

Realtime Vision System

User Manual

Version 1.0.0

Resonon Inc.

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Table of Content

1	Overview	3
2	Mechanical Components Setup	3
3	Data Acquisition Setup.....	4
4	Software.....	4
4.1	Main menu items description	6
4.2	Step by Step.....	6
4.2.1	Authorize	6
4.2.2	Installing the License	6
4.2.3	The Camera Setup Screen	6
4.2.4	Aligning the light source.....	7
4.2.5	Adjusting the focus.....	8
4.2.6	Setting the integration time.....	10
4.2.7	Setting the target framerate	10
4.2.8	Imager calibration	10
4.2.9	Master Reference.....	10
4.2.10	Completing the camera setup	10
4.3	Encoder setting.....	11
4.3.1	Setting the encoder counts per frame	11
5	Training The Realtime Vision System.....	13
5.1	Introduction to training the vision System	13
5.2	Training: step-by-step.....	14
5.2.1	Creating a new cube.....	14
5.2.2	Creating classes	15
5.2.3	Training tips:.....	16
5.2.4	Selecting a model.	17
5.2.5	Model Parameters.....	17
5.2.6	Training and Saving the model.....	18
5.3	Exiting the training screen	18

6	Object Detection	18
6.1	Configuring Object Detection	19
7	Configuring the output.....	20
8	Using the Realtime Vision System.....	21
9	Using RVS to Collect Datacubes	22
10	Quick Step-by-Step Reference Guide.....	23
11	Addendum	24
11.1	Using Configuration Files.....	24
11.1.1	Creating a configuration File.....	24
11.1.2	Launching RVS with configuration file	24
11.1.3	Configuration File Options	24
12	Glossary of terminology	26
13	Product Support.....	28
14	Copyright Notice	29

1 OVERVIEW

The Realtime Vision System utilizes hyperspectral imaging and powerful machine learning algorithms to produce accurate and real-time classification or grading of objects. Because the system relies on hyperspectral imaging, it can often differentiate objects that appear identical to the human eye. This document will guide you through the process of setting up the system and training it to classify objects, whether you are trying to distinguish genuine from counterfeit products, quantify a material property such as moisture content, detect foreign material or blemishes, monitor homogeneity, or sort a mixed stream of materials.

Major system components include the hyperspectral imager, the computer and software, and a lighting system. Also essential to the system's operation is a conveyor belt to carry objects past the scanning imager, a referencing system for calibration, an encoder, and an USB encoder adapter to synchronize the imager's operation with the conveyor belt movement.

While the primary capability of the system is to classify objects and output the results to other machinery, databases, or processes, it can also be used to quickly collect datacubes for analysis in other software. Both capabilities are described in this manual.

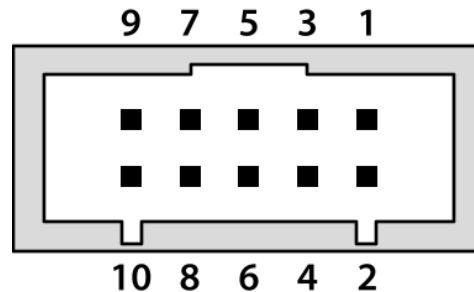
2 MECHANICAL COMPONENTS SETUP

It is essential to align your system's mechanical and optical components to ensure the system's optimal operation. General setup operations include the following.

1. Setting the camera height so that the entire width of the conveyor belt fills the imager's cross-track field of view.
2. Ensuring that the imager's cross-track field of view is perpendicular to the conveyor belt motion direction.
3. Adjusting the imager's position and angle, in coordination with the lighting, to optimize the amount of light reflected by the objects onto the imager. The fine-tuning of the lighting will be explained below in this guide.
4. Establishing a connection from an appropriate belt encoder to the Realtime Vision System.

Note: Appropriate encoders are incremental quadrature encoders. They have 3-channel differential signaling, typically with a 10-pin connector. Resonon provides the QSB-D model USB adapter to complete the connection with the belt system. The pinout setting for this adapter is below:

1	Digital I/O, Channel 0
2	Ground
3	Index-
4	Index+
5	A-/PWM0-
6	A+ or EAN0 or PWM0+
7	+5 Volts
8	No connection
9	B-
10	B+



* Pin 6 EAN0 is an A/D input designed for the MAE3-A10 and MA3-A10 analog output encoders. It can be used as a generic 10-bit A/D input (0-5V range). * Pin 6 PWM0+/PWM0- is a differential pulse width modulation input designed for the 10 or 12-bit PWM output of the MA3/MAE3 encoders.

3 DATA ACQUISITION SETUP

Once the mechanical and optical components are installed, they must be connected and powered in the following way:

1. Computer is connected to a power source.
2. Depending on the specific imager used, the imager is either connected to the computer's ethernet port that is labeled for the imager, or to the computer's USB 3.0 port.
3. Imager is connected to a power source (standard wall outlet) using the provided cable. Note that some imagers are powered through the USB data cable.
4. Encoder is connected to the computer via a USB port.
5. Light source is on. It is advisable to turn on the light source 15 to 20 minutes before beginning scanning for temperature stabilization, thereby ensuring repeatable/reliable operation.

4 SOFTWARE

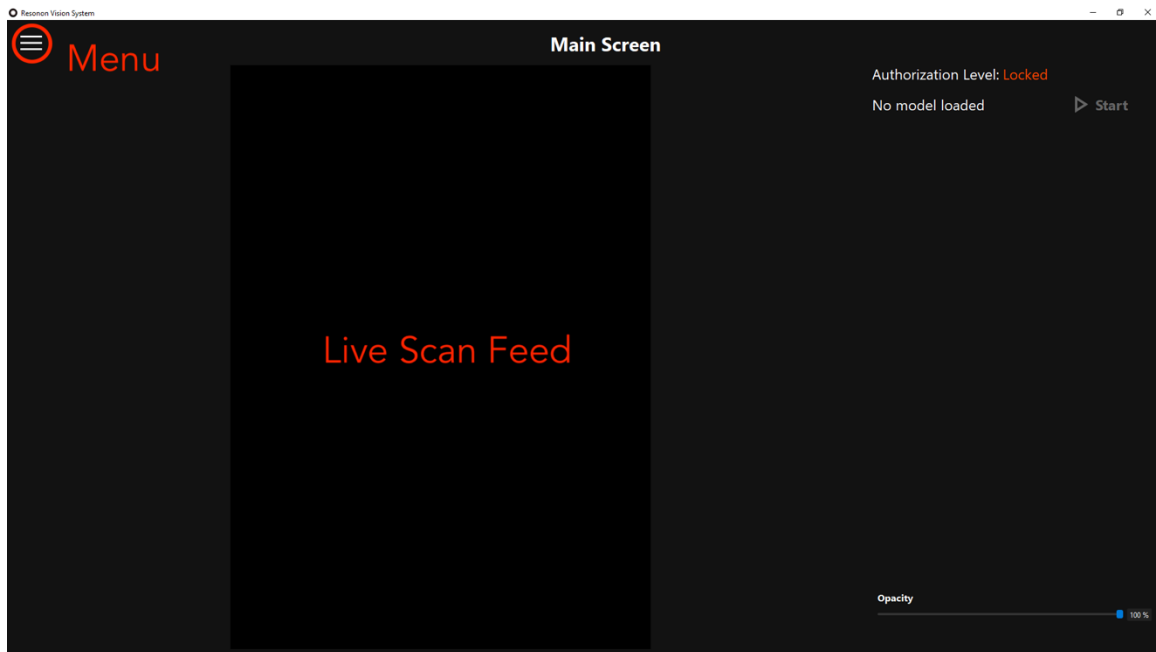
The Realtime Vision System (RVS) software can be configured to run at boot in full screen or launched in the normal manner by the user after boot. It will automatically detect the peripherals (imager and encoder). If you are launching the software with a new encoder, please follow the prompts and accept the requested changes.

Note: the window for configuring the encoder may be hidden by the main RVS window, so use Alt-Tab to bring it to the front.

If the imager is not connected, you will see an error message informing you that “Camera Initialization Failed.” In this case, exit the software*, check the imager connection, and launch the software again.

* You can exit the software by clicking ≡ (*Menu*) in the main screen’s top left corner, and then ↵ *Exit*.

The main screen is also the standard operation screen. Until you set up the system, it will be mostly empty.















Main screen

Click ≡ (*Menu*) in the main screen’s top-left corner to view the drop-down main menu and access any sub-screens.

Note: Until authorized, many of the menu items will be hidden. Also, until the Camera Setup has been completed, some menu items will be grayed-out and unavailable.


To exit any sub-screen, click ⬅ (*Back*) next to the screen’s name in the top left corner of that screen.

4.1 MAIN MENU ITEMS DESCRIPTION




 Lock	Enables an administrator to lock the system for normal operation (after the system has been set up)
 Authorize	Enables an administrator to unlock the system and access back-end training and settings.
 About	Contains software version information and other legal information
 License	Brings up the software license information and allows you to install a valid license to use the software
 Camera Setup	Accesses a suite of tools to focus and calibrate the imager
 Encoder Setup	Sets the encoder count and belt direction
 Logs	Accesses logs of various operations carried out on the system for future diagnosis and/or improvements. The logs are simple text files that are recorded locally on your machine
 Datacube Recorder	Collect datacubes that can be opened and analyzed in Spectronon. The datacubes can also be opened later in the training screen.
 Training	Contains tools to train the vision system to perform the desired task
 Object Detection	Provides tools to configure the object detection functionality
 Settings	Allows the user to change between Object and Pixel modes and configure the Object Output Format
 Exit	Shuts down the Realtime Vision System software

4.2 STEP BY STEP



4.2.1 AUTHORIZE

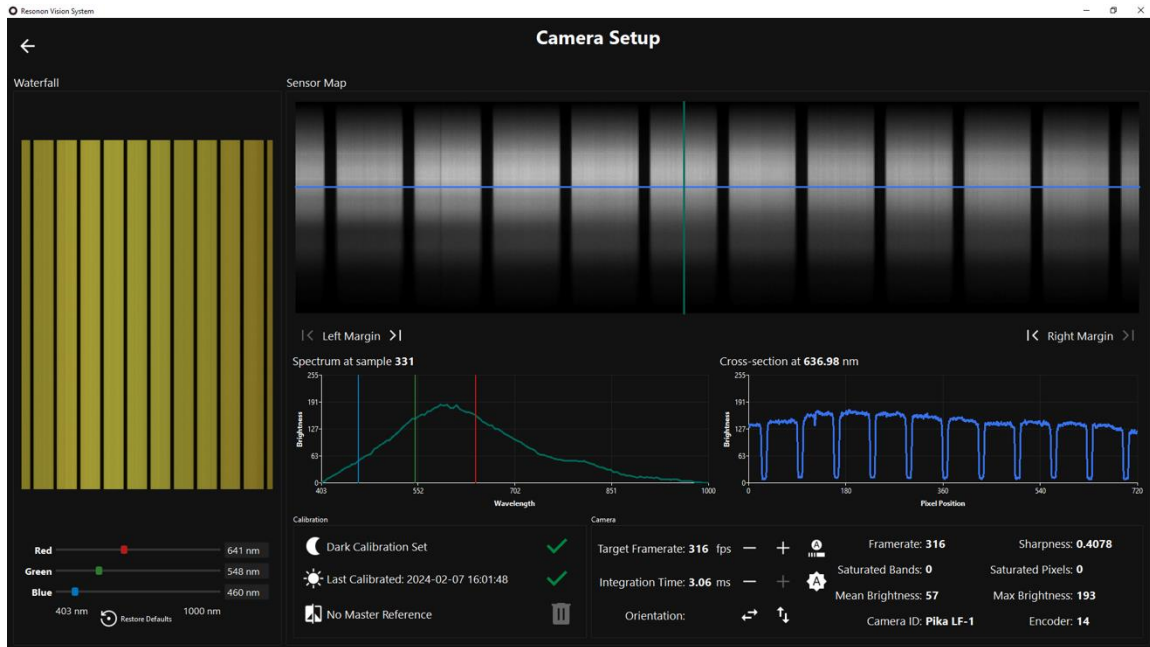
Different functionality of the software is accessed with different codes, allowing managers to determine which personnel have access to different aspects of the software (setup, training, running, etc). Click the  *Authorize* item in the Main Menu and enter in the appropriate code.

4.2.2 INSTALLING THE LICENSE

Access the License screen by clicking  (*Menu*), and then  *License*. Follow the on-screen instructions to install your license. If you have not yet obtained a license, please contact us at software@resonon.com. Please be prepared to provide the System ID number (also found on the license screen). Exit the *License* screen by clicking  (*Back*) in the top left corner.

4.2.3 THE CAMERA SETUP SCREEN

Click  (*Menu*), and then  *Camera Setup* to open a screen that contains tools to calibrate and align the imager for a specific setup. Most of these steps need only be done once unless the camera position or other setup parameters are changed. The *White Reference Calibration* is the exception to this rule, it should be done on a regular basis. The schedule for white reference calibration depends on the environmental conditions, shift or downtime constraints, and the stability of illumination.



Camera Setup screen


On the *Camera Setup* page, the top left image shows RGB spatial data as a function of time. This is the *Waterfall Scan Feed*, where the top of the waterfall is by default the most recently scanned line by the imager. You may change the direction of the live feed, or flip the image, using the ↔ (*Flip*) and ⇅ (*Reverse*) toggle icons at the bottom center of the screen.

The top right image is a *Sensor Map*. To understand this image, it is useful to explain that the imager is a scanning imager that captures a single line of light at a time in the cross-track direction of the conveyor belt, filling the sensor's x-axis. The light is then spread into its spectral components, filling the sensor's y-axis. Therefore, the *Sensor Map's* x-axis is a direct spatial representation of the live objects being imaged but its y-axis conveys the spectral makeup of each of those pixels along that x-axis.

Clicking anywhere on the *Sensor Map* with the crosshairs selects a point in the two-dimensional position/wavelength space. The center panel below the *Sensor Map* plots the brightness vs wavelength at the crosshair's spatial coordinate. The right panel below the *Sensor Map* plots the brightness vs cross-belt position at the crosshair's wavelength coordinate, which can be useful when focusing the imager.

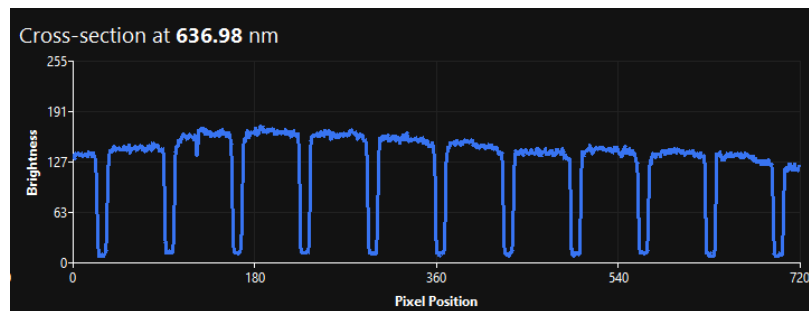
4.2.4 ALIGNING THE LIGHT SOURCE

Place the white reference material on the belt in the imager's field of view. Ensure that the white reference covers the entire imager's linear field of view. Loosen the thumb knob that locks the line light in position and swivel the line light back and forth across the imager's field of view until you maximize the image's brightness, then re-tighten the thumb knob. Red regions on the sensor map indicate

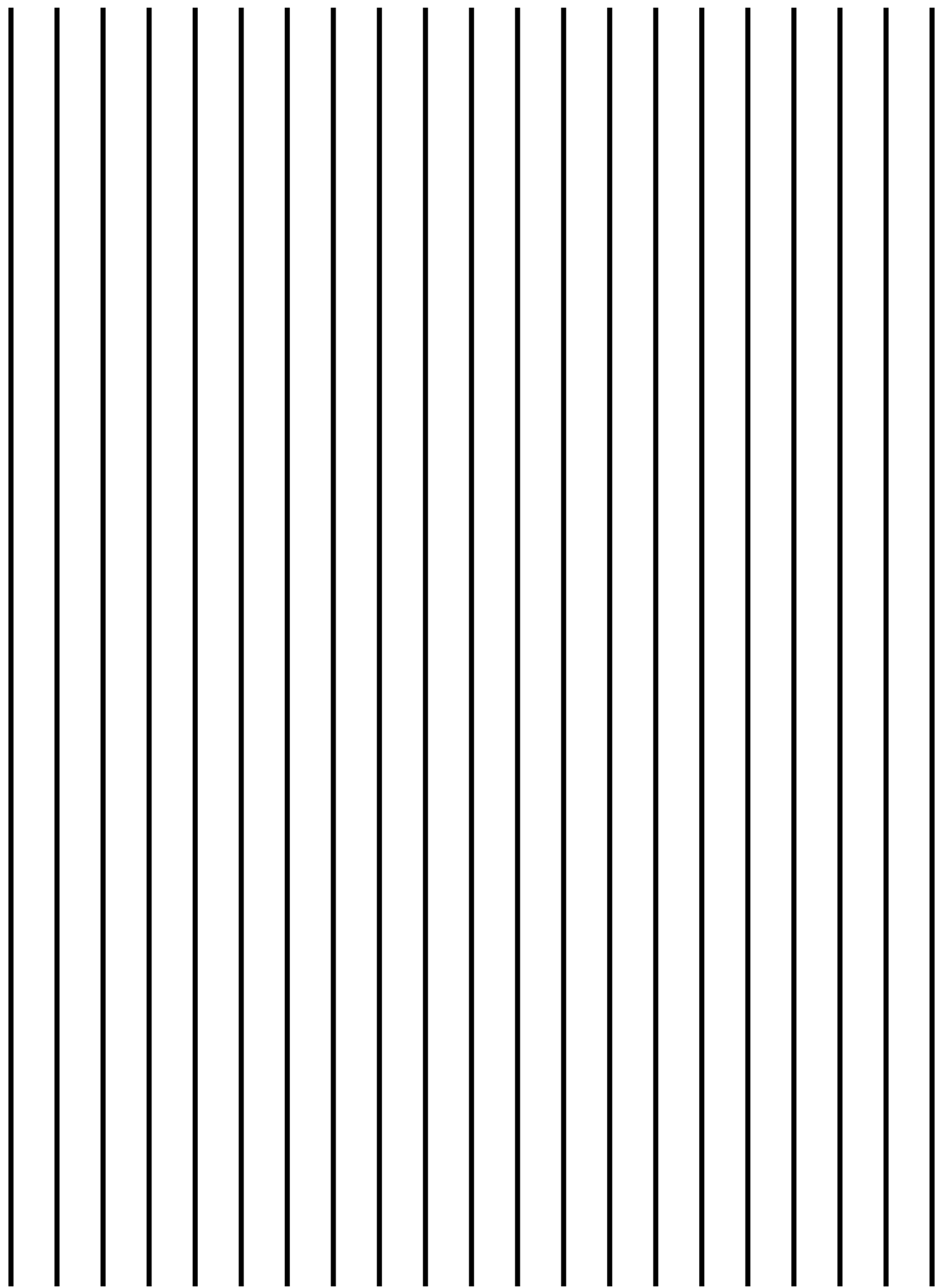
saturated pixels. Correct saturated pixels by adjusting the *Integration Time* using either the + and – buttons or the  *Auto Expose* button in the *Camera* panel near the bottom of your screen.

4.2.5 ADJUSTING THE FOCUS


Place a *Focusing Sheet* on the belt in front of the imager (any paper with sharp lines that run parallel to the belt will work). Loosen the set screw that locks the lens's focusing mechanism. Rotate the lens back and forth until you optimize the focus. Several tools can help optimize the focus. First, the line sharpness can be visually optimized in the *Sensor Map*. Second, you may maximize the depth and steepness of the dips in the *Brightness vs Pixels* plot (the dips in intensity represent the dark lines on the paper). This is shown in the plot below. Finally, you may adjust the focus by maximizing the *Sharpness* index number shown below the plot.



4.2.5.1 FOCUSING SHEET




4.2.6 SETTING THE INTEGRATION TIME


Keep the white reference material on the belt, making sure that it is clean, and that the imager's entire field of view lands on the reference material, (the entire width of the *waterfall scan feed*, and *sensor map*, are white). Click  *Auto Expose* near the bottom of the screen. You can also adjust the integration time manually with the – and + buttons.


Note: Integration time can limit maximum framerates. If higher framerates are desired more light may be necessary.

4.2.7 SETTING THE TARGET FRAMERATE



You may decrease or increase the target framerate using the -/+ adjustment buttons to the right of the *Target Framerate* label or set it automatically to the maximum possible framerate by clicking  *Automatic Framerate* at the bottom of your screen. It is normally recommended to use the highest framerate available.

4.2.8 IMAGER CALIBRATION


The *Calibration* panel is bottom and center of your screen. Click  *Record Dark Reference*. Follow the prompt to block the lens with the lens cap and click to continue. This step corrects readings for the baseline sensor activity in the absence of light. This only needs to be done once during the initial set up of the system.

Next, click  *Record White Reference*. You will be prompted to place the supplied white reference material in the imager's field of view and click to continue. This step allows the software to account for sensor response and spatially nonuniform illumination effects. This step needs to be performed frequently depending on the environmental conditions, shift or downtime constraints, and the stability of illumination.

4.2.9 MASTER REFERENCE

The two last icons in the *Calibration* panel allow you to set () or delete () a Master Reference. By setting a master reference, any subsequent *White Reference Calibration* that differs substantially from the master reference will trigger a warning message. **The warning suggests that something may have gone wrong with the setup such as a burnt-out bulb in the lighting system, a change to camera or lighting alignment, or a dirty white reference, and should always be investigated before proceeding further.**


4.2.10 COMPLETING THE CAMERA SETUP

You may now exit the *Camera Setup* screen using the  (*Back*) button in the top left of your screen.



4.3 ENCODER SETTING


The encoder function is to ensure that the imager's frame capture rate is properly synchronized with the conveyor belt's translation. This, in turn, ensures that images appear with the correct aspect ratio, even if the speed of the conveyor changes. Therefore, setting the *Encoder Counts per Frame* is equivalent to setting the image's aspect ratio.

4.3.1 SETTING THE ENCODER COUNTS PER FRAME

Navigate to the  *Encoder Setup* screen from the main menu. The first step is to check the direction of the encoder counts as the belt is running in its desired 'forward' direction. This is done by turning on the belt and observing whether the *Encoder Position* number is increasing or decreasing. If the number is decreasing, check the *Reverse Direction* box. If the number is increasing, the box should be unchecked.

Note: The *Reverse Direction* box just configures the software on the expected direction of the encoder counts, there is no need to change the direction of the belt travel.

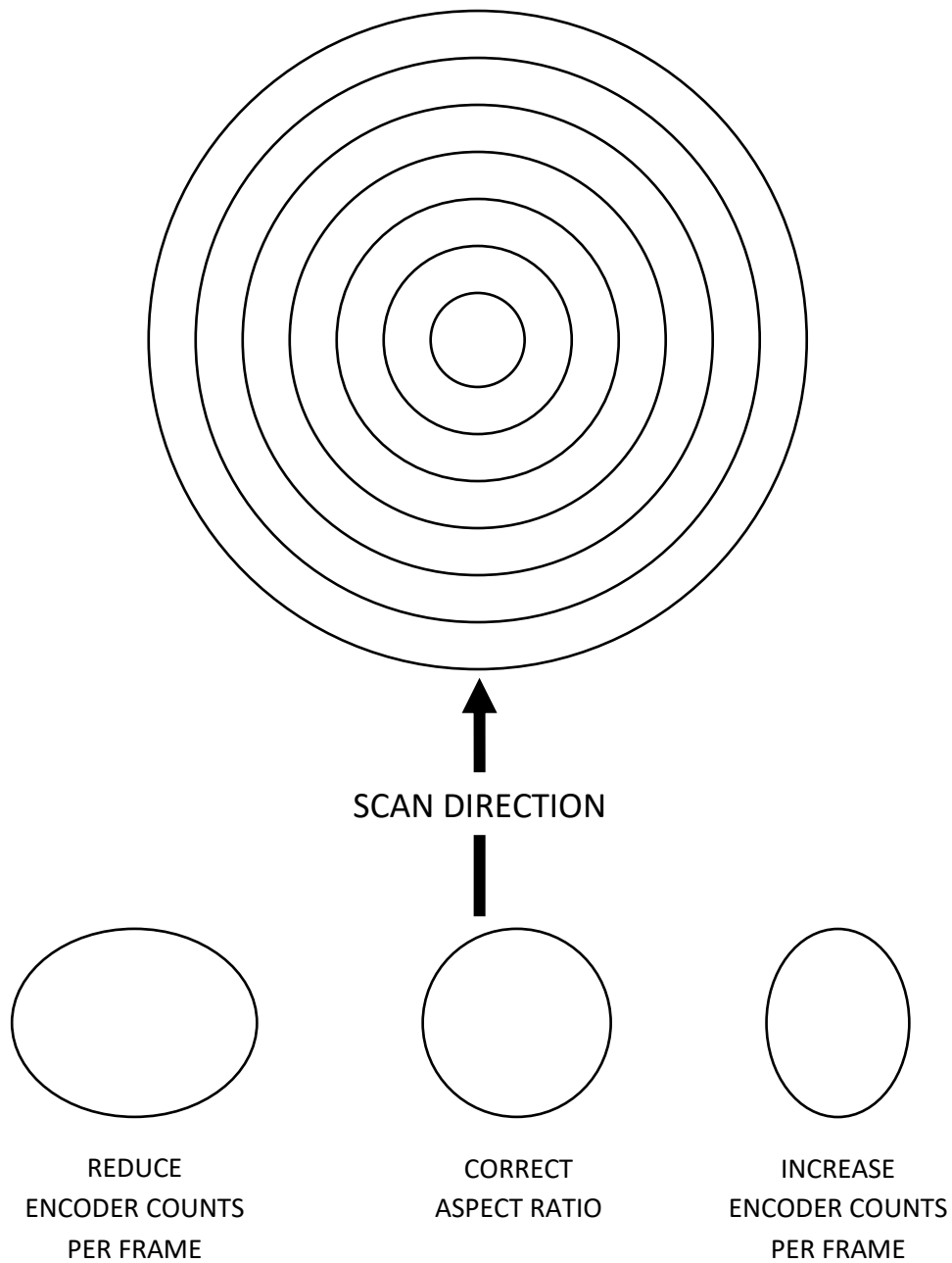
Place the included circular target (or flat circular object of the correct size) on the belt. Click the  *Start Camera* button. Remember that the software will not start recording until the encoder detects belt movement. Turn on the belt. After a full circle has been imaged you may stop the belt and then end the recording by clicking  *Stop*.

Note: If the software does not start recording even when the belt is in motion, the *Encoder Direction* setting may be incorrect. In this case, stop the belt,  *Stop Recording*, check or uncheck the *Reverse Direction* box.

Now press the *Detect Target* button. This feature will attempt to automatically set the correct *Counts Per Frame* for unity aspect ratio (also referred to as *square pixels*). This feature will only work if the circular target is the only object in the scene and that it has sufficient contrast. If the target appears to be properly detected, press *Confirm* to set the *Counts Per Frame*.

To check the setting, record another image of the circular target. Observe the image of the circle as it appears on the screen. If the circle is circular (proper aspect ratio) the encoder setting is correct. If the circle appears compressed along the belt's direction of travel, the imager is not taking enough frames and you need to reduce the *Encoder counts per frame*. If the circle appears stretched, you must increase the *Encoder counts per frame*.



4.3.1.1 ASPECT RATIO CALIBRATION SHEET

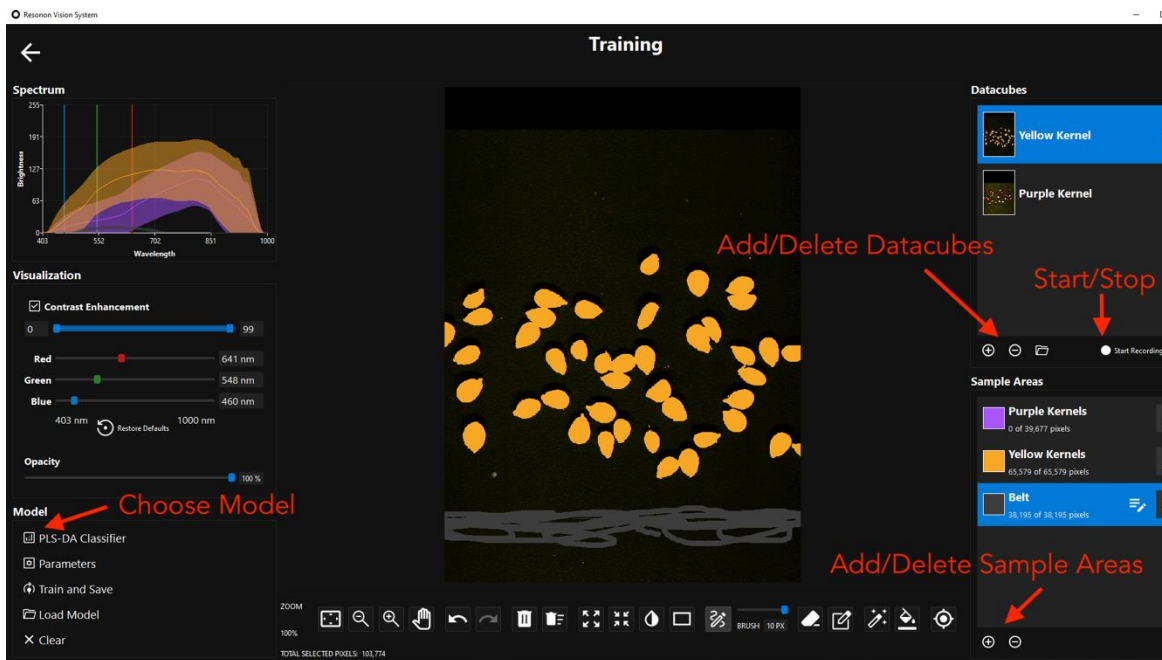


Note: this sheet will only work for the *Detect Target* function if the circle is carefully cut out.

5 TRAINING THE REALTIME VISION SYSTEM


5.1 INTRODUCTION TO TRAINING THE VISION SYSTEM

Before you are ready to use the Realtime Vision System, you must train it to distinguish the items of interest, for example, between good fruit and under-ripe fruit, between product and foreign material, between one object and another, or a combination of those classes. You will need to have representative samples available for each of the classes. Before proceeding, you should perform a *White Reference Calibration* (accessed via the *Camera Setup* screen). After that has been done, go back to the main screen, click  *Main Menu*, and then  *Training*.



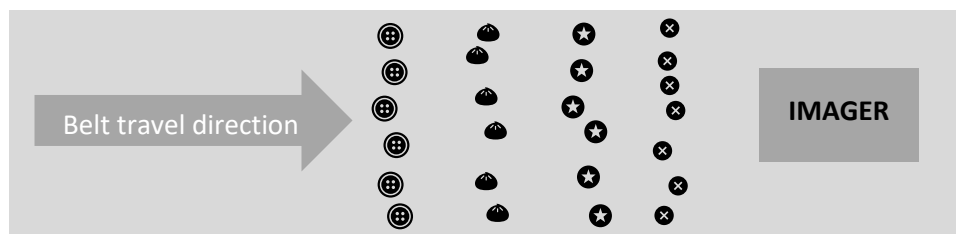
5.2 TRAINING: STEP-BY-STEP

5.2.1 CREATING A NEW CUBE

To the right of the screen is the *Datacubes* panel. In hyperspectral imaging, a *datacube* contains all the information that is acquired in a scan (spatial and spectral information for each pixel). Create a new cube by clicking the  *Add datacube* button. This is a placeholder for the cube that you will record next.


5.2.1.1 PREPARING THE TRAINING SET


Set down a variety of reference objects on the belt in a cross-track configuration in preparation for a scan that you will use to train the system. Since you can use multiple cubes for training, it is not





necessary that all the samples are present in a single scene. In fact, it might be useful to record a separate cube for each category or class of sample.

5.2.1.2 ACQUIRE A DATACUBE

Click  **Start Camera**. Note that the camera will not start recording until the encoder detects belt movement. Start the belt and let it run until all rows of objects have been scanned by the camera. You will see the objects appear in the *Scan feed* as this happens.

Stop the belt. Stopping the belt will halt the recording but you must also click  **Stop Camera** to proceed with the remainder of the training process. You have now acquired a *datacube* and are ready to start identifying various objects.



Note: You may acquire several *datacubes* to train a model. To acquire another *datacube* click  (*Add datacube*) and repeat the scan acquisition steps above. You may also load a previously acquired data cube from disk by clicking  (*Load cube from disk*). You may see a message that the program will interpolate the data. This will reformat the *datacube* to match the wavelength calibration of the current system's imager, if necessary.



Hint: The left panel contains image visualization tools. These settings do not affect the data, they simply modify how the image is rendered for your convenience. The overlay opacity refers to the areas of the image highlighted with the various selection tools. A




value of less than 100 will make the selected areas semi-transparent, allowing you to still see the objects below your selections.



5.2.2 CREATING CLASSES


Classes represent the different categories of objects or qualities the system is trained to recognize. The user creates classes by labeling regions within one or more datacubes.

To create a class, click the  (*Add Sample Area*) button. A new class will appear in the panel. On the right of that new class, click  (*Edit Area Label*) to rename the class to represent the category. Click OK. Then click the colored square on the left of the class row to change the color associated with this class. The next step is to use one of many tools to select the pixels that belong to that class.


















If you are using the Pixel mode (opposed to the Object mode, see Section 6 for more information), the conveyor belt needs to be trained as a class. In the *Selection Toolbar* below the scan, click the  (*Select pixels by drawing freehand*) tool and change the Brush size to 10 pixels. Then draw lines over several large areas of the conveyor belt, avoiding the objects on the belt, but including some of all parts of the belt (polished, scuffed, dirty, both edges, etc.) Finally, ensure that your training selection spans the full width of the belt and that it includes the belt's seam. You could also use the  (*Select pixels with a rectangle*) as an alternative.





Now click  (*Add Sample Area*) button again to add another class. Rename it to something representative and pick the color of your choice to represent the first type of objects you will train the system to identify. The  (*Select contiguous pixels*) tool tends to be quite useful for this purpose. Click  (*Select contiguous pixels*) and then click near the center of one of the objects of interest. The tool will automatically select contiguous pixels that are spectrally similar to the pixel you picked. You may use the *Tolerance* slider next to the tool to increase or decrease the extent of contiguous pixels. This tool updates the extent in real-time so you can see the results as you move the slider. **When you are finished, click the tool button again (or any other tool in the toolbar) to finalize the selection.**

The  (*Select pixels across the entire image*) tool operates in a similar manner to the  (*Select contiguous pixels*) tool but doesn't require the selected pixels to be contiguous. This tool also has a *Tolerance* slider and will similarly only finalize the selection after clicking another this tool button or any other tool button.

There is a range of tools you may use to select areas of the scan, which are listed in the table below. Experiment with each tool to see which ones may be most useful to select the appropriate pixels. At any time, you may click  *Undo* to reverse an operation.

Selection Tools	
	View the entire image

	Zoom in
	Zoom out
	Pan
	Undo
	Redo
	Send the current selection to the trash bin
	Send all selections to the trash bin
	Expand the current selection around the edges
	Contract the current selection around the edges
	Invert the selection
	Exclude the center of a selection, retaining only the border
	Freehand pixel selection (adjust the brush stroke with the BRUSH PX slider to the right)
	Freehand erase selected pixels (adjust the brush stroke with the BRUSH PX slider to the right)
	Rectangular selection tool
	“Magic wand” selection tool selects contiguous spectrally similar pixels. The tool’s sensitivity (to spectral similarity) can be adjusted with the TOLERANCE slider to the right
	Similar to the “magic wand” tool above but selects all spectrally similar pixels in the scan, whether they are contiguous or not
	Inspect the spectrum at the cursor location

You may add as many classes as you need. In the example above you would create a class for each of the objects you originally scanned: , , , and , in addition to the conveyor belt. Again, you only need to train the belt as a class if using Pixel mode instead of Object mode.

At any time, you may go back and select additional areas for any class by clicking/highlighting that class in the *Sample Areas* panel. Whichever class is highlighted will be the one you are actively working on. Alternate clicks on the class name will activate (highlight) and deactivate that class.

Repeat the above steps until you have acquired several thousand pixels (if possible) for each class.



5.2.3 TRAINING TIPS:

Make sure that your training areas span the full range of variability of the objects you are training. For example, if you are training nuts and some nuts are naturally lighter or darker than others, make sure you have some of the lightest, some of the darkest, and some of the middle range included in the training set.


Train each class across the entire belt width. In other words, do not put all “A” objects on one side of the belt and “B” objects on the other for training purposes.

Train to the edges of the objects of interest, while being careful not to include pixels that don’t belong. This is especially important for non-flat objects that cast shadows or reflect light differently at the sides compared to the center.


Shadows should be trained as belonging to the belt class.

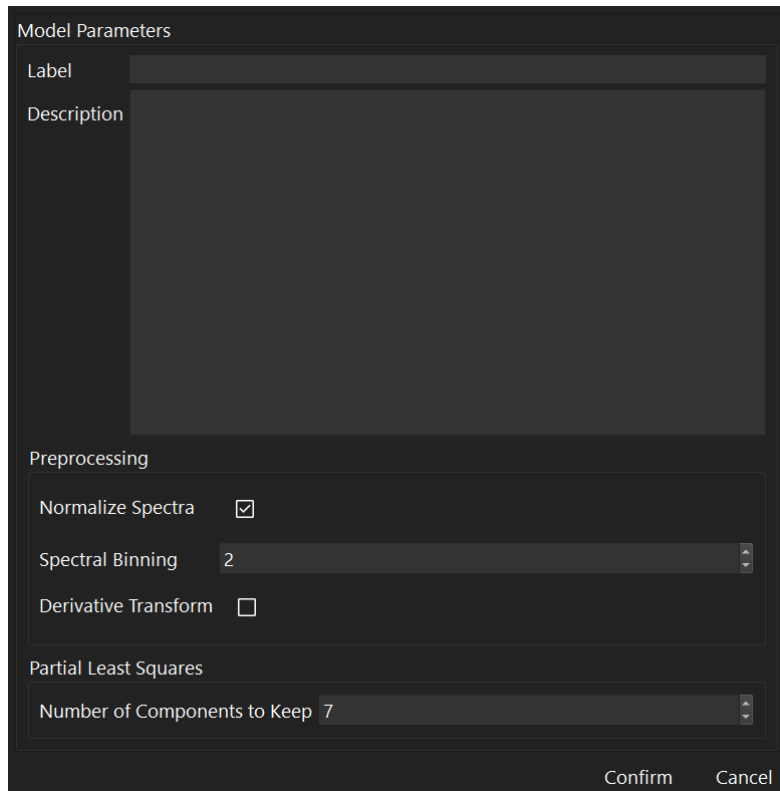
It may be possible to streamline the training process by selecting the entire belt with one of the magic wand tools, and then inverting the selection to obtain the objects of interest. However, be careful to only train the items you intend to train, excluding dirty belt spots, broken product pieces, shadows, etc. The  Dilate and  Erode functions are useful for controlling the selected areas in this case.

5.2.4 SELECTING A MODEL.

Once you have finished creating and labeling classes in the datacube(s), you can train and save a model. A model contains all the data and analytical steps the software needs to accomplish the required tasks. You may train the system to accomplish different tasks, thereby creating different models that can be saved and recalled whenever a specific task is required. Click the  (*Current Model Name*) button to bring up the model selection window, which has descriptions of all the models. The PLS-DA Classifier is a good place to start for classification problems, and the Partial Least Squares Regressor is a good starting point for regression problems.


5.2.5 MODEL PARAMETERS

You may modify the parameters used by the model algorithm by clicking  *Parameters* on the *Model* toolbar. The Label and Description can be used by the user to identify the specific implementation of the model when evaluating different models and parameters. For information on how each parameter impacts the results and speed, hover the mouse over the parameters.




The image shows a 'Model Parameters' dialog box with a dark theme. It has a title bar 'Model Parameters'. Below the title bar, there are two input fields: 'Label' and 'Description'. The 'Description' field is larger and occupies more space. Below these fields, there is a section titled 'Preprocessing' which contains three options: 'Normalize Spectra' with a checked checkbox, 'Spectral Binning' with a dropdown menu showing the value '2', and 'Derivative Transform' with an unchecked checkbox. Below the 'Preprocessing' section, there is another section titled 'Partial Least Squares' which contains a dropdown menu for 'Number of Components to Keep' showing the value '7'. At the bottom right of the dialog box, there are two buttons: 'Confirm' and 'Cancel'.

5.2.6 TRAINING AND SAVING THE MODEL

Click the  to train and save the model. First supply a name and file location for the model, then click OK. This system will then train and save the model, which may take a minute. When it is completed, a window will pop up with information regarding the model's fit with details that depend on the chosen model. In the *Cross-validation confusion matrix*, scores tending towards 1.00 on the diagonal, and tending towards 0.00 everywhere else indicate that the model is likely to perform as expected.

Close the report to continue.



5.3 EXITING THE TRAINING SCREEN

You may now exit the Training screen using the  (*Back*) at the top left of your screen. The system will prompt you to confirm that you have saved your model. Click Exit to proceed.

6 OBJECT DETECTION



The Realtime Vision Software can be used in two different units of classification, *pixels* or *objects*. In Pixel mode, each pixel in the acquired image is classified independently of all other pixels. In Objects

mode, objects are first identified as a group of continuous pixels unique from the conveyor belt, then each group is classified as a singular object using the trained model.

To switch between Pixel mode and Object mode, press the  *Settings* button from the Menu and toggle between the two modes. If using Object mode, you need to configure the object detection settings in the  Object Detection screen. This procedure is explained in the next section.

When in Object mode, two actions (or both) can be executed when an object is detected, Run the Model and/or Save a Datacube. Run the Model runs the previously trained classification/regression model on the object. As the name implies, Save a Datacube will save a datacube of the detected object in the specified folder. The object in the datacube will be surrounded by zero-value pixels to make the image rectangular, as required by the datacube format.

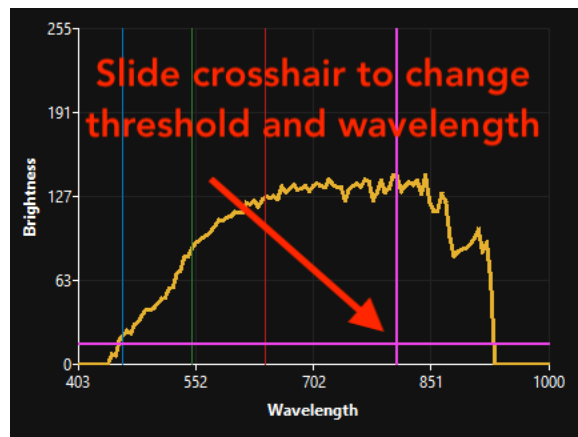
6.1 CONFIGURING OBJECT DETECTION

Pixels can be grouped into objects if they meet two criteria: Minimum or maximum brightness at a specific wavelength, and minimum or maximum number of contiguous pixels. Once a group of pixels meeting these criteria is identified, the trained model is run on the object to predict its class or quantity. To begin, set up your objects on the conveyor belt. In the  Object Detection screen, select  Record and start the belt, stopping both the belt and the recording when the objects have passed under the imager.



In most cases, the objects will be brighter than the belt as conveyor belts are usually made dark black rubber. If this is the case, click the Brighter than Threshold box. If the belt/background is brighter than the objects, click the Darker than Threshold box.

Then click on an object in the acquired image. This will show the spectrum in the Brightness plot in the upper left side of the screen. Then, click in this plot to move the Threshold up and down, and the Wavelength left and right. When the threshold condition is met, objects will show up as solid colors in the screen. Use this visual aid to fine tune your threshold adjustment. You can further constrain the object detection criteria by using the Minimum and Maximum Size Constraints. The plot below shows the threshold set below the object brightness (yellow), above the belt brightness (not shown), and at ~800 nm.

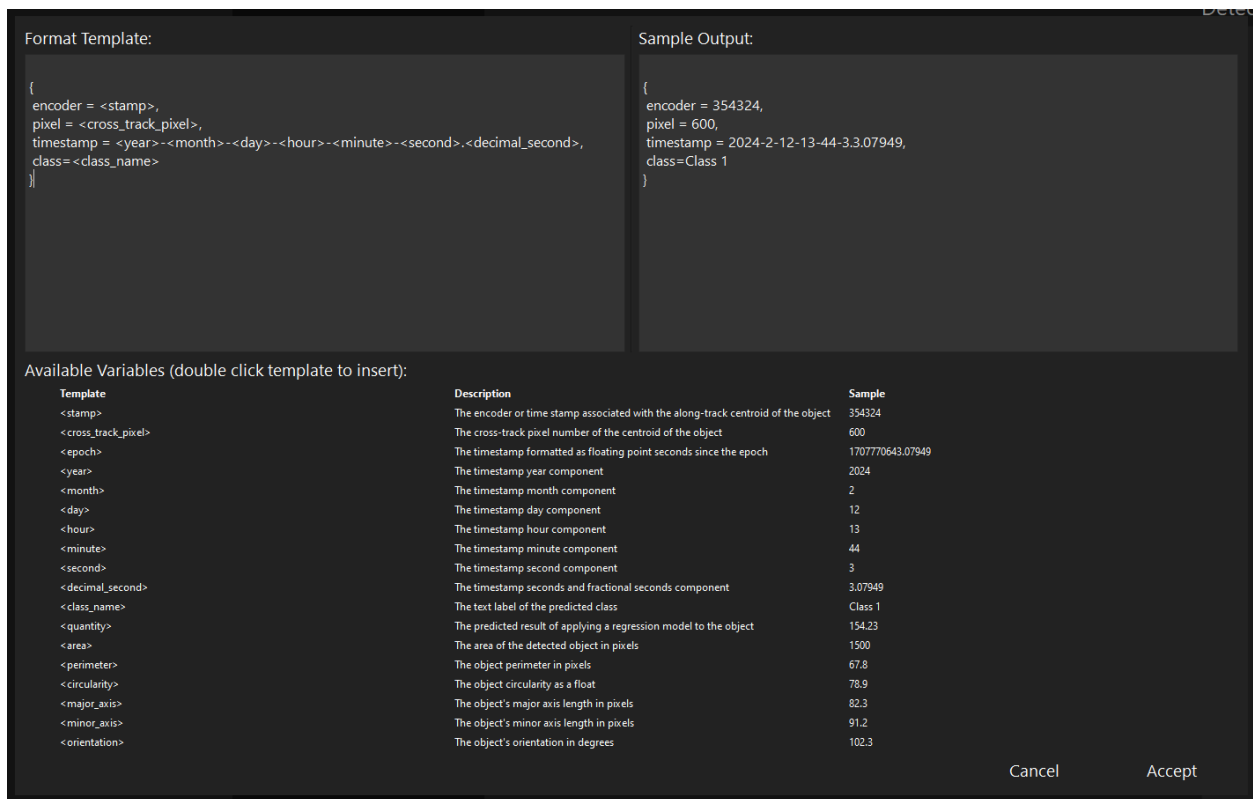


7 CONFIGURING THE OUTPUT

When using RVS with Objects as the Classification Unit, the software can be configured to output the classification or regression results to a socket on the ethernet port in formats determined by the user. To set up the output format, go to the Settings screen, then click the Configure Object Output Format.

Note: If this setting is grayed out, it is because the software is configured for Pixel mode instead of Object mode.

In the resulting screen, type the desired formatting characters/words in the Format Template box and double-click one or more of the Available Variables to insert it into the Template box.



In the example below, the system will output everything between the braces (including the braces) for each object detected.

```
{
encoder = <stamp>,
pixel = <cross_track_pixel>,
timestamp = <year>-<month>-<day>-<hour>-<minute>-<second>.<decimal_second>,
class=<class_name>
}
```

Here is a simpler example that uses commas as the delimiter between fields, and a semi-colon as the delimiter between objects.

```
<stamp>, <cross_track_pixel>, <class_name>;
```

8 USING THE REALTIME VISION SYSTEM

Standard operation of the Vision System occurs in the main screen. If you are on another screen, you can always return to it by using the ← (Back) at the top left of whichever sub-screen you are on.

To use/test the system, place a mixed collection of objects on the belt, click ► *Start* (top right of the main screen), start the conveyor belt, and observe the classification occur in real-time on the *Scan feed* in the center of the screen.

It is important to remember that the system will assign a class or quality to every pixel/object in the image, meaning that untrained objects may get classified in unexpected ways. For best results, try to train as many categories/conditions of expected objects as practical.

A Smoothing filter can be applied to the scan feed by clicking the +/- *Result Smoothing* icons in the bottom right panel. Smoothing effectively removes the smallest pixel clusters from the scan feed. A larger smoothing *window* size removes larger isolated groups of pixels. A window of zero means that no smoothing is being performed on the data.



Main screen

9 USING RVS TO COLLECT DATACUBES

RVS can also be used to collect datacubes for other software or code, quickly and easily. To enable this functionality, go to the ⚙️ *Settings* screen. First, make sure *Object* mode is enabled (you will need to set up 📦 *Object Detection* as well if you haven't already). Then select *Save a Datacube* and select a Folder and Filename base. Then hit close. When the system is run from the main screen, datacubes will be created and saved from all detected objects. As noted earlier, the object in the datacube will be surrounded by zero-value pixels to make the image rectangular.

10 QUICK STEP-BY-STEP REFERENCE GUIDE

Once you have gone through the setup process several times, you are likely to remember how to accomplish each step, but it is easy to forget to perform one of the steps. You may use this Step-by-Step Quick Reference Guide to ensure the system is set up properly. Refer to the main body of this manual if you have forgotten details of how to perform a specific step.

- ✓ Check components.
 - Check that the computer is connected to a power source (standard AC outlet) and to the network (if applicable) via the correct ethernet port (labeled) on the computer.
 - Check that the imager is properly connected. Some imagers require an ethernet connection to the computer for data transfer, and a power connection to a standard outlet. Other imagers are connected to the computer via a Micro-B USB cable that serves for both power and data transfer.
 - Check that the encoder is connected to one of the computer USB ports with the supplied QSB-D model USB adapter.
 - Check that the light source is plugged in and turned on (15 to 20 min to warm up).
- ✓ Launch the software.
- ✓ If any components have been moved or modified, go through the entire Camera Setup procedure.
 - Focus the imager.
 - Set the *Integration Time* (use the Automatic Integration Time).
 - Set the *Target Framerate* (use the Automatic Framerate).
 - Perform the *Dark Reference Calibration*.
 - Perform the *White Reference Calibration*.
 - If appropriate, reset the *Master White Reference*.
 - Briefly run the belt to make sure that the encoder counts are increasing. If not, go to the *Settings* screen to check (or uncheck) the *Reverse Direction* box for the encoder.
 - Check the images' aspect ratio. If it is incorrect, fix it by adjusting the *Encoder Counts per Frame* in the *Encoder Setup* screen.
 - Exit the *Camera Setup* screen and begin using the system.
- ✓ If you need to train the system to perform a new classification, perform a *White Reference Calibration* and then go through the training procedure using the *Training* screen.
 - Add a new datacube.
 - Start the camera, run the belt, and acquire a scan (datacube) of your training objects.
 - Create object classes and select areas of the scan for each class.
 - *Train and Save* the model.
 - Exit the *Training* screen.
 - Configure Pixel or Object mode in *Settings* and set up *Object Detection* parameters if applicable.
 - Begin using the system.
- ✓ Once the system is fully focused, calibrated, and trained, perform a *White Reference Calibration* and start using the system by clicking ► *start* on the top right of the main screen and turning on the belt.

11 ADDENDUM

11.1 USING CONFIGURATION FILES

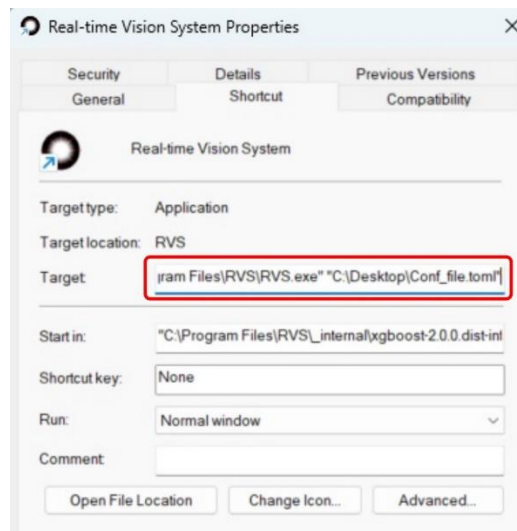
The behavior of RVS can be configured for specific scenarios by using a configuration file. Multiple files can exist, which allows the user to select which specific configuration to use when running RVS. This can be useful for using RVS in demonstrations, use without an encoder, or with a simulated camera instead of an actual imager.

11.1.1 CREATING A CONFIGURATION FILE

A configuration file is an ordinary text file with a *.toml* extension. They can be placed anywhere on the computer's file structure. Files can be created and edited using Notepad or other text editors. An example name and path might look like: *c:\RVS Configurations\demo_mode.toml*

11.1.2 LAUNCHING RVS WITH CONFIGURATION FILE

First, locate or create a shortcut to the RVS executable. Then right-click on the shortcut and select Properties. In the Target field, insert the cursor to the right side of the text field, past the quotation mark. Type a space and then the path to the *.toml* file. Press OK. An example is shown below.



You can create multiple shortcuts, each with their own configuration file path. It is helpful to name each shortcut to represent its configuration.

11.1.3 CONFIGURATION FILE OPTIONS

The following are some useful options for the configuration file. Multiple options can be included in the same configuration file.

11.1.3.1 FREE RUN (NO ENCODER)

RVS can be operated without an encoder for demonstration purposes or for laboratory use. In this case, the aspect ratio of the images is set by framerate of the imager and belt speed of the conveyor. To use this mode, include the following line in the configuration file:

```
use_encoder = false
```

11.1.3.2 SIMULATED IMAGER

RVS can use a pre-recorded datacube to simulate an imager when an actual imager is not practical, usually for demonstration purposes or evaluating the feasibility of a problem. To do this, include a line similar to the one below:

```
simulated_camera_file = "C:\\datacubes\\almonds.bip"
```

Where *C:\\datacubes\\almonds.bip* is the path to your datacube. Include the quotation marks on both ends. The corresponding header file to the datacube must be in the same folder.

11.1.3.3 FULL SCREEN

RVS can be launched in full screen with the following addition to the configuration field:

```
fullscreen = true
```

11.1.3.4 START AUTHORIZED

RVS can be launched without need for authorization to access all the functionality. It can be de-authorized after launch, if desired.

```
start_authorized = true
```

12 GLOSSARY OF TERMINOLOGY

Class: In Realtime Vision System, a *class* is a group of spectrally similar objects, or parts of objects, that we wish to differentiate from the rest. If you simply want the Vision System to identify objects as they run down the conveyor belt, you will create two classes (one for the objects, and another for the belt). If you wish the system to differentiate good objects from bad objects, you will create three classes (one for good objects, one for bad objects, and one for the belt,). If you wish the system to differentiate between “good” parts of an object from “bad” parts of an object you will again create three classes (one for the good parts, one for the bad parts, and one for the belt).

Dark Reference calibration: Calibration that is done to compensate for the sensor’s dark current.

Datacube: The entire dataset associated with a scan. A hyperspectral image has two physical dimensions but also a third spectral dimension. The data set must keep track of intensity as a function of x, y, and w. Hence the designation *datacube*.

Encoder: Device used to keep track of conveyor belt movement, much like the odometer in your car.

f-1 score: A metric to rate a classification model’s quality, or ability to perform the classification task. Mathematically: $f-1 = (2 * Precision * Recall) / (Precision + Recall)$

Integration time: This is the imager’s dwell time to acquire each line in a scan. It is exactly like the exposure time on a traditional camera. Longer integration times allow the imager to capture more light. Too long of a dwell time will saturate pixels and/or lead to motion blur.

Model: In Realtime Vision System, a model consists of all the information acquired to perform a specific classification task. It includes the sample areas designated by the user as representative of the various classes, and the mathematical algorithm applied to those classes to sort whether a subsequently acquired pixel belongs to one class or another, based on its spectral makeup.

Precision: Indicates a model’s success rate as to whether the pixels it identified as belonging to a class *indeed* belong to that class. Mathematically: $TruePositives / (TruePositives + FalsePositives)$.

Recall: Indicates a model’s ability to correctly identify all pixels corresponding to a given class. A score of 1.00 indicates the model correctly identified 100% of the pixels it was aiming to identify. Mathematically: $TruePositives / (TruePositives + False Negatives)$.

Sample area: In Realtime Vision System, this refers to areas of a scan selected by the user as belonging to a chosen class for the purpose of training the system.

Scan: The process of acquiring a datacube.

Scan feed: The on-screen live image of objects travelling down the belt, which can be an RGB visualization of the data (regular image) or a color-coded classification of the objects travelling down the belt.

Sensor Map: Two-dimensional live representation of what the camera sensor is seeing. The horizontal axis corresponds to the physical cross-track location in the line scan, and the vertical axis represents the array of wavelengths associated with each of the physical locations in the line scan.

Target Framerate: The number of line images acquired by the imager every second. It is a “target” framerate because the software only retains as many lines as it needs to produce images with the correct aspect ratio.

Waterfall scan feed: A recent history of the imager’s linear field of view. The horizontal axis corresponds to the physical cross-track dimension while the vertical axis represents time from $t = \text{“a few seconds in the past”}$ to $t = \text{“now”}$.

White Reference Calibration: Process to acquire a reference datacube used to correct all subsequent datacubes with respect to instrument-sensor-response and spatially nonuniform illumination effects. This should be redone regularly to account for possible lighting fluctuations.

White reference material: High diffuse reflectance material such as Spectralon®, Fluorilon®, or sheet of white Teflon® that is used to calibrate the imager response.

13 PRODUCT SUPPORT

Please contact Resonon by phone, email, or via the form on our website:

Phone: 1.406.586.3356

Website: <https://resonon.com/support>

Email: support@resonon.com or software@resonon.com

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