** (only one selected band is shown in the image window) and optimize these settings in each band, see [Adjust the Acquire tab rendering settings](#) on page 23.
 2. Roughly adjust the **Integration time (ms)**: of the camera, see [Set the integration time of the camera](#) on page 21 and then focus the lens on the sample.
 3. Fine tune the **Integration time (ms)**:, see [Set the integration time of the camera](#) on page 21.
2. In the second step, you determine the context parameters depending on the pipeline you will use and acquire the image.
 - [The irradiance pipeline](#) on page 24
 - [Determine context and non-uniformity \(irradiance pipeline\)](#) on page 25
 - [Define and add a custom lens \(irradiance pipeline\)](#) on page 26
 - [Add a predefined lens \(irradiance pipeline\)](#) on page 26
 - [Delete a lens \(irradiance pipeline\)](#) on page 27
 - [The reflectance pipeline](#) on page 27

When you acquired an image, you can export the context parameters and reuse them for new acquisitions with the same context, see:

- [Export collections and/or context](#) on page 33
- [Export/import a context](#) on page 29

NOTE

The larger the aperture (diaphragm opening), the lower the f-number of the lens and the more light is collected, but the shallower the depth of focus. The maximum aperture (lowest f-number) to be used is f/2.8. We recommend to start focusing at f/2.8. If you examine a 3D sample, start focusing at the average depth of the sample. Then gradually increase the focus depth (by increasing the f-number) until the part of the sample that matters for your research is in focus.

4.2 The acquire tab histogram

The **Histogram** in the **Acquire** tab shows the **Pixel counts** as a function of the **Digital number**.

To optimally use the dynamic range of the sensor, you can adjust the integration time and monitor the histogram: a higher dynamic range results in a higher pixel count in the histogram. See [Set the integration time of the camera](#) on page 21.

You can highlight the pixels in the image window with a pixel count below a set **Lower threshold** or above a set **Upper threshold** of the **Digital number**. Standard the **Lower threshold** is 0 and the **Upper threshold** is at the maximum. With the standard settings, only saturated pixels are highlighted (red).

You can:

- Make the thresholds **Visible** () or **Hidden** (.
- Change the color of the thresholds.
- Change the thresholds by entering their values, with the arrows or with the sliders.
- Reset () the threshold values to their standard values.

4.3 The temperature graph

The **Temperature** graph in the **Acquire** tab shows the sensor **Temperature (°C)** as a function of the **Acquisition time (hh:mm)** of the last 30 minutes.

Sensor temperature affects the leakage current of the pixels. Calculations that use dark reference images will compensate for sensor leakage.

HSI Mosaic can acquire and save multiple dark reference images during an image acquisition session to cope with the temperature changes. To get the best spectral accuracy in acquisitions, wait until the camera temperature stabilizes before acquiring images and white/dark references. Also, wait for temperature stabilization between individual acquisitions during longer sessions.



NOTE

Usually, the temperature decreases when the lens is covered or when a snapshot is taken.



CAUTION

In direct sunlight or near a heat source, the temperature of the sensor can become too high. Move the camera or use insulation to shield it.

4.4 Set the integration time of the camera

The first step to achieve a quality image is the accurate configuration of the camera, with setting the integration time and focusing the lens, see [Acquire workflow](#) on page 20.

The integration time determines how long the sensor of the camera collects photons from the scene. The longer the integration time, the more light is collected from the scene before the sensor is read and the higher the pixel intensity values.

The goal is to expose the sensor to the light of the scene for as long as possible so that the intensity (digitized and recorded as a digital number) of the pixels is as high as possible without saturation of the sensor. In this way, the dynamic range of the sensor is optimally used.

NOTE

You can monitor the histogram to optimally use the dynamic range of the sensor, see [The acquire tab histogram](#) on page 20.

Standard, HSI Mosaic shows the saturated pixels in the rendered image as red pixels. Start with a long integration time, then reduce it until there are no red pixels visible in areas of interest for the scene.

NOTE

Saturation (red pixels) in the area of the scene background or from specular (mirror-like) reflection of the scene can be tolerated so that the intensity values of the areas of interest can be kept as high as possible. You can for example tolerate saturation of specular reflection of a polished metal, water, a shiny glass or apple, ...

In the **Acquire** tab, in the **Camera configuration** panel, at **Integration time (ms)**:, type the integration time or use the slider or arrows.

See also

[Select the bit depth of the camera](#) on page 22

4.5 Select the bit depth of the camera

Bit depth is the number of bits used per pixel to digitize the intensity values into digital numbers.

Standard (recommended), the highest bit depth is selected. You can only decrease the default bit depth in extended view.

Decreasing the bit depth decreases precision. Since less bits are used to save the image data, decreasing the bit depth also decreases the storage amount. Reducing the bit depth should be avoided as much as possible, but allows higher frame rates.

In the **Acquire** tab, in the **Camera configuration** panel, at **Bit depth**:, select the desired bit depth from the drop-down menu.

See also

[Set the integration time of the camera](#) on page 21

4.6 Enable/disable demosaicing

An image sensor is a 2D array of light-sensitive photodiodes, the pixels. In order to capture differences in wavelength (color), a filter array (mosaic) is placed over the sensor, so that specific pixels register specific wavelengths of light.

Without processing (demosaicing disabled) you see the raw image. When you zoom in, you see the 'mosaic' pattern generated by the wavelength filter array.

A demosaicing algorithm reorders the sensor pixels into multiple band images, each corresponding to a specific wavelength.

Demosaicing is enabled as default, rendering all band images in a grid. This rendering does not do any other processing on the image, but allows you to optimally set the integration time and to focus the lens properly, see [Acquire workflow](#) on page 20.

1. Select the **Acquire** tab.
2. In the **Processing** panel, enable/disable **Demosaicing**.

4.7 Enable/disable edge detection for focus assistance

HSI Mosaic edge detection highlights the edges of your sample. Focusing will increase the number of highlights. You can temporary add an object with more edges than your sample (for example, a paper with printed text) to the scene for easier focusing.

1. Select the **Acquire** tab.
2. In the **Focusing assist** panel, enable/disable **Edge detection**.

4.8 Adjust the Acquire tab rendering settings

Rendering settings in the Acquire tab and the Analyze tab are independent of each other.

The first step to achieve a quality image is the accurate configuration of the camera, see [Acquire workflow](#) on page 20. While setting the integration time and focusing the lens, with **Demosaicing**: turned on (default), you can select **Tiles** or **Single band** to render the live view image in the image window and optimize these settings in each band.

1. Select the **Acquire** tab.
2. In the **Processing** panel, enable **Demosaicing**.
3. In the **Rendering** panel, from the top drop-down list, select the rendering type:
 - **Tiles**: all bands are shown side by side in the image window.
 - **Single band** and select a band with the slider: the selected band is shown in the image window.
4. At **Colormap**:, from the drop-down list, select an appropriate color map.

See also

[Export the current rendered image](#) on page 23

[Adjust the Analyze tab rendering settings](#) on page 38

4.9 Export the current rendered image

You can export the rendered image in the image window as PNG.

1. Select the **Acquire**.
2. In the **Rendering** panel, click  **Export**.
The **ExportDialog** dialog box appears.

3. Browse to a **Destination Folder:**, enter a unique name and confirm.
The image is saved in the destination folder as a PNG file.

See also

[Export/import: overview](#) on page 12

4.10 The irradiance pipeline

HSI Mosaic's irradiance pipeline (reference spectrum pipeline) is a method to acquire top quality images in all conditions and in any environment. This pipeline is selected by default.

The reflectance pipeline is a lot more limited in use, see [The reflectance pipeline](#) on page 27.

Once the camera is configured properly (integration time and focusing the lens), the context parameters have to be determined in a lab set up, see step 1. In the following steps the actual acquisition of your sample (in the field or in the lab) are performed.

NOTE

When external synchronization is required, hardware triggering can be enabled.

1. [Determine context and non-uniformity \(irradiance pipeline\)](#) on page 25.
2. Select the **Acquire** tab.
3. At **Lens:**, from the drop-down list, select the lens mounted on your camera.
4. At **F-number:**, enter the used lens aperture.
5. Place your sample and a part of the white reference tile in the camera's field of view and adjust the focus until you see a sharp image of the sample in the image window.

To focus, you can disable demosaicing and zoom in on an edge with high contrast or use focus assistance. see [Enable/disable edge detection for focus assistance](#) on page 23.

The part of the white reference tile in the acquired image shall be used for balancing during analysis.

6. In the **Acquisition** panel, at the **Name:** field, enter an acquisition name. Choose a new name if you don't want to overwrite previous acquisitions.
7. In the **Acquisition** panel, perform one of the following acquisition type procedures:
 - The snapshot acquisition:
 1. From the **Type** drop-down list select **Snapshot**.
 2. Click **Acquire**, (when enabled, wait for the hardware trigger), follow any pop-up dark reference instructions and confirm if you want to analyze the acquisition.
 - The video acquisition:
 1. From the **Type** drop-down list select **Video**.
 2. In the **FPS** field, set the video recording frame rate (frames per second).
When the framerate is higher then the maximum frame rate of your setup

(camera, computer, settings, ...), you will see that frames are dropped (in the **Dropped** field). Lower your frame rate to prevent this.

3. Click **Acquire**, (when enabled, wait for the hardware trigger) and follow any pop-up dark reference instructions.

The recording starts.

You can monitor the **Duration**, the number of taken **Images**, the number of **Dropped** images, the instantaneous **FPS**, and your computer's remaining **Disk space (GB)** Disk space (GB).

4. Click **Acquire** and confirm if you want to analyze the acquisition.

The recording stops.

See also

[The reflectance pipeline](#) on page 27

[Add a predefined lens \(irradiance pipeline\)](#) on page 26

[Define and add a custom lens \(irradiance pipeline\)](#) on page 26

[Delete a lens \(irradiance pipeline\)](#) on page 27

4.10.1 Determine context and non-uniformity (irradiance pipeline)

Once the camera is configured properly (integration time and focusing the lens), the context parameters have to be determined, see [Acquire workflow](#) on page 20:

- The calibration file (already imported during the connect phase, see [Authenticate a camera in HSI Mosaic](#) on page 16)
- The optical setup, i.e. selecting the mounted lens and the aperture (f-number) used, see [Acquire workflow](#) on page 20.
- Record non-uniformity calibration images:
 - The non-uniformity image
 - The dark reference

The context information will be used to translate the digital numbers of the sensor back to the irradiance.

NOTE

- *This task is performed in a lab setup with the supplied white reference tile and supplied halogen lamps with their specific spectrum. You have to repeat this step for each lens/f-number combination.*
- *You can reset the context with the  button.*
- *When external synchronization is required, hardware triggering can be enabled.*

The context information can be determined as follows:

1. Select the **Acquire** tab.
2. At **Lens:**, from the drop-down list, select the lens mounted on your camera. When your mounted lens is not in the drop-down menu, click + to add it (as predefined or custom lens). See also [Define and add a custom lens \(irradiance pipeline\)](#) on page 26 and [Add a predefined lens \(irradiance pipeline\)](#) on page 26 Click  to delete a lens.

3. At **F-number:**, enter the used lens aperture. See [Acquire workflow](#) on page 20 for more info on setting the aperture on the lens.

NOTE

Enter 0.0 when you can't get the correct lens aperture.

4. Place the white reference tile in the field of view of the camera. Make sure the tile covers the whole field of view.

The white reference tile is a critical optical component. Handle the tile with care to prevent it from getting dirty.

5. Adjust the focus of the lens to the presumed distance of the sample you will eventually acquire.

6. Click **Non-uniformity** and follow any pop-up instructions for manually covering and uncovering the camera.

Make sure all incoming light is blocked while covering the camera, because at that moment a dark reference will be acquired. The white reference will be acquired after uncovering the camera.

Do not touch the lens glass to prevent it from getting dirty.

4.10.2 Define and add a custom lens (irradiance pipeline)

1. Select the **Acquire** tab.
2. In the **Context** panel, from the **Pipeline:** drop-down list, select **Reference spectrum**.
3. At **Lens:**, click + **New lens > Custom**.
The **Lens properties creator** dialog box appears.
4. Enter the **Manufacturer name:**
5. Select the **Spectral range:** from the drop-down list:

- **VNIR:** visible and near-infrared
- **SWIR:** shortwave-infrared

6. Enter the **Focal length (mm):**.
7. Enter the **Exit pupil distance (mm):**. This information can be found in the data sheet of the lens or can be obtained from the lens manufacturer.

NOTE

Enter 0.0 when you can't get the correct exit pupil distance.

8. Click **OK**.
The lens is created, added and selected as the current lens in the drop-down list.

See also

[The irradiance pipeline](#) on page 24

[Add a predefined lens \(irradiance pipeline\)](#) on page 26

4.10.3 Add a predefined lens (irradiance pipeline)

1. Select the **Acquire** tab.

2. In the **Context** panel, from the **Pipeline:** drop-down list, select **Reference spectrum**.
3. At **Lens:**, click + **New lens > Predefined**.
The **Predefined lens properties** dialog box appears.
4. From the drop-down list, select a lens and confirm.
The lens is added and selected as the current lens in the drop-down list.

See also

[The irradiance pipeline](#) on page 24

[Define and add a custom lens \(irradiance pipeline\)](#) on page 26

4.10.4 Delete a lens (irradiance pipeline)

1. Select the **Acquire** tab.
2. In the **Context** panel, from the **Pipeline:** drop-down list, select **Reference spectrum**.
3. At **Lens:**, click  **Delete** and confirm.
The lens is deleted and **Unknown** is the current lens.

See also

[The irradiance pipeline](#) on page 24

4.11 The reflectance pipeline

In addition to the irradiance pipeline (default), HSI Mosaic still offers the classic but much less widely applicable reflectance pipeline (full coverage pipeline).

The reflectance pipeline is a workflow that is only suitable for acquiring images of a sample smaller than the white reference used for the calibration. You want, for example, to acquire the image of a single leaf or flower and not a whole tree or a field of flowers. This pipeline is used in lab conditions.

The irradiance pipeline can be used in the lab and in the field and for any sample size, see [The irradiance pipeline](#) on page 24.

NOTE

When external synchronization is required, hardware triggering can be enabled.

1. [Determine context and non-uniformity \(reflectance pipeline\)](#) on page 28. For multiple acquisitions with the same light, focus, and lens conditions, you don't have to repeat this step until you reset the context with .
2. Place your sample in the camera's field of view and adjust the focus until you see a sharp image of the sample in the image window.
To focus, you can disable demosaicing and zoom in on an edge with high contrast or use focus assistance. see [Enable/disable edge detection for focus assistance](#) on page 23.
3. In the **Acquisition** panel, at the **Name:** field, enter an acquisition name. Choose a new name if you don't want to overwrite previous acquisitions.

4. In the **Acquisition** panel, perform one of the following acquisition type procedures:
- The snapshot acquisition:
 1. From the **Type** drop-down list select **Snapshot**.
 2. Click **Acquire**, (when enabled, wait for the hardware trigger), follow any pop-up dark reference instructions and confirm if you want to analyze the acquisition.
 - The video acquisition:
 1. From the **Type** drop-down list select **Video**.
 2. In the **FPS** field, set the video recording frame rate (frames per second).

When the framerate is higher then the maximum frame rate of your setup (camera, computer, settings, ...), you will see that frames are dropped (in the **Dropped** field). Lower your frame rate to prevent this.
 3. Click **Acquire**, (when enabled, wait for the hardware trigger) and follow any pop-up dark reference instructions.

The recording starts.

You can monitor the **Duration**, the number of taken **Images**, the number of **Dropped** images, the instantaneous **FPS**, and your computer's remaining **Disk space (GB)** Disk space (GB).
 4. Click **Acquire** and confirm if you want to analyze the acquisition.

The recording stops.

NOTE

A new dark reference acquisition is only needed when it is not yet available for the current temperature and integration time.

See also

[The irradiance pipeline](#) on page 24

4.11.1 Determine context and non-uniformity (reflectance pipeline)

The reflectance pipeline requires a full field of view white reference tile measurement that includes information about:

- The non-uniformity of the sensitivity of the system due to lens vignetting, variance of silicon thickness of the sensor, etc
 - The non-uniformity of the illumination of the scene
 - The light spectrum
1. Select the **Acquire** tab.
 2. Place a white reference tile (for example, 95% reflectance) in the field of view of the camera. Make sure the tile covers the whole field of view.

The white reference tile is a critical optical component. Handle the tile with care to prevent it from getting dirty.
 3. At **White reflectance**: enter the reflectance value of your reference tile, for example, 95, 00.

4. Click **White reference**, (when enabled, wait for the hardware trigger) and follow any pop-up instructions for manually covering and uncovering the camera. Make sure all incoming light is blocked while covering the camera, because at that moment a dark reference will be acquired. The white reference will be acquired after uncovering the camera.

Do not touch the lens glass to prevent it from getting dirty.

5. Remove the white reference tile.

4.12 Export/import a context

The context contains files regarding calibration, the dark reference(s), the white reference, the non-uniformity and the optical setup.

Use cases for context export/import:

- When you acquired an image, you can first export the context of the acquisition
 - In the Acquire tab (see below: step 2, Export the context)
 - In the Analyze tab (see [Export collections and/or context](#) on page 33)

and then import it to reuse it for a new acquisition with the same context (see below: step 2: Import the context).

- You can import unprocessed (raw-frame) workspace data ([Import an unprocessed collection to analyze](#) on page 34) and its context that you previously exported, tune the processing parameters and export the resulting processed data into hypercubes.
- When you use the irradiance pipeline for outdoor acquisitions, you can import the context you created in a lab environment.

NOTE

Be careful not to use the same context in different circumstances. For example, using a different f-number or a different lens always requires a new context.

1. Select the **Acquire** tab.
2. In the **Context** panel, perform one of these procedures:
 - Export the context:
 1. Click .
 - The dialog box appears.
 2. At **Destination**, click  to select the destination **Folder**.
 3. At **Name**, enter the folder name where all files and folders will be saved.
 4. Click **OK**.
 - Import the context
 1. Click .
 - The **Import context** dialog box appears.
 2. Browse for the desired context folder with the name `Context` and click **Select Folder**.

See also

[Export/import: overview](#) on page 12

[Export collections and/or context](#) on page 33

5. Data processing, viewing and exporting

5.1 Hyperspectral imaging data naming conventions

Data type	Description
Cube	Raw or processed hyperspectral information of a single frame
Hypercube	Fully processed and exported cube
Acquisition	Cube(s) that is (are) acquired in a single process. An acquisition can have - One cube: Acquisition Type Snapshot - More cubes: Acquisition Type Video
Context	Set of files that are necessary to process a raw cube: the calibration file, the lens information, the white reference cube, the dark reference cube, and the sensor temperature information
Collection	Set of acquisitions that share the same context and that are exported together. A collection can also include context.

Table 6: Naming conventions

5.2 Analyze workflow

The data processing pipelines will process the raw frame data into spectral cubes, after which they can be viewed and exported.

The processing steps are determined by the chosen pipeline and can be partially configured to tune the output data size and quality.

HSI Mosaic renders the processed data and enables you to analyze them through spectrographs and histograms. You can analyze these images in real time or offline. You can also classify images in HSI Mosaic using spectral angle mapping.

Step	Action	Related topics
1	Select the data to be analyzed. • Workspace: currently acquired image(s). • Live stream: real-time camera (video-stream) data. • Offline data: previously exported image data.	Data input and output on page 32 Select workspace data to analyze on page 33 Select live stream data to analyze on page 34 Import an unprocessed collection to analyze on page 34
2	Set the processing parameters.	Select the processing pipeline on page 35 Enable/disable spatial median filtering on page 35 Apply spatial resampling on page 36 Enable/disable spectral correction on page 36 Enable/disable the angularity correction on page 36 Apply spectral balancing (irradiance pipeline) on page 37 Reset applied spectral balancing (irradiance pipeline) on page 38
3	Adjust the rendering parameters.	Adjust the Analyze tab rendering settings on page 38
4	Make selections and visualize spectra.	Image selection actions on page 39 Selection actions workflow example on page 40 Spectrograph analysis on page 46 Histogram analysis on page 47
5	Classify the image pixels based on the selections.	Classification on page 48 Classification workflow on page 48

Table 7: Analyze workflow steps

5.3 Data input and output

In the Analyze tab, in the IO panel, you can select the image data you want to analyze and export the processed or unprocessed (raw-frame) image data and the context.

When your image data is a video, you can select the frame you want to see, using one of these options:

- Move the slider
- Click the up and down arrows in the frame number field
- Enter a frame number in the image number field
- Click the play button to start and pause
- Click the left and right arrows

See also

[Select workspace data to analyze](#) on page 33

[Select live stream data to analyze](#) on page 34

[Import an unprocessed collection to analyze](#) on page 34

[Export collections and/or context](#) on page 33

5.3.1 Select workspace data to analyze

Workspace analysis: you can select the currently acquired image(s).

When you just finished an acquisition and you confirmed to analyze the last acquisition, HSI Mosaic automatically jumps to the Analyze tab. In the IO panel, the last workspace acquisition is already selected in the list with all acquired images to be analyzed.

1. In the **Analyze** tab, in the **IO** panel, at **Source:**, select **Workspace** from the drop-down list.
The acquisition list is shown.
2. Select the name of the desired acquisition in the list.

See also

[Select live stream data to analyze](#) on page 34

[Import an unprocessed collection to analyze](#) on page 34

5.3.2 Export collections and/or context

When you acquired one or more images, you can export a processed collection of hypercubes or an unprocessed collection of cubes, and their context. For example, you can export unprocessed workspace data and the context and later import both to process that data into hypercubes (spectral data cubes).

These export options are possible:

- Processed: final export of the processed collection of hypercubes with the current pipeline and processing parameters applied. All files are saved in the sub-folder **<name>_processed**. You can then start using these hypercubes for your application, for example, you can analyze the hypercubes in HSI Studio. See also [ENVI file format](#) on page 53.
- Unprocessed: unprocessed or raw-frame workspace data. When you import these files later (together with the context, see the export option below), you can still tune the

processing parameters and generate hypercubes. All files are saved in the sub-folder **<name>_unprocessed**. See also [Export data XML file format](#) on page 55.

- **Context:** the calibration file, the optical setup, the temperature information, the dark reference, white reference and non-uniformity cubes. All files are saved in the subfolder **<name>_unprocessed\context** .

1. Select the **Analyze** tab.
2. In the **IO** panel, from the **Source:** drop-down list, select **Workspace**.
3. Click **Export**.
The **ExportDialog** dialog box appears.
4. At **Destination**, click  to select the destination **Folder:**.
5. At **Name:**, enter the collection name where all files and folders will be saved.
6. At **Preferences**, select one or multiple acquisitions (mouse drag or press **Ctrl** for multiselect).
7. At **Preferences**, select one or more of the following options:
 - **Context:** the sub-folder context with nested sub-folders and the according context files are created and saved for each selection.
 - **Unprocessed:** the sub-folder unprocessed and a frame.raw and frame.raw.xml file are created for each selection, [Export data XML file format](#) on page 55.
 - **Processed:** the sub-folder processed, a RAW and an HDR file are created for each selection, [ENVI file format](#) on page 53.
8. Click **OK**.

See also

[Export/import: overview](#) on page 12

[Export/import a context](#) on page 29

[Import an unprocessed collection to analyze](#) on page 34

[Export metadata](#) on page 53

5.3.3 Import an unprocessed collection to analyze

You can import unprocessed collections that you previously exported together with their context, see [Export collections and/or context](#) on page 33, tune the processing parameters and export the resulting processed data into hypercubes.

1. In the **Analyze** tab, in the **IO** panel, at **Source:**, select **Offline data** from the drop-down list.
2. Click  and select the folder in Windows Explorer.

See also

[Export/import: overview](#) on page 12

[Select workspace data to analyze](#) on page 33

[Select live stream data to analyze](#) on page 34

[Export collections and/or context](#) on page 33

5.3.4 Select live stream data to analyze

Live stream analysis: you can select real-time camera data (video-stream).

In the **Analyze** tab, in the **IO** panel, at **Source:**, select **Live stream** from the drop-down list.

The live stream is shown in the image window. You can pause (⏸) and restart (▶) the live stream.

See also

[Select workspace data to analyze](#) on page 33

[Import an unprocessed collection to analyze](#) on page 34

5.4 Processing

In the **Analyze** tab, in the **Processing** panel you can configure how the data processing pipeline will process the raw frame data into spectral cubes.

See also

[Enable/disable spatial median filtering](#) on page 35

[Apply spatial resampling](#) on page 36

[Enable/disable spectral correction](#) on page 36

[Enable/disable the angularity correction](#) on page 36

[Apply spectral balancing \(irradiance pipeline\)](#) on page 37

[Reset applied spectral balancing \(irradiance pipeline\)](#) on page 38

5.4.1 Select the processing pipeline

Depending on your [Acquire workflow](#) on page 20, you have to select a processing pipeline.

In the **Analyze** tab, in the **Processing** panel, from the **Pipeline:**, select one of these options:

- (Default) **Reference spectrum** (Irradiance pipeline)
- **Full coverage** (Reflectance pipeline)

5.4.2 Enable/disable spatial median filtering

By default spatial median filtering is enabled on each of the hypercube's band images. As such, the filter is active only in the spatial domain of the data. You can only enable/disable spatial median filtering in extended view.

Signal spikes (hot and dead pixels and other outliers) cause salt and pepper noise (bright and dark spots) in the image. You can use the spatial median filter to smoothen the image by removing the signal spikes. The spatial median filter replaces each pixel intensity value by the median value of its neighborhood pixels.

The filter size defines the number of surrounding pixels used by the filter to calculate the median. With a 3x3 filter size, 9 pixels are used to calculate the median. A 5x5 filter uses 25 pixels, which results in a stronger filtering of the image data.

NOTE

A large filter size requires a lot of processing power for big data sets.

1. In the **Analyze** tab, in the **Processing** panel, enable/disable **Spatial median filtering**.
2. (Optional) Select a different **Filter size**: from the drop-down list.

See also

[Apply spatial resampling](#) on page 36

5.4.3 Apply spatial resampling

The processing pipeline incorporates a kind of de-bayering algorithm to demosaic the raw image into individual band images. In this demosaicing step, each band image is resampled to a new grid. This spatial resampling can be configured to determine the pipeline's output data size up to the native sensor size.

1. In the **Analyze** tab, in the **Processing** panel, enable **Spatial resampling**:
2. Select one of the following options:
 - **Full sensor** to resample data for the whole sensor resolution.
 - **Custom** and set you own resolution for resampling by adjusting the **Width**: or **Height**:

See also

[Enable/disable spatial median filtering](#) on page 35

5.4.4 Enable/disable spectral correction

Spectral correction is applied by default. Spectral correction or deconvolution removes all transformations introduced by the system to translate the captured spectral signal into discrete digital numbers. As such, spectral correction is a model inversion step and recomputes the true light spectrum captured by the lens of the camera.

1. In the **Analyze** tab, in the **Processing** panel, disable/enable **Spectral correction**:
2. (Optional) Select another **Correction matrix**: (availability depends on your system) from the drop-down list.

5.4.5 Enable/disable the angularity correction

Angularity correction is enabled by default. You can only disable the angularity correction in extended view.

Light reflected or transmitted by a sample will be projected by the lens onto the sensor at specific angles. Depending on the place on the sensor, these angles will be different. The filters on the sensor are Fabry-Perot interference filters and are for that reason sensitive to the angle of the incident light in a cosine relation. The angularity correction will compensate for the spectral shift caused by these differences.

Since the focal length, exit pupil distance and aperture (f-number) of the lens determine these angles, proper lens selection and aperture adjustment during the Acquire phase are crucial to

ensure a correct angularity correction, see [Determine context and non-uniformity \(irradiance pipeline\)](#) on page 25.

In the **Analyze** tab, in the **Processing** panel, enable/disable **Angularity**:

5.4.6 Select the spectral resampling method

Spectral resampling is applied by default.

After the angularity correction is applied to the data, each pixel in a band image will have the value which corresponds to a measurement at a slightly different wavelength than the other pixels. This wavelength depends on the location of the pixel on the sensor. To have consistent information inside a band image, each pixel in that band image must be resampled to a common wavelength. The wavelengths corresponding to the virtual bands created like this can be selected in two different ways:

- **Non-equidistant** (default): such that they are as close as possible to the actual bands of the filters, but taking into account the average wavelength shift.
- **Equidistant**: such that the spectral range of the sensor is uniformly sampled. Depending on the sensor model, equidistant resampling can cause a small or a significant loss in spectral accuracy. If the virtual bands thus created are too far from the original bands of the sensor, equidistant resampling can produce very inaccurate results. Equidistant resampling can however be a prerequisite for a number of post-processing algorithms.

In the **Analyze** tab, in the **Processing** panel, select a **Method** from the drop-down list:

- **Non-equidistant**
- **Equidistant**

5.4.7 Apply spectral balancing (irradiance pipeline)

Spectral reflectance or transmittance is retrieved by dividing the spectral irradiance by the light source spectrum. This process is also called white balancing, and can be done by estimating the light spectrum from a spectrally flat surface (to obtain reflectance) or a perfectly transmissive surface (to obtain transmittance).

It is recommended to position a reference target with a spectrally flat response somewhere in the field of view and to select a region in that target for spectral balancing.

NOTE

You can click  to use the non-uniformity image in the context as a reference, but only when a white reference is not available because it will cause less spectral accuracy. Click the  again to reset.

1. In the **Analyze** tab, in the **Selection** panel, select one of the following selection tools:

-  **Freehand**
-  **Line**
-  **Rectangle**
-  **Circle**

2. In the **Processing** panel, at **Spectral balancing**, enter the **Coefficient:** of your white reference, for example 0.95 for a 95% white reference.
3. In the **Processing** panel, at **Spectral balancing**, click .
4. In the image window, click and hold to drag a selection in the white reference.
The balancing is applied instantly.

See also

[Reset applied spectral balancing \(irradiance pipeline\)](#) on page 38

5.4.8 Reset applied spectral balancing (irradiance pipeline)

Resetting previously applied white balancing can be handy when the selected area while balancing wasn't significant large enough or when you accidentally balanced more than once.

In the **Analyze** tab, in the **Processing** panel, next to **Spectral balancing**, click the toggle button.

5.4.9 Extended view information in the Analyze tab

In the Analyze tab, the extended view provides you with all processing and settings information and functionality for in depth comprehension; this allows you, for example, to export unprocessed data (see [Export collections and/or context](#) on page 33) which you can use for your own processing or experimental work (for example, in Python or Matlab).

NOTE

Unprocessed data is not true spectral data and must be treated with care.

Analyze tab Extended View	Description
Bias correction:	Indicates the processed image was corrected using the dark reference, see The reflectance pipeline on page 27 or The irradiance pipeline on page 24.
Demosaicing:	Indicates demosaicing was applied, see Enable/disable demosaicing on page 22.
Alignment:	Indicates that the pixels of the image have been corrected for the spatial distance between its constituent pixels.
Non-uniformity:	Indicates the image was corrected for non-uniformity in the reference spectrum pipeline, see The irradiance pipeline on page 24

Table 8: Information in Extended view

5.5 Adjust the Analyze tab rendering settings

Rendering settings in the Acquire tab and the Analyze tab are independent of each other. These settings are only view settings and do not affect the processing.

1. Select the **Analyze** tab.
2. In the **Rendering** panel, from the drop-down list select one of the following options:
 - **Tiles**: all bands are shown in the image window.
 - **Single band** and select a band with the slider: the selected band is shown in the image window.
 - **Color**: creates an artificial color image, applying CIE curves to the spectral data. In case the sensor doesn't cover the visible spectrum range, the CIE curves are transposed to the sensor's range to create a broadband color reconstruction.
 - **False color**: specific single bands of interest for your sample are assigned to a red, green and blue color channel to display a high contrast rendering in the image window. Select the **Red Band**, the **Green Band** and the **Blue Band** with the sliders.
 - **NDVI**: the Normalized Difference Vegetation Index for agriculture. Select the **Red Band** and the **Infrared Band** with the sliders.
3. Adjust the **Gain** with the slider.
The brightness changes.
4. Adjust the **Gamma** with the slider.
The intensity of the middle tones changes without changing much the highlights and the shadows.
5. Adjust the **Contrast** with the slider.
The contrast between lighter and darker midtones changes.
6. At **Colormap**: (only applicable if **Tiles**, **Single band** or **NDVI** are selected in step 2), from the drop-down list, select an appropriate color map.

See also

[Adjust the Acquire tab rendering settings](#) on page 23

5.6 Image selection actions

In the HSI Mosaic image window, you can make selections in the image to visualize spectra. You can use multiple layers and multiple selections in each selection layer.

Each layer has its own color and will be recognized as such in the image window and all related panels in the HSI Mosaic user interface.

See also

- [Selection actions workflow example](#) on page 40
- [Add a first selection in a first selection layer](#) on page 42
- [Add a new selection layer](#) on page 43
- [Add a selection to a selection layer](#) on page 43
- [Clear the selections in a selection layer](#) on page 43
- [Delete a selection layer](#) on page 44
- [Delete all selection layers](#) on page 44
- [Change the color of a selection layer](#) on page 44
- [Change the name of a selection layer](#) on page 44
- [Export the selection information and/or mask for reuse](#) on page 45
- [Import the selection information and/or mask for reuse](#) on page 45
- [Right click image selection shortcuts](#) on page 42

5.6.1 Selection actions workflow example

This example demonstrates how to distinguish nuts from their shells using a snapshot SWIR camera. Specifically this demo exploits differences in lipid absorption between both object types, which heavily influences the shape of the spectrum in the SWIR spectral range.

You first acquire (or import) an image of the separate objects, adjust the rendering options and then start your analysis.

1. You add a first selection in the first selection layer with the color blue and give the selection layer the name 'nuts'
2. You add multiple selections of the nuts.
3. You add a second layer with the color green and give it the name 'shell exterior'.
4. You add multiple selections of the exterior of the shells
5. You add a third layer with the color fuchsia and give it the name 'shell interior'.
6. You add multiple selections of the interior of the shells

In the image below three layers with a selection for each layer are shown:

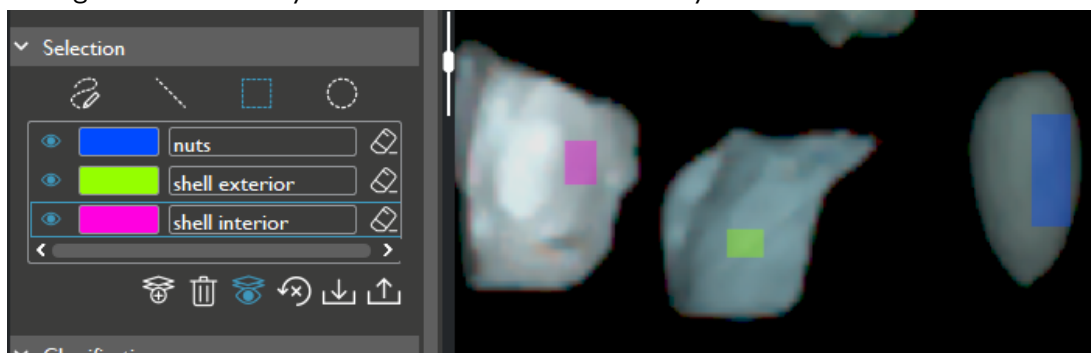


Figure 10: Selection layers with selections

The spectrograph and histogram are plotted in real-time as soon as you start adding selections. For the nuts and shells blue, green and fuchsia graphs will be plotted.

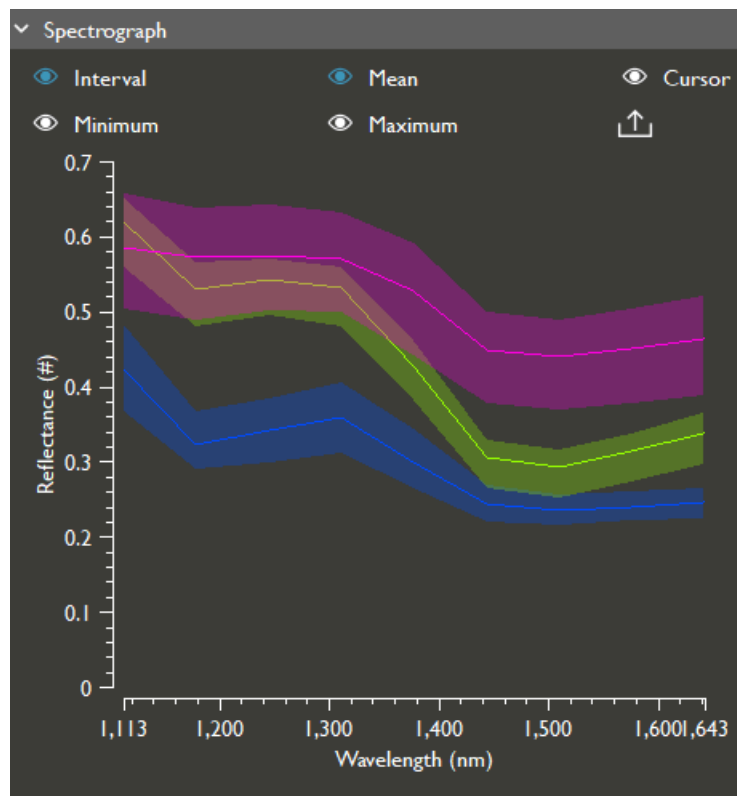


Figure 11: Spectrograph

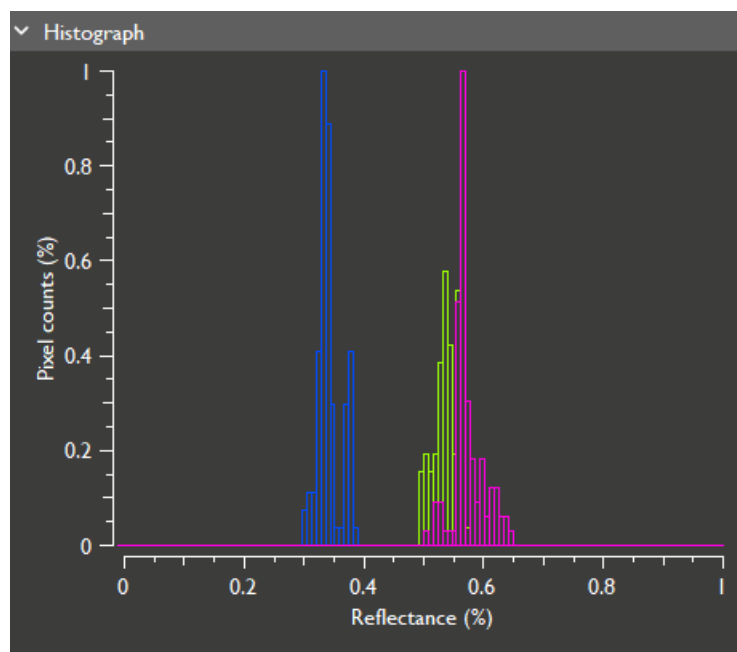


Figure 12: Histogram

You can now use the selection layers to classify the image: this allows you to recognize other parts of the scene as nuts or as shell interior or exterior.

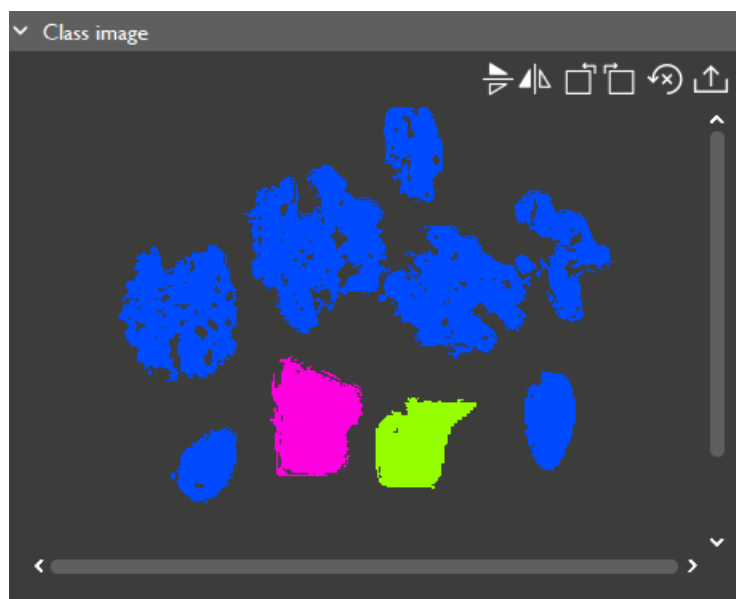


Figure 13: Class image

You can export the selection information to reuse it with other similar images. For example, you want to analyze the image of nuts and shells. You import the selection information and start adding selections in the image in the preloaded layers and can start analyzing and classifying.

You can also export the selection mask for reuse. For example, you want a colleague to be able to reproduce your analysis of the nuts and shells image using the same selections (mask).

5.6.2 Right click image selection shortcuts

Right click shortcut	Description
	Add a new selection layer with the last used selection tool (for example  Rectangle).
	Clear all selections in the current selection layer.

Table 9: Selection shortcuts

5.6.3 Add a first selection in a first selection layer

1. In the **Analyze** tab, in the **Selection** panel, select one of the following selection tools:

-  **Freehand**
-  **Line**
-  **Rectangle**
-  **Circle**

2. In the image window, click and hold to drag a selection.

A first selection is created in the image in a first selection layer. The layer is shown in the **Selection** panel. The graphs in the **Spectrograph** and **Histogram** panels are plotted in real-time.

See also

- [Add a new selection layer](#) on page 43
- [Add a selection to a selection layer](#) on page 43
- [Right click image selection shortcuts](#) on page 42

5.6.4 Add a new selection layer

In the **Analyze** tab, in the **Selection** panel, select .

A new selection layer is generated and added to the list in the **Selection** panel. The selection layer is now active and new selections will be added to this layer until you select another layer.

See also

- [Add a first selection in a first selection layer](#) on page 42
- [Add a selection to a selection layer](#) on page 43
- [Delete a selection layer](#) on page 44
- [Change the color of a selection layer](#) on page 44
- [Change the name of a selection layer](#) on page 44
- [Right click image selection shortcuts](#) on page 42

5.6.5 Add a selection to a selection layer

1. In the **Analyze** tab, in the **Selection** panel, select a selection layer.

NOTE

When no layer is available, adding a selection, automatically creates the first selection layer, see [Add a first selection in a first selection layer](#) on page 42 or [Add a new selection layer](#) on page 43.

2. Select one of the following selection tools:

-  **Freehand**
-  **Line**
-  **Rectangle**
-  **Circle**

3. In the image window, click and hold to drag a selection.

A new selection is added to the image in the selection layer color. The graphs in the **Spectrograph** and **Histogram** panels are plotted in real-time in the color of the new layer.

See also

- [Clear the selections in a selection layer](#) on page 43

5.6.6 Clear the selections in a selection layer

Clearing the selections in a selection layer doesn't delete the selection layer itself.

In the **Analyze** tab, in the **Selection** panel, at the selection layer, double click .

See also

[Delete a selection layer](#) on page 44

[Delete all selection layers](#) on page 44

[Right click image selection shortcuts](#) on page 42

5.6.7 Delete a selection layer

When you delete a selection layer, the layer and its selections are deleted.

To only delete the selections in a selection layer, see [Clear the selections in a selection layer](#) on page 43.

1. In the **Analyze** tab, in the **Selection** panel, select a selection layer.
 2. Click .
- The layer and all its selections are deleted.

See also

[Clear the selections in a selection layer](#) on page 43

[Delete all selection layers](#) on page 44

5.6.8 Delete all selection layers

In the **Analyze** tab, in the **Selection** panel, click .

See also

[Clear the selections in a selection layer](#) on page 43

[Delete a selection layer](#) on page 44

5.6.9 Change the color of a selection layer

1. In the **Analyze** tab, in the **Selection** panel, double click the color of the selection layer.
The **Select Color** dialog box appears.
2. Use one of the following options to select a color:
 - Select one of the **Basic colors** or other color maps and adjust with the brightness slider.
 - Click **Pick Screen Color** and click on a color anywhere in one of your computer displays.
 - Enter your own color preferences in the text boxes.
3. Click **OK**.

See also

[Change the name of a selection layer](#) on page 44

5.6.10 Change the name of a selection layer

1. In the **Analyze** tab, in the **Selection** panel, double click the name of the selection layer.

2. Use **Backspace** to delete and enter the new name.
3. Click anywhere next to the selection layer to confirm.

See also

[Change the color of a selection layer](#) on page 44

5.6.11 Export the selection information and/or mask for reuse

You can export selection information and/or masks to reuse them later for acquisition images.

- The exported selection layer information can be reused for analyzing other but similar images. When you import the selection layer information, you can add selections in the new images in these preloaded layers and start analyzing and/or classifying.
 - The exported mask can be reused, for example, by another user to analyze the same image.
1. In the **Analyze** tab, in the **Selection** panel, click .
The **ExportDialog** dialog box appears.
 2. (Optional) At **Folder:**, click  to change the destination folder.
 3. At **Preferences** select one or more of the following options:
 - **Information:** selection layer information.
 - **Mask:** the selection mask; all layers are flattened in one image.

See also

[Export/import: overview](#) on page 12

[Import the selection information and/or mask for reuse](#) on page 45

5.6.12 Import the selection information and/or mask for reuse

You can export selection information and/or masks to reuse them later for acquisition images.

- The exported selection layer information can be reused for analyzing other but similar images. When you import the selection layer information, you can add selections in the new images in these preloaded layers and start analyzing and/or classifying.
 - The exported mask can be reused, for example, by another user to analyze the same image.
1. In the **Analyze** tab, in the **Selection** panel, click .
The **Import selection model** dialog box appears.
 2. Browse for and select the desired files:
 - SMDL: **Information** file format.
 - PNG: **Mask** file format
 3. Click **Open**.

See also

[Export/import: overview](#) on page 12

[Export the selection information and/or mask for reuse](#) on page 45

5.7 Spectrograph analysis

When you make a selection in the image in the image window, the selection is immediately visualized in the spectrograph in the corresponding color of the selection layer (unless all visibility statuses in the spectrograph panel are set as hidden).

During analysis the spectrograph shows the reflectance as a function of the wavelength.

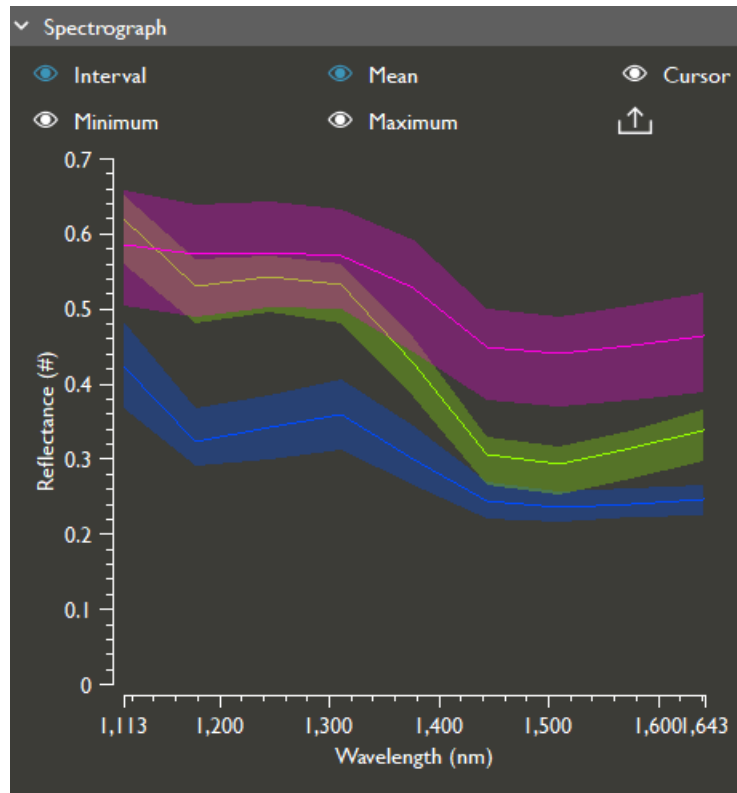


Figure 14: Spectrograph

Following graphs are **Visible** (👁) or **Hidden** (👁):

- The **Mean** reflectance of the selection(s) at each wavelength.
- The **Minimum** reflectance of the selection(s) at each wavelength.
- The **Maximum** reflectance of the selection(s) at each wavelength.
- The **Interval** between the minimum and maximum reflectance
- The reflectance at each spectrum at the **Cursor** (mouse pointer) position of the image.

See also

[Histogram analysis](#) on page 47

[Export spectrograph data](#) on page 46

5.8 Export spectrograph data

In the spectrograph, the current graph can be exported as a PNG image or a CSV spreadsheet file, see [Spectrograph CSV file format](#) on page 57. In the CSV export file, each row has

values for all bands for a pixel. If a mean value export is made, each selection will have one data entry. Otherwise each pixel in each selection will be saved as a single row.

1. Select the **Analyze** tab.
2. In the **Spectrograph** panel, select .
The **ExportDialog** dialog box appears.
3. At **Destination**, click  to select the destination **Folder**.
4. At **Name**, enter the name of the file(s) that will be saved.
5. At **Preferences** select one or more of the following options:
 - **Screenshot**: a screenshot (PNG) of the current spectrograph in the **Spectrograph** panel will be generated.
 - **Spectrums** and from the drop-down list, select **Mean** or **All**: a CSV file will be generated with respectively the average spectrum or all spectra of each selection.

 NOTE

Exporting all spectra may generate very large CSV files.

6. Click **OK**.

See also

[Spectrograph analysis](#) on page 46

[Export/import: overview](#) on page 12

5.9 Histogram analysis

When you make a selection in the image in the image window, the selection is immediately visualized in the histogram in the corresponding color of the selection layer.

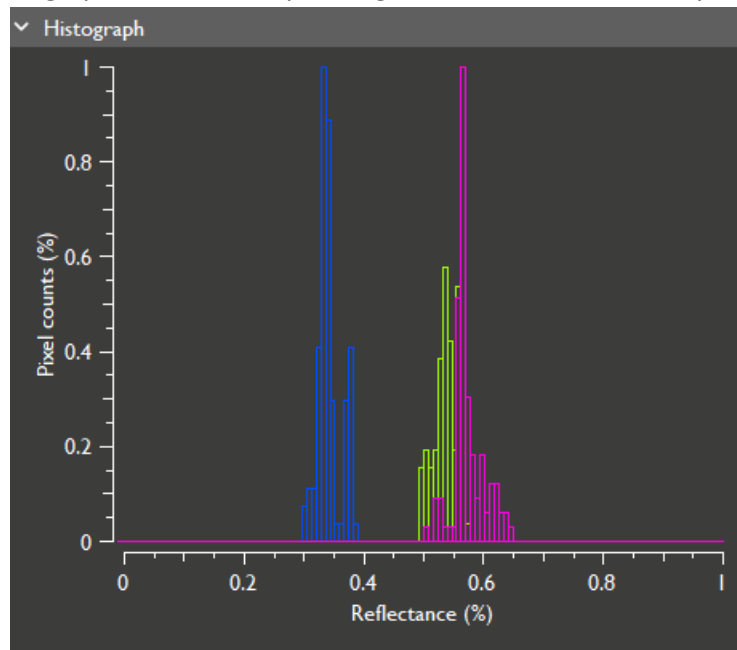


Figure 15: Histogram

The histogram shows the pixel counts as a function of the reflectance at a specific wavelength. The wavelength is selected by sliding the slider in single band image rendering. The histogram

of a selection which is mainly in the high reflectance or 'light' areas of the image will result in high peaks on the right side of the graph, 'dark' selections will result in high peaks on the left. Average reflectance area selections will result in peaks in the middle of the graph.

See also

[Spectrograph analysis](#) on page 46

5.10 Classification

HSI Mosaic allows you to group and mark pixels with the same spectral shape as the pixels you select. In an image of a tree for example you can select some healthy leafs and HSI Mosaic will recognize other pixels in the whole image as healthy leafs and mark them as such. You can repeat this process in a second selection layer, for example, for dry leafs, etc.

HSI Mosaic uses spectral angle mapping (SAM) for classification. The spectral angle or correlation between the pixels of the image and the pixels of the selection layer is calculated. When pixels differ less than a set maximum angle, they are allotted to the same class. The imec SAM classifier is implemented in HSI Mosaic and ready to use. HSI Mosaic provides also integration with the perClass Mira classifier.

NOTE

The spectra of individual pixels can be described as vectors in an n -dimensional space, where n is the number of spectral bands. Each vector has a certain length representing the brightness of the pixel and a direction representing the spectral shape of the pixel. The more similar the spectra are, the better they correlate, and the smaller the spectral angle between them.

5.10.1 Classification workflow

HSI Mosaic allows you to classify images, for example images of trees in a forest.

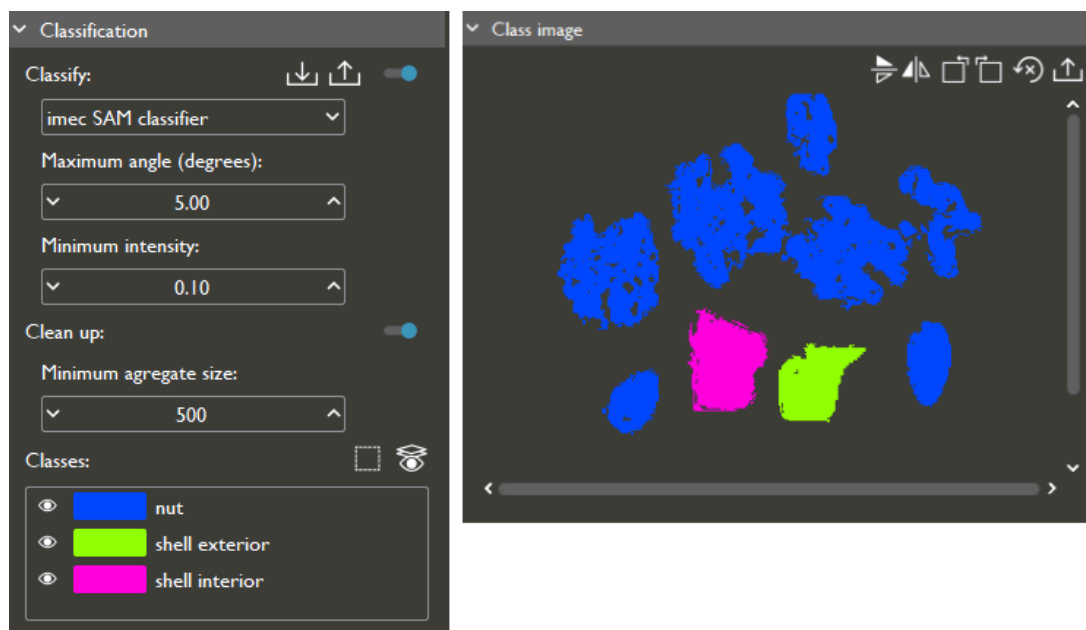


Figure 16: Classification panel and class image

Step	Related topics
Create a selection layer with one or more selections for each class. For example, create a first selection layer with different selections of leaf-parts in the image of the tree. Then create a second layer with selections of branches of the tree.	Image selection actions on page 39
Set the classifying parameters: classifier, maximum angle and minimum intensity	Set up the classifying parameters on page 50 Classify on page 50 Select a classifier on page 50
Classify	Classify on page 50
Clean up pixels that do not contribute to a particular class.	Clean up the class image on page 51
Reuse the classifier: after classifying an acquisition, you can export your classifier, acquire a new image (or import or live stream one), import the classifier and classify the image. To analyze the data in the spectrograph and histogram, you need to convert the classes to selections.	Export the classifier on page 51 Import a classifier on page 52 Convert to selection on page 52
Export	Export the class image on page 52

5.10.2 Set up the classifying parameters

To classify an image, you can set two parameters:

- The **Maximum angle (degrees)**: the maximum angle that HSI Mosaic uses to classify pixels of the image in the same (spectral angle) class as the selection layer.
 - The **Minimum intensity**: used to filter out noise. Noise on low intensity spectra has a big impact on the spectral angle. Pixels with an intensity lower than this minimum intensity are not classified.
1. In the **Analyze** tab, in the **Classification** panel, at **Maximum angle (degrees)**, enter the maximum spectral angle difference.
 2. At **Minimum intensity**, enter the minimum spectrum intensity.

See also

[Classification workflow](#) on page 48

5.10.3 Select a classifier

HSI Mosaic uses spectral angle mapping (SAM) for classification, see [Classification](#) on page 48 and [Classification workflow](#) on page 48. The default imec SAM classifier is implemented in HSI Mosaic and ready to use. HSI Mosaic provides also integration with the perClass Mira classifier.

In the **Analyze** tab, in the **Classification** panel, at **Classify**, from the drop-down list, select a SAM classifier.

See also

[Classification workflow](#) on page 48

5.10.4 Classify

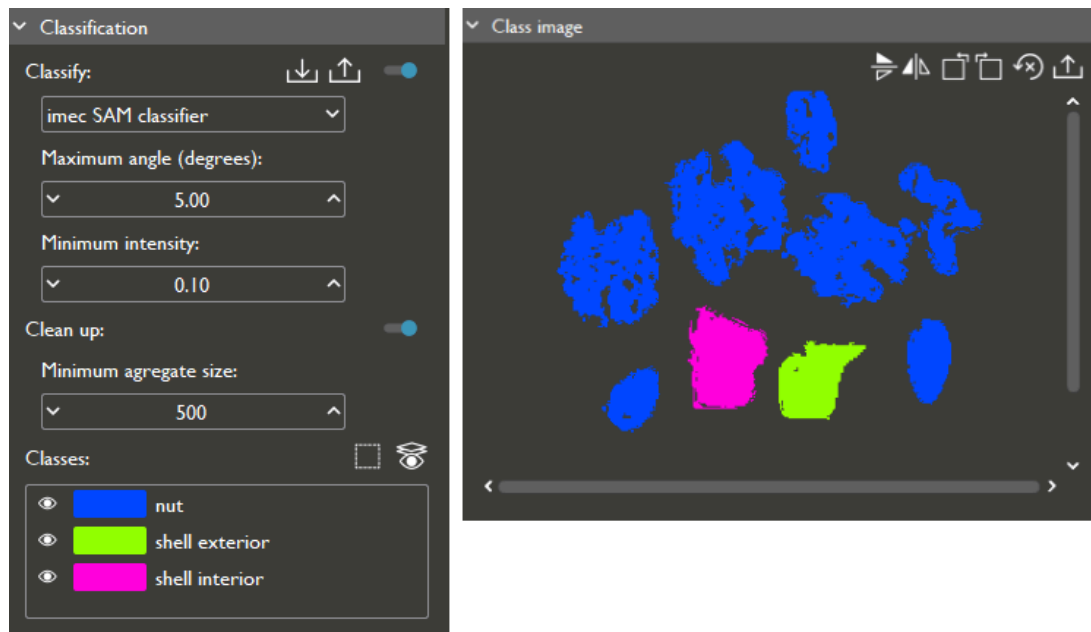


Figure 17: Classification panel and class image

In the **Analyze** tab, in the **Classification** panel, enable **Classify**. The pixels of the image are classified based on your selections and according to the classifying parameters. This results in the class image in the image window, where the class image is overlayed on the rendering, and in the **Class image** panel.

NOTE

Layers can be shown/hidden individually (👁) or at once (👁), see [Show/hide an item or selection](#) on page 12.

See also

[Classification workflow](#) on page 48

5.10.5 Clean up the class image

After classification, there are usually still loose pixels or small pixel aggregations that often do not contribute to a particular class. These artifacts can be eliminated with the clean-up tool.

1. In the **Analyze** tab, in the **Classification** panel, enable **Clean up**.
2. At **Minimum aggregate size**: enter the size of the pixel aggregates that have to be cleaned up.

See also

[Classification workflow](#) on page 48

5.10.6 Export the classifier

After classifying an acquisition, you can export your classifier. You can reuse this classifier later: acquire a new image (or import or live stream one), import the classifier and classify the image.

1. In the **Analyze** tab, in the **Classification** panel, click .
The **ExportDialog** dialog box appears.
2. At **Destination**, click  to select the destination **Folder**.
3. At **Name**:, enter the name of the XML file that will be saved.
4. Click **OK**.

See also

[Export/import: overview](#) on page 12

[Import a classifier](#) on page 52

[Export the class image](#) on page 52

5.10.7 Import a classifier

After classifying an acquisition, you can export your classifier. You can import this classifier to reuse it for classifying a new image acquisition (or an imported offline one or a live stream).

1. In the **Analyze** tab, in the **Classification** panel, click .
The **Import classifier** window opens.
2. Browse for the classifier XML file and click **Open**.
The classifier is imported and can be used to classify.

See also

[Export/import: overview](#) on page 12

[Export the classifier](#) on page 51

[Convert to selection](#) on page 52

5.10.8 Convert to selection

The convert to selection functionality is only available in extended view.

When you imported a classifier to reuse it in another acquisition, you can convert this classifier's classes to selection layers, providing you a spectrograph and histogram for analysis.

In the **Analyze** tab, in the **Classification** panel, at **Classes**: click  **Convert to selection**.

The classes are converted to selections and the spectrograph and histogram are shown for these selection layers.

5.10.9 Export the class image

Classification info of an acquisition can be exported to a XML file, see [Classifier XML file format](#) on page 57. This file can be imported to another classification.

1. Select the **Analyze** tab.
2. In the **Class image** panel, select .
The **ExportDialog** dialog box appears.
3. At **Destination**, click  to select the destination **Folder**.
4. At **Name**:, enter the name of the XML file that will be saved.

5. Click **OK**.

See also

[Classification workflow](#) on page 48

[Export/import: overview](#) on page 12

[Export the classifier](#) on page 51

5.11 Export metadata

1. Select the **Analyze** tab.
2. In the **Metadata** panel, select .
The **ExportDialog** dialog box appears.
3. At **Destination**, click  to select the destination **Folder**.
4. At **Name**, enter the name of the CSV file that will be saved.
5. Click **OK**.

See also

[Export/import: overview](#) on page 12

[Export collections and/or context](#) on page 33

5.12 Output file formats

5.12.1 ENVI file format

All processed acquisitions (hypercubes) can be exported to binary files. An ENVI standard compatible header file is also exported together with the data. ENVI is a commonly used format in the HSI area. ENVI header file includes important parameters that lets different viewer software to read the binary information correctly. The HSI Mosaic export file header includes ENVI standard information plus imec specific info which will only be used by imec software. Other ENVI reader software can read files exported from HSI Mosaic without any problems.

NOTE

The header and/or binary files of some ENVI reader programs and scripts must have a specified file extension. It causes no problems if you change the file extension.

ENVI Standard

Variable	Description
acquisition time	Time of the image acquisition in YYYY-MM-DDTHH:MM:SS:Do00:mm format. Do00 is the time offset from UTC time.
band names	The names of image bands.
bands	The number of bands per image file.

Variable	Description
byte order	Order of the bytes in the data. 0 - Least Significant Byte First 1 - Most Significant Byte First
data type	The type of data representation: 1 = Byte: 8-bit unsigned integer 2 = Integer: 16-bit signed integer 3 = Long: 32-bit signed integer 4 = Floating-point: 32-bit single-precision 5 = Double-precision: 64-bit double-precision floating-point 6 = Complex: Real-imaginary pair of single-precision floating-point 9 = Double-precision complex: Real-imaginary pair of double precision floating-point 12 = Unsigned integer: 16-bit 13 = Unsigned long integer: 32-bit 14 = 64-bit long integer (signed) 15 = 64-bit unsigned long integer (unsigned)
file type	The ENVI-defined file type. Please check ENVI standard documentation for more details.
fwhm	Lists full-width-half-maximum (FWHM) values of each band in an image.
header offset	The number of bytes of embedded header information present in the file. ENVI skips these bytes when reading the file.
interleave	Refers to whether the data interleave is Band Sequential (BSQ), Band-interleaved-by-pixel (BIP) or Band-interleaved-by-line (BIL).
lines	The number of lines per image for each band.
samples	The number of samples (pixels) per image line for each band.
wavelength	Lists the center wavelength values of each band in an image.
wavelength units	Text string indicating the wavelength units.

Table 11: ENVI Standard

imec extension

Variable	Description
max value	Maximum pixel value possible in the data.

Variable	Description
saturation value	Starting from this value to the max value, pixels will be shown as oversaturated.
no data value	Value used to flag invalid data.
data source	Name and version of the acquisition software.
system id	Identification number of the sensor.
correction matrix name	Name of the correction matrix used in the image.
exit_pupil_distance_mm	Exit pupil distance of the lens to the sensor.
f_number	If the aperture opening is f/2.8, f number will be 2.8.
sensor_refractive_index	Refractive index of the sensor. Please refer to HSI Sensors User Manual.
spatial median filter size	Size of the median neighborhood
white value	Coefficient used in the white balancing if white balancing is applied.

Table 12: imec extension

Flags

Flags directly refer to the related operation in the processing pipeline.

Flag	Value
corrected data	0 (Off) or 1 (On).
reflectance data	0 (Off) or 1 (On).
alignment	0 (Off) or 1 (On).
angularity correction	0 (Off) or 1 (On).
bias correction	0 (Off) or 1 (On).
non-uniformity	0 (Off) or 1 (On).
spatial median filtering	0 (Off) or 1 (On).
spatial resampling	0 (Off) or 1 (On).
spectral correction	Deprecated, do not use.
white balancing	Deprecated, do not use.

Table 13: Flags

See also

[Export collections and/or context](#) on page 33

5.12.2 Export data XML file format

Unprocessed acquisitions (cubes) can be exported to binary files. An XML header file is also exported together with the data. The header file includes important parameters that lets HSI Mosaic to read the file in the analyze section later.

Data format

Variable	Description
byte_depth	Number of bytes used in the data type.
data_type	Type of the exported data. (Float, int, etc...)
max_value	Max possible value of the data.
saturation_value	Starting from this value to the max value, pixels will be shown as oversaturated.
no_data_value	Value used to flag invalid data.
nr_cols	Number of columns in image in pixels.
nr_rows	Number of rows in image in pixels.
offset_sensor_x	The image starts from this pixel on the sensor in the X axis.
offset_sensor_y	The image starts from this pixel on the sensor in the Y axis.

Table 14: Data format

Data info

Variable	Description
data_source	Name and version of the software which exported the data.
system id	ID tag of the camera system.
valid	Flags whether the data is valid or not.
acquisition_time	Time of the image acquisition in YYYY-MM-DDTHH:MM:SS:Do:mo format. Do:mo is the time offset from UTC time.
completion_time	Time of the completion of acquisition.
integration_time_ms	Integration time in ms.

Table 15: Data info

Properties

Variable	Description
burst_index	Imec Internal
dm lost frames	Imec Internal
gain mode	Imec Internal
hdr flag enabled	Imec Internal
hdr integration times per band	Imec Internal
hdr nr frames	Imec Internal
number of averaged frames	Imec Internal
sensor bit depth	Number of bits per pixel.
timestamp s	Imec Internal

Table 16: Properties

See also

[Export collections and/or context](#) on page 33

5.12.3 Spectrograph CSV file format

In the spectrograph, the current graph can be exported as a PNG image or as a CSV spreadsheet file. In the CSV export file, each row contains values for all bands for a pixel. If a mean value export is made, each selection will have one data entry. Otherwise each pixel in each selection will be saved as a single row.

Variable	Description
Name	Name of the selection.
Color	Color of the selection.
x	X position of a pixel in the selection area.
y	Y position of a pixel in the selection area.

Table 17: Histogram

See also

[Export spectrograph data](#) on page 46

5.12.4 Classifier XML file format

Classification info of an acquisition can be exported to a XML file. This file can be imported to another classification.

Classifier XML

Variable	Description
input_dimensionality	Number of bands.
nr_classes	Number of classes.
max_angle_degrees	Maximum angle value used for the exported classification.
min_intensity	Minimum intensity value used for the exported classification.

Table 18: Classifier XML

Class infos

This part is the identification of the selections used for classifications.

Variable	Description
version	Version of the class info.
id	ID number of the class.
name	Name of the class
color	Color coding of the selection in #RRGGBB.

Table 19: Class infos

Centroids

Classification info of an acquisition can be exported to a XML file. This file can be imported to another classification.

Variable	Description
version	Version of the centroid info.
class_id	ID number of the class.
nr_elements	Number of band values stored for defining this centroid. After this variable, all values are stored back to back with a space character between them.

Table 20: Centroids

See also

[Import a classifier](#) on page 52

[Export the classifier](#) on page 51

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