Intel® RealSense™ D400 Series/SR300 Viewer

User Guide

Revision 002

May 2018

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Contents

Revision History

Document Number	Revision Number	Description	Revision Date
337495	001	• Initial Release	May 2018
337495	002	• Added Post Processing Segment	May 2018

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1 Introduction

1.1 Purpose and Scope of this Document

This document is the user guide for the Intel® RealSense™ Viewer for Intel® RealSense™ D400 series/SR300 depth modules and cameras. The Intel® RealSense™ Viewer includes support for Windows* and Linux*.

1.2 Reference Documents

Documents
Intel® RealSense™ D400 Series (DS5) Product Family/SR300 Datasheet https://www.intel.com/content/www/us/en/support/articles/000026827.html
https://www.intel.com/content/dam/support/us/en/documents/emerging-technologies/intel-realsense-technology/realsense-sr300-datasheet1-0.pdf
Intel® RealSense™ Camera Depth Testing Methodology

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2 RealSense™ Viewer Overview

2.1 Intended Users

RealSense™ Viewer Tool is designed for end users/developers to test or evaluate the D400 series/SR300 cameras.

2.2 Features

- Tools works for all Intel® RealSense™ D400 series/SR300 cameras
- Tool supports Windows* 10 and Linux*

2.3 Description

RealSense™ Viewer is a sample tool allowing a user access to most camera functionality through a simple, cross-platform UI. The tool offers the ability to:

- Stream from multiple RealSense™ devices at the same time
- Explore point cloud data in real time or by exporting to file
- Record RealSense™ data, or playback of recorded data
- Access to most camera specific controls, including 3D-generation ASIC registers when available

2.4 Implementation

RealSense™ Viewer is provided in a binary form on Windows* and Linux*, or it can be built from source along with the rest of the libRealSense library. The viewer is designed to be lightweight, requiring only a handful of embedded dependencies. Cross-platform UI is a combination of raw OpenGL calls, GLFW for cross-platform window and event management, and IMGUI for the interface elements.

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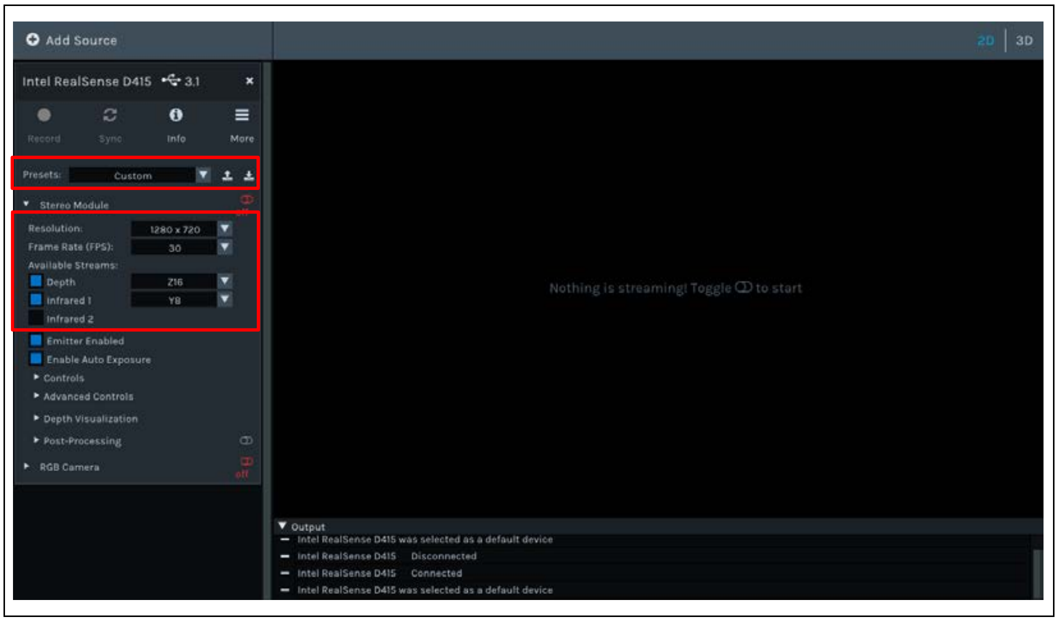
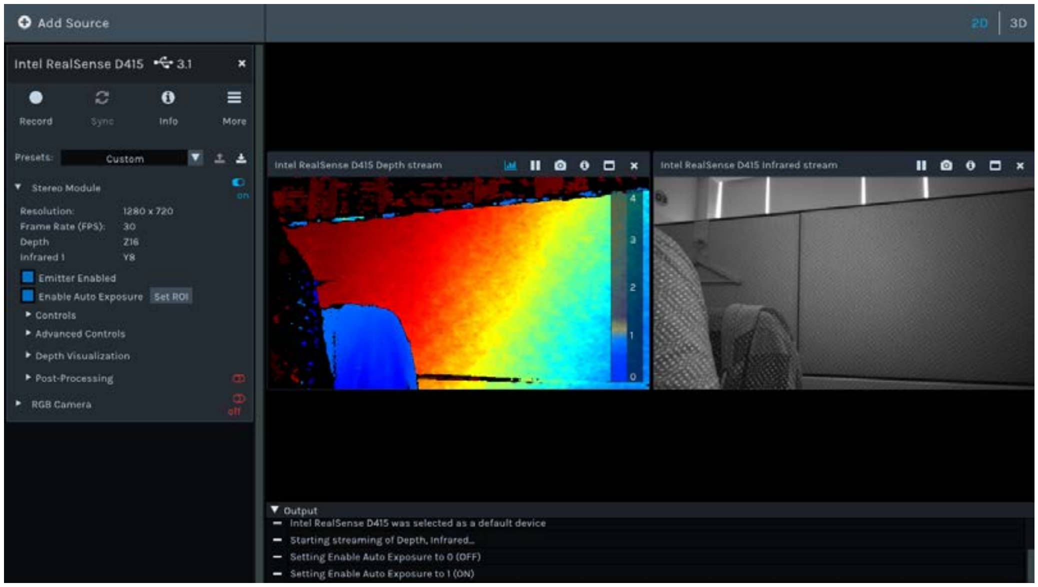
3 RealSense™ Viewer Usage

3.1 Streaming

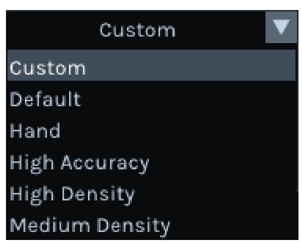
RealSense™ viewer allows the user to select and configure streams for depth, infrared and RGB. This section provides an overview of the parameters that are customizable by the user in the tool. After the user has completed the configuration, they must click  button to start streaming. The viewer supports both USB2.0 and USB3.0, so the available configuration parameter will be different due to USB2.0/USB3.0 capability.





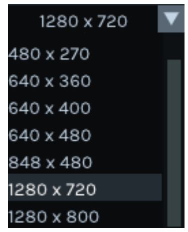
3.1.1 Preset

To assist users Intel has created a series of predefined presets that can be selected according to user's usage. The initial Preset is "Custom", which may be the default or a user modified preset. Only when the user actively selects a preset, or loads JSON file, it will be updated in the Preset menu accordingly. A detailed description of the presets are covered in Chapter 4.



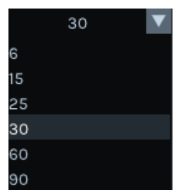
3.1.2 Resolution

The D400 series camera provides the end user with a wide range of resolutions to choose from to meet their solution needs. For example the D415 can support resolutions from 424x240 ~ 1920x1080; the D435, can support resolutions ranging from 424x240 ~ 1280x800. The user should select the resolution that best suits the usage. Note higher resolution has higher accuracy but results in an increase the min-Z and computational intensity. Refer to the D400 Series datasheet https://www.intel.com/content/dam/support/us/en/documents/emerging-technologies/intel-realsense-technology/Intel-RealSense-D400-Series-Datasheet.pdf, for further details on frame rate, resolution and format combinations.



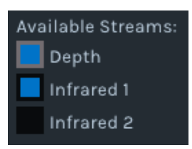
3.1.3 Frame Rate

The D400 series camera provides the end user with multiple frame rates to choose from to meet their solution needs. Ranging from 6 to 90 FPS, the supported frame rate will differ depending on the resolution selected. Refer to the D400 Series datasheet, https://www.intel.com/content/dam/support/us/en/documents/emerging-technologies/intel-realsense-technology/Intel-RealSense-D400-Series-Datasheet.pdf, for further details on frame rate, resolution and format combinations.



3.1.4 Available Streams

The RealSense™ viewer allows the user to select a combination of streams for depth, infrared and RGB. The user can select a stream by checking/unchecking from the list of available streams to enable/disable the stream.



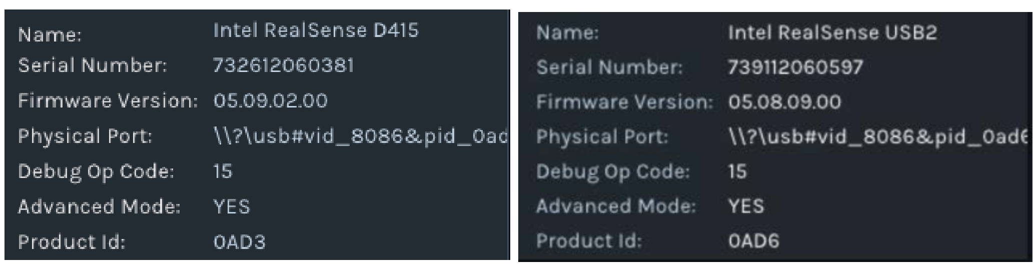
3.1.5 Stream Formats

Format for specific stream, available formats for each stream might different, the picture below shows format of D400 IR channel.

3.2 Device Information

RealSense™ viewer contains simple device information, such as Serial number, firmware version and Product id etc. To display/hide the device information section, click the info button at the top of the configuration panel. The information will be different when connect to different USB type.

USB 3.0 **USB 2.0**



3.3 Visualization

Within Depth Visualization segment, the RealSense™ viewer provides multiple settings to provide for better visual feedback.

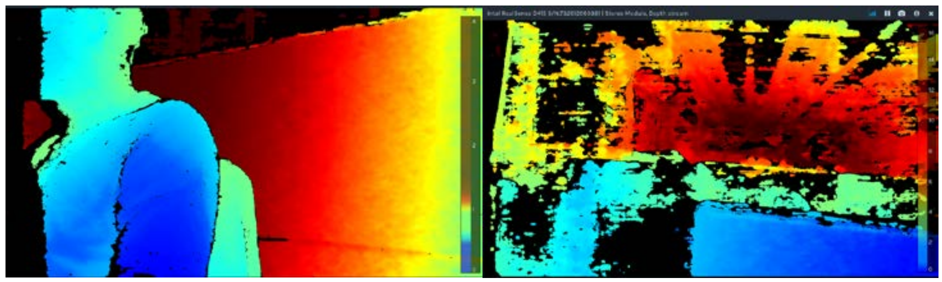
3.3.1 Visual Preset

The RealSense™ viewer provides four available preset to better visualize with different environment.

3.3.1.1 Dynamic

The color will be changed dynamically based on the valid depth pixel value range. For example, if within the image the valid depth pixel value range from 45cm~120cm, then the 45cm pixel is colored in blue color and 120cm pixel is colored in red color. But if valid depth pixel range from 45cm ~ 4m+, then the 45cm pixel is colored in blue and 4m+ pixels is colored in red.

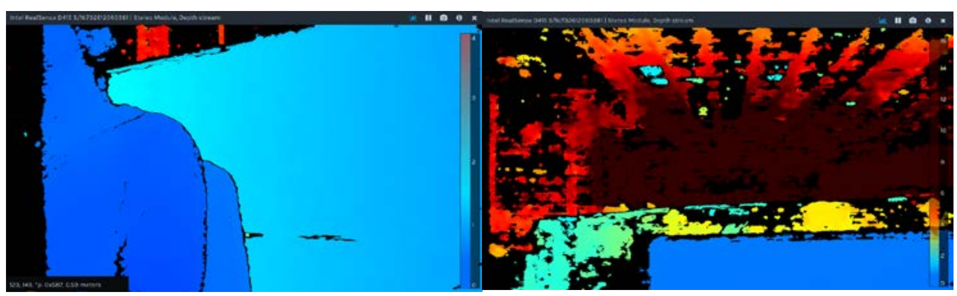
45 ~ 120cm 45cm ~ 4m+



3.3.1.2 Fixed

The color change is proportional to the distance between device min-z to 6m.

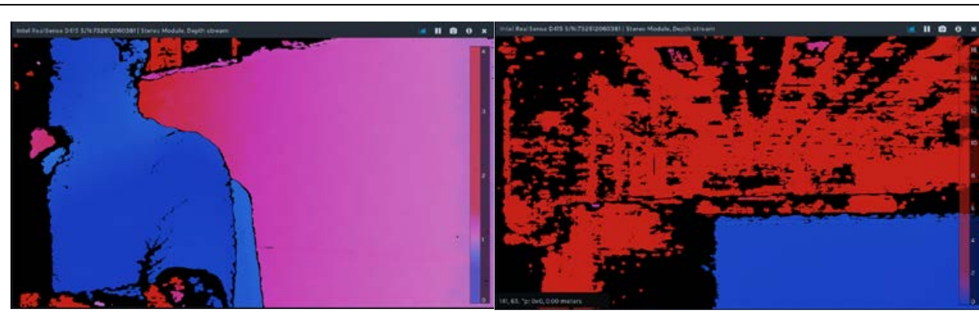
45 ~ 120cm 45cm ~ 4m+



3.3.1.3 Near

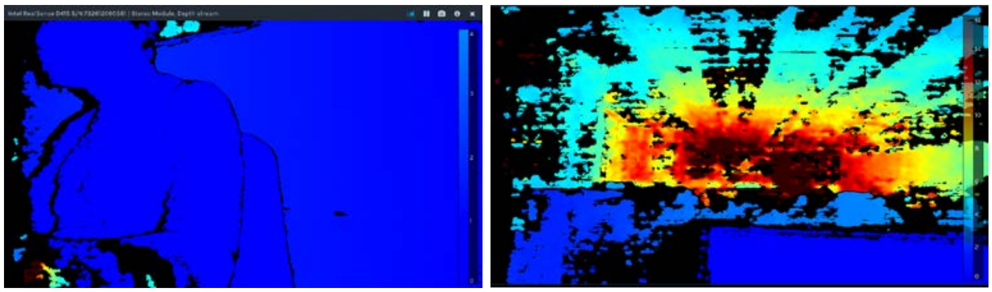
The color changes proportionally only in short range within around 1.5m, distance further than 1.5m will be in similar color.

45 ~ 120cm 45cm ~ 4m+



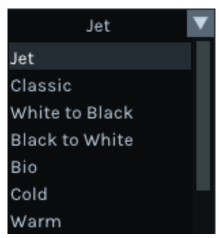
3.3.1.4 Far

The color changes proportionally starting from 6m to as far as camera can see.



3.3.2 Color Scheme

Different color representation.

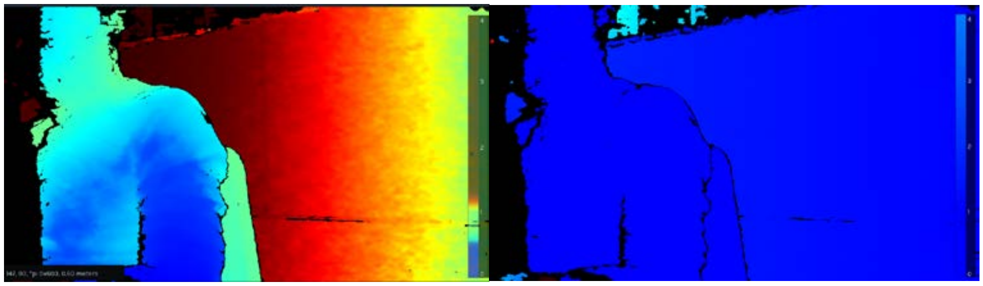


3.3.2.1 Histogram Equalization

Histogram equalization makes the color changes proportionally within the available valid pixel value range, just like the Dynamic preset.

Disabling the feature will cause the color representation changes based on the min/max distance configuration. For example, if the depth image contains valid depth pixels value ranging from 45cm ~ 3m, the color will spread proportionally within the range. When disabled, the color will spread base on min/max distance settings.

Enabled	Disabled



3.3.3 Min Distance

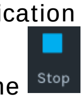
The minimum distance for color visualization.

3.3.4 Max Distance

The maximum distance for color visualization.

3.4 Recording

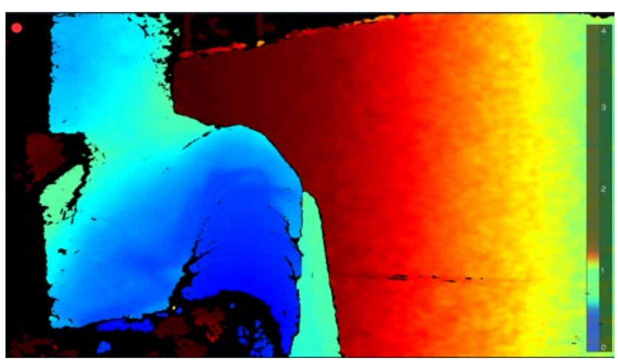
Video recording can be used as input resource for issue reduplication and debug. To record the video, click the 

button. To stop recording, click the 

button and the recording will be saved. You can check the **output panel** to view where it is being saved to.

Saved recording to: C:\Users\cpai\Documents\20180425_142709.bag

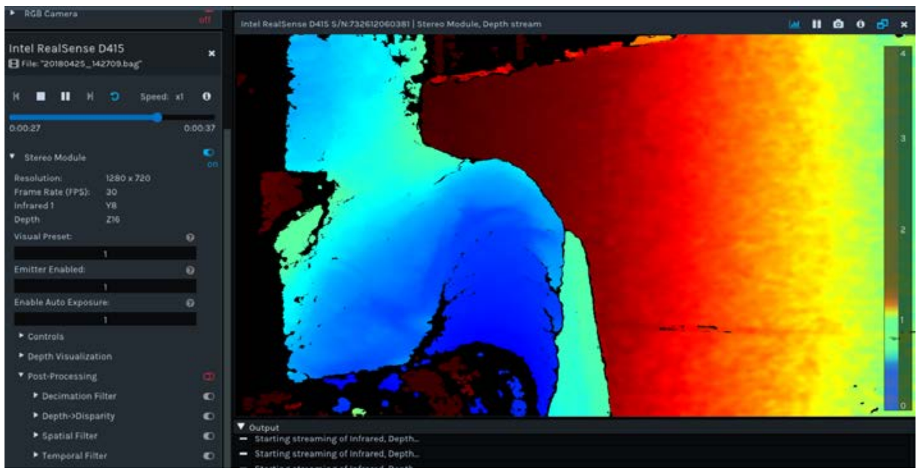
When recording starts, the display area will have splashing red dot on top of the streaming.



3.5 Playback

Select the recorded .bag file as input source by clicking 

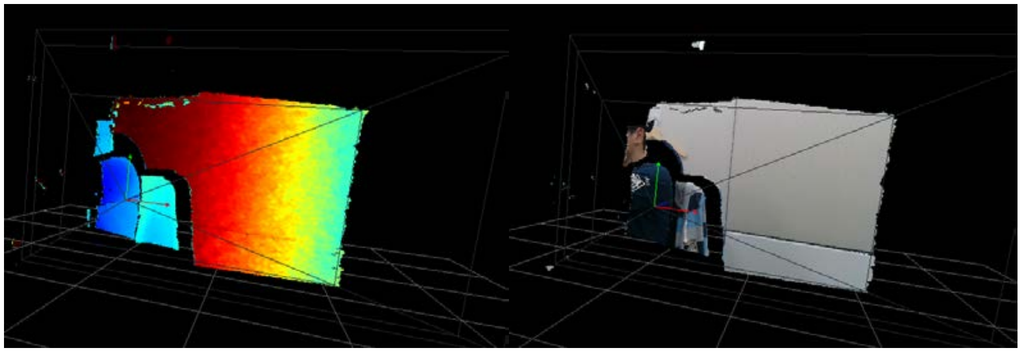
button at left-top corner, the playback contains the configuration of stream when recording was being made, such as preset, exposure, laser power etc. The playback can then be treated the as streaming from camera to apply any post processing and change the visualization.



3.6 3D Point Cloud Viewer

Click 

to switch to 3D point cloud view, inside the viewer, you can change the texture source to different stream by selecting from the drop box.



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4 Preset

4.1 Overview

The Intel® RealSense™ Viewer tool supports several predefined depth presets that can be selected according to the user's requirements. The predefined presets are listed in the table below. The table explains some of the recommended use cases for each predefined preset. There are also examples of images with each preset and a corresponding JSON file.

4.2 Preset Table

Note: Some of the presets are different based on the resolution and some are the same for all resolutions. The resolution range is:

- High Res - 1280x720 or 848x480
- Med Res - 640x480 or 640x360
- Low Res - 480x270 or 424x240

Resolution \ Preset	Use Cases Recommended for Usage	Resolution Based?	JSON Files
High Density	Higher Fill factor, views more objects. (Ex. BGS and 3D Enhanced Photography, Object recognition)	Yes	HighResHighDensityPreset.json, MedResHighDensityPreset.json, LowResHighDensityPreset.json
Medium Density	Balance between Fill factor and accuracy.	Yes	HighResMedDensityPreset.json, MedResMedDensityPreset.json, LowResMedDensityPreset.json
High Accuracy	High confidence threshold value of depth, lower fill factor. (Ex. Object Scanning, Collision Avoidance, Robots)	Yes	HighResHighAccuracyPreset.json, MedResHighAccuracyPreset.json, LowResHighAccuracyPreset.json
Hand	Good for Hand Tracking, Gesture recognition, good edges	No	HandGesturePreset.json
Default	Best Visual appeal, Clean edges, Reduced PointCloud Spraying	No	DefaultPreset_D415.json, DefaultPreset_D435.json

Additional Presets not in the Viewer:

Preset Use Case	JSON File
Vacuum Cleaner	ShortRangePreset.json
Body Scan	BodyScanPreset.json
Remove IR pattern	D415_RemoveIR.json

4.3 Example Pictures

Refer to the example pictures below captured with the various presets. The depth presets are evaluated and compared based on:

- Depth quality based on a 3D scene configured to include a variety of object types, textures, and distances.
- A flat target depth metric test

All pictures were taken with these settings/conditions:

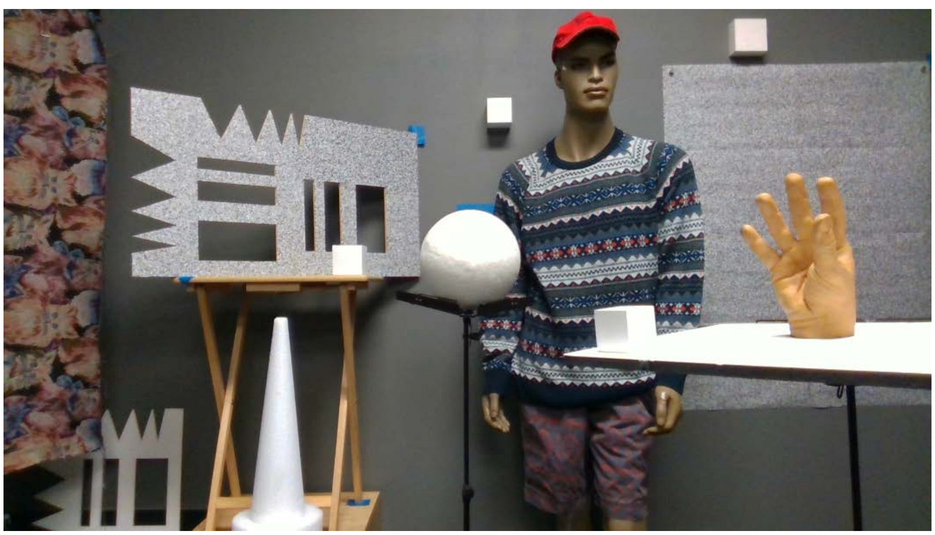
- Resolution: 1280 x 720
- Frame Rate: 30
- Auto Exposure: On
- Ambient fluorescent lighting (~100 - 200 lx)

4.3.1 RGB Images

The following RGB images captured as a test scene with objects ranging from ~0.6m (foreground cube and hand) to ~2m (back wall) from camera.

4.3.1.1 D415 Camera

4.3.1.2 D435 Camera

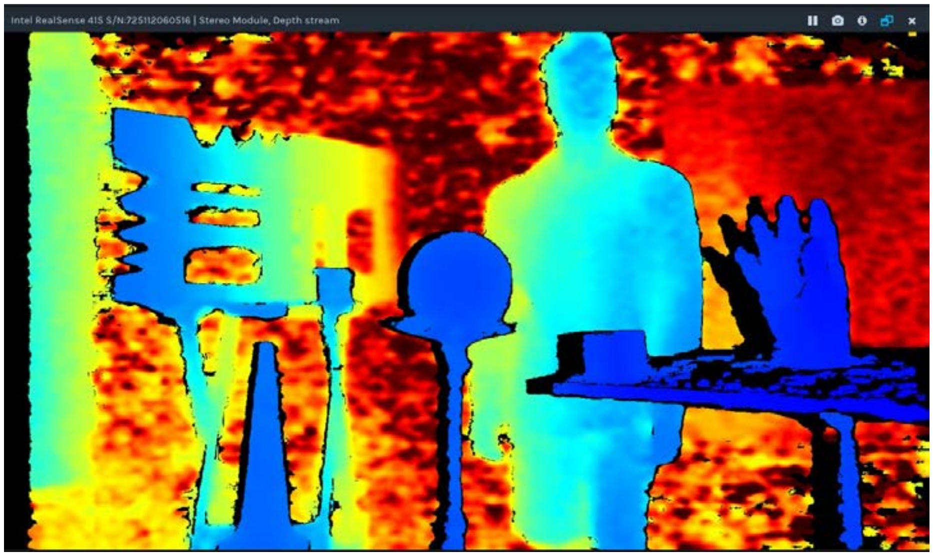


4.3.2 Corresponding Depth Image Using Presets

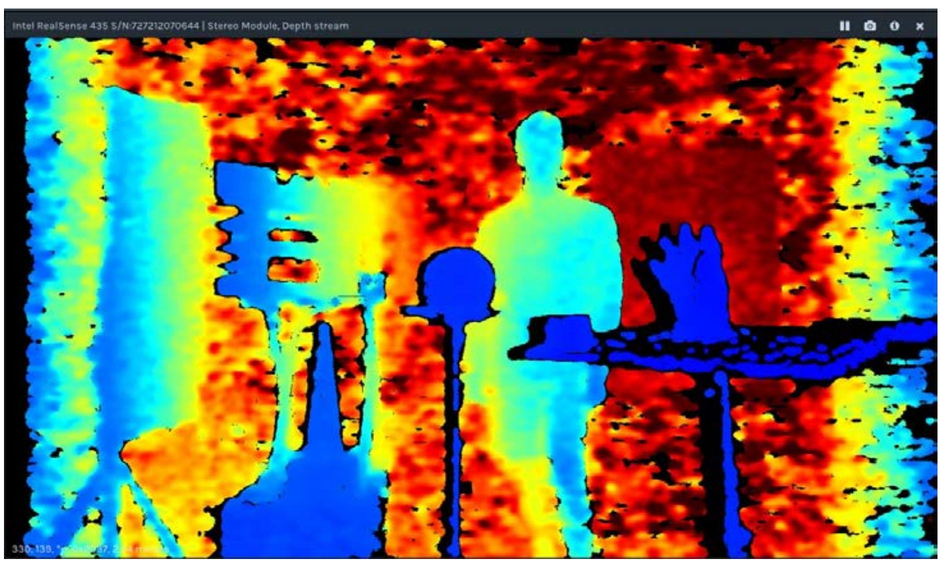
- Default Preset

Best visual appeal, clean edges and reduced Point Cloud spraying.

4.3.2.1 D415 Camera



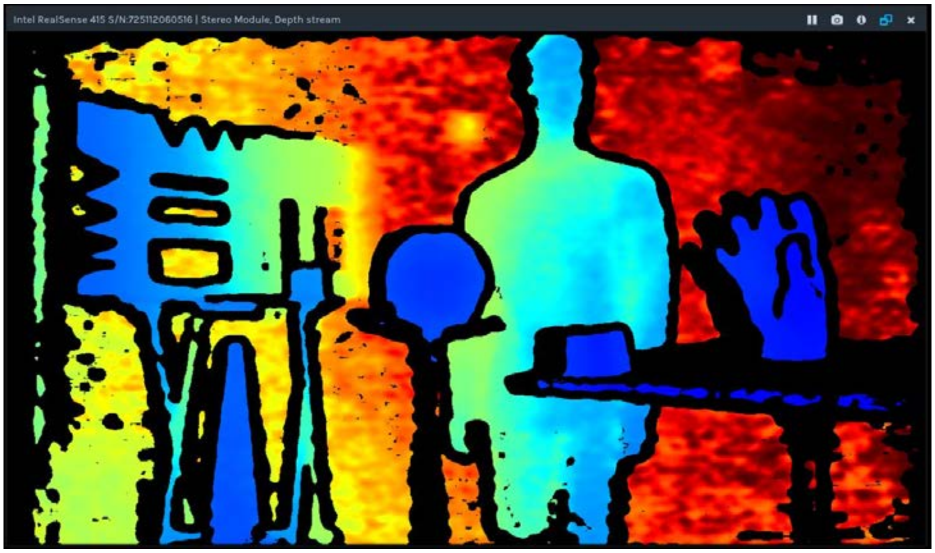
4.3.2.2 D435 Camera



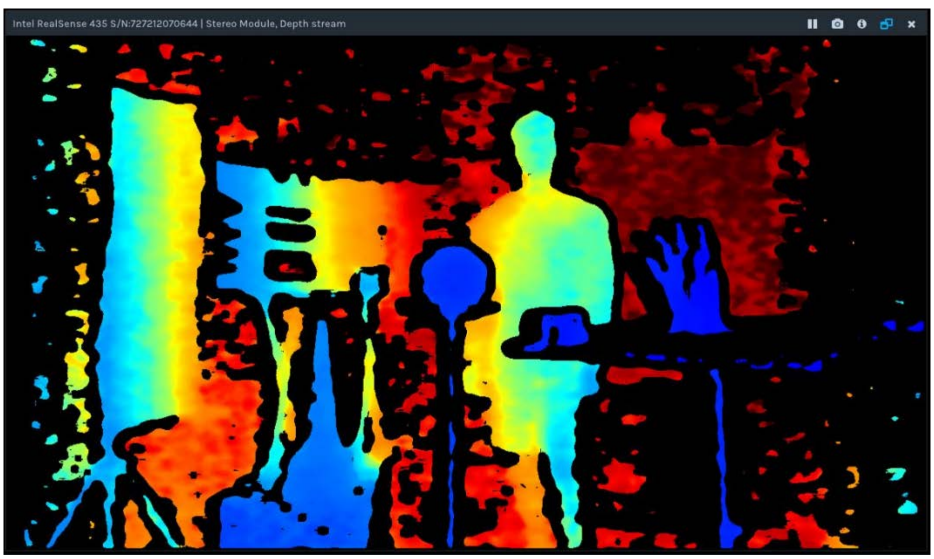
4.3.3 High Accuracy Preset

High confidence threshold value of depth, lower fill factor.

4.3.3.1 D415 Camera



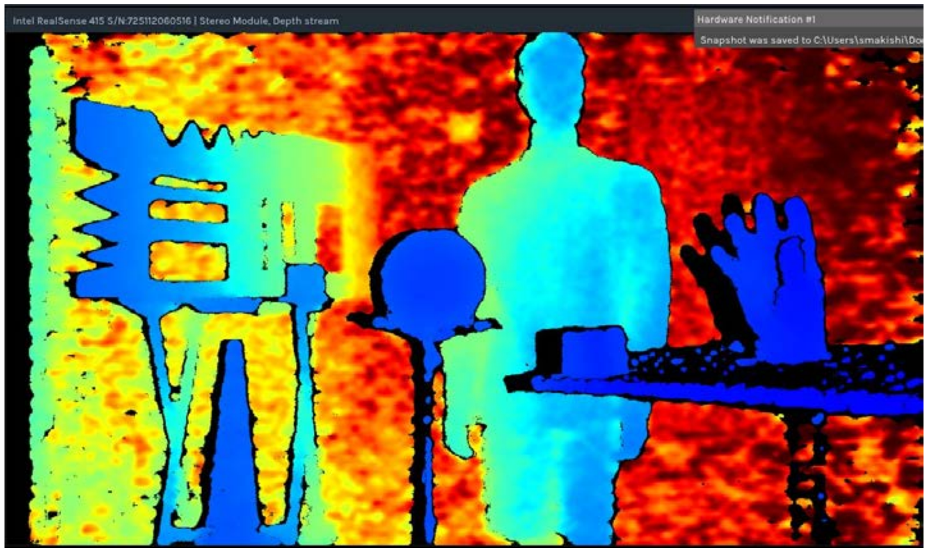
4.3.3.2 D435 Camera



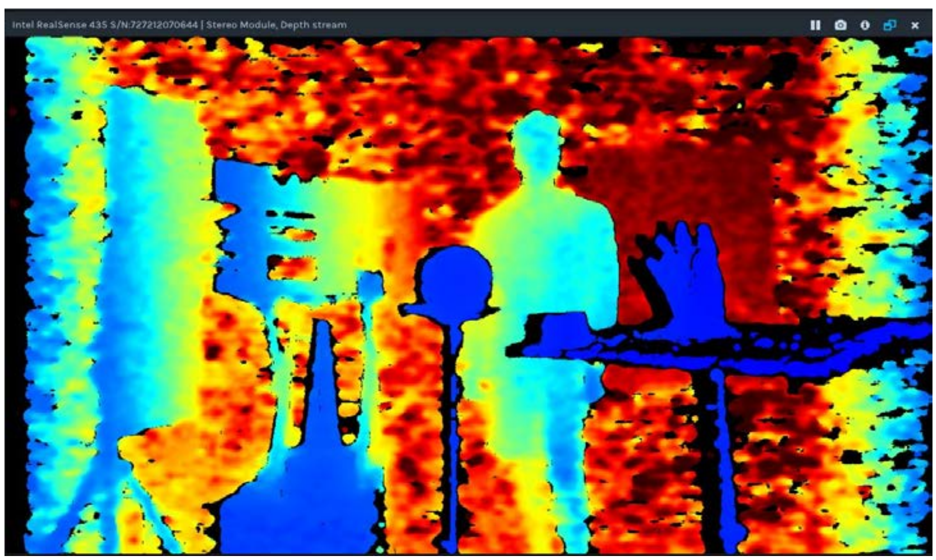
4.3.4 High Density Preset

Higher fill factor which views more objects.

4.3.4.1 D415 Camera



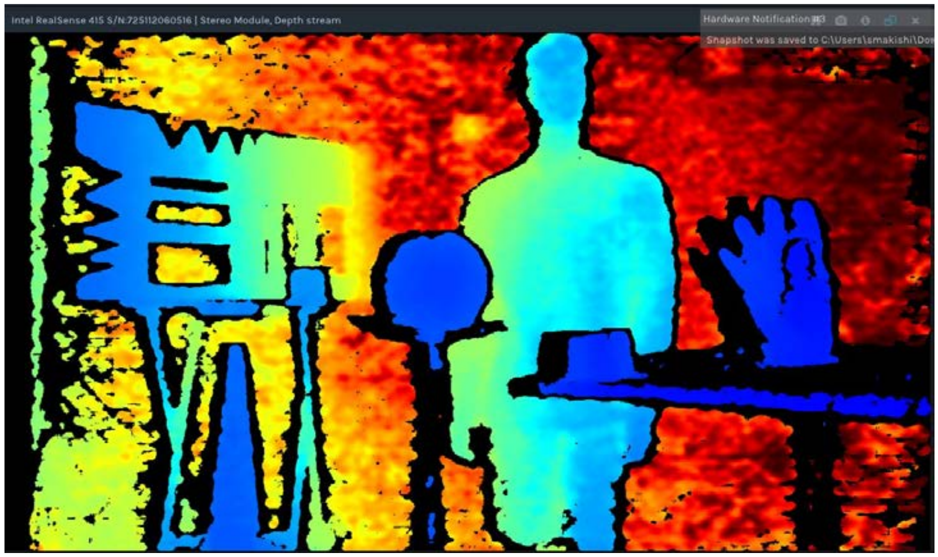
4.3.4.2 D435 Camera



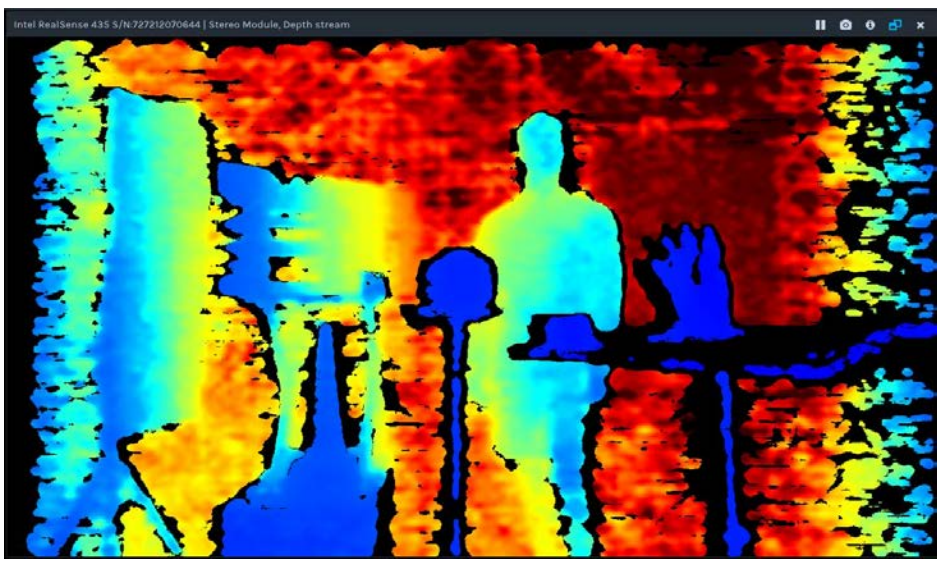
4.3.5 Medium Density Preset

Balance between fill factor and accuracy.

4.3.5.1 D415 Camera



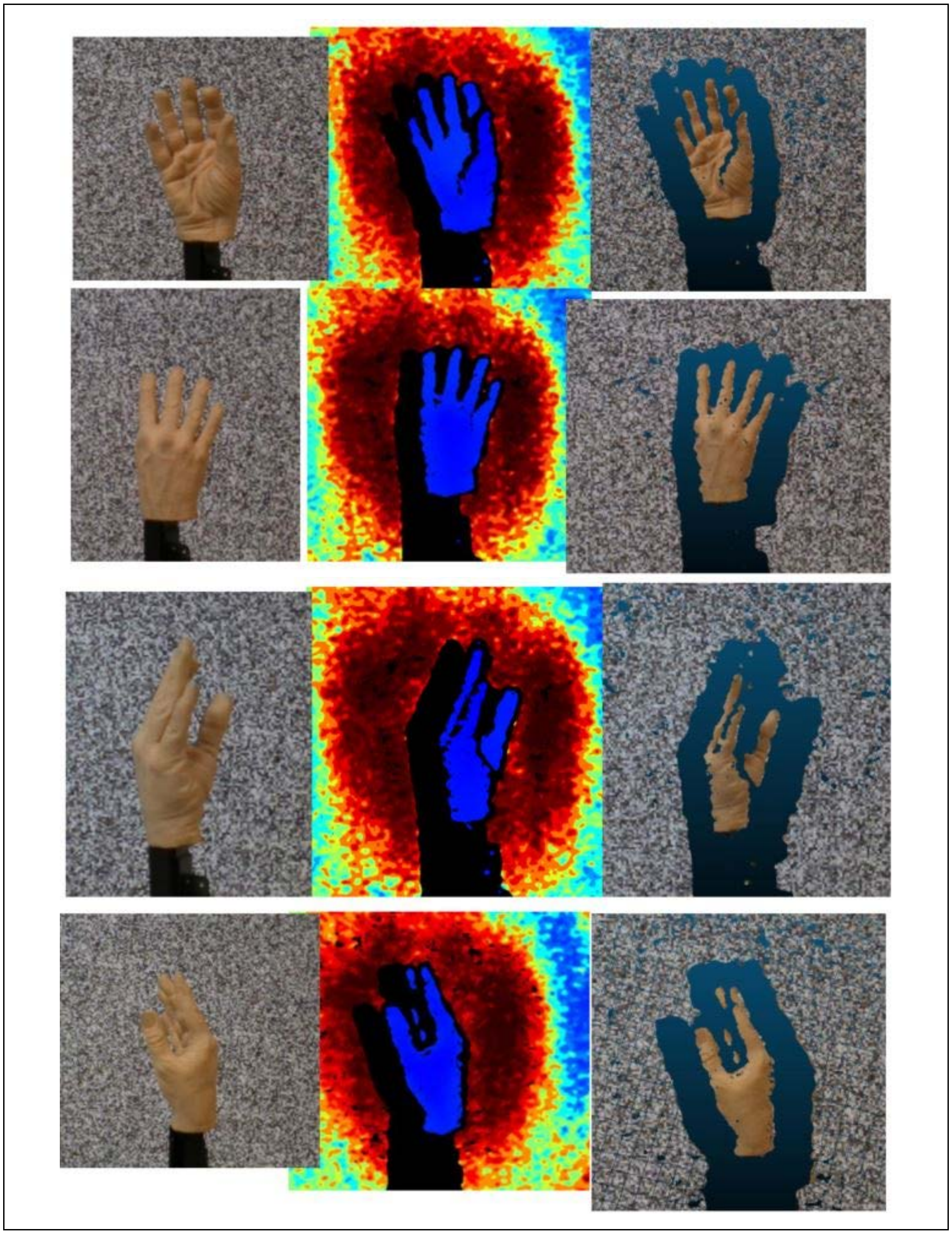
4.3.5.2 D435 Camera



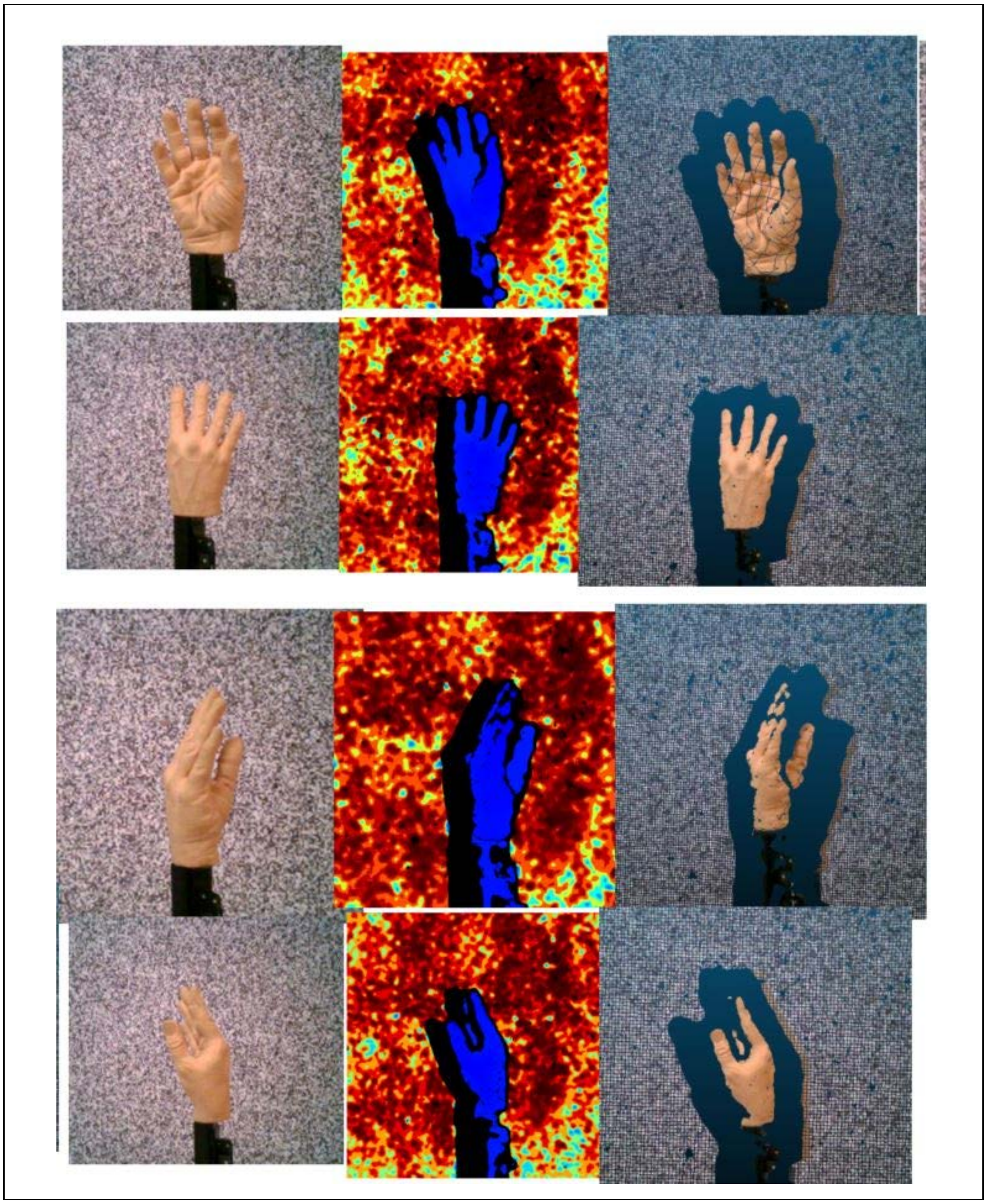
4.3.6 Hand Gesture Preset

Hand tracking and gesture recognition.

4.3.6.1 D415 Camera



4.3.6.2 D435 Camera



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5 Post Processing

5.1 Overview

Librealsense implementation includes post-processing filters to enhance the quality of depth data and reduce noise levels. All the filters are implemented in the library core as independent blocks to be used in the customer code

5.2 Design and Implementation

Post-processing modules are encapsulated into self-contained processing blocks, which provide for the following key requirements:

1. Synchronous/Asynchronous invocation
2. Internal frames memory/lifetime management

The filters are capable to receive frames from different sources, though performance-wise, maintaining filter pipe per camera source is recommended. Internally, the filters preserve the original data and generate a new (filtered) frame to pass on. The re-generation of new frames allows to share frame among different consumers (thread) without the risk of the data being overwritten by another user.

All filters support discreet as well as floating point input data formats. The floating point inputs are utilized by D400 stereo-based Depth cameras that support Disparity data representation. The discreet version of the filters is primarily used with SR300 camera, but also can be applied to D400 devices (though not recommended).

5.3 Filters Description

5.3.1 Decimation Filter

Effectively reduces the depth scene complexity. The filter operates on patches of [2x2] to [8x8] pixels using median filter as pass-criteria. The image size is scaled down proportionally in both dimensions to preserve the original aspect ratio. Internally, the filter imposes 4-pixel block alignment for the output frame size width and height. E.g. for input size (1280X720) and scale factor 3 the output size calculation is:
[1280,720]/3 -> [426.6666667, 240] -> [428,240]
*The padded rows/columns are zero-filled.

After the resulted frame is produced, the frame intrinsic parameters are recalculated to compensate for the resolution changes.

The filter also provides some hole filling capability, as the median filter uses valid (non-zero) pixels only.

5.3.1.1 Filter Controls

Controls	Operation	Range	Default
Filter Magnitude	The decimation linear scale factor	Discrete steps in [2-8] range	2

5.3.2 Spatial Filter

*The implementation is based on paper by Eduardo S. L. Gastal and Manuel M. Oliveira.

Key characteristics:

- 1D edge-preserving spatial filter using high-order domain transform.
- Linear-time compute, not affected by the choice of parameters.

The filter performs a series of 1D horizontal and vertical passes or iterations, to enhance the smoothness of the reconstructed data.

5.3.2.1 Filter Controls

Controls	Operation	Range	Default
Filter Magnitude	Number of filter iterations	[1-5]	2
Smooth Alpha	The Alpha factor in an exponential moving average with Alpha=1 - no filter . Alpha = 0 - infinite filter	[0.25-1]	0.5
Smooth Delta	Step-size boundary. Establishes the threshold used to preserve "edges"	Discrete [1-50]	20
Hole Filling	An in-place heuristic symmetric hole-filling mode applied horizontally during the filter passes. Intended to rectify minor artefacts with minimal performance impact	[0-5] range mapped to enumerated [none,2,4,8,16,unlimited] pixels.	0 (none)

5.3.3 Temporal Filter

The temporal filter is intended to improve the depth data persistency by manipulating per-pixel values based on previous frames. The filter performs a single pass on the data, adjusting the depth values while also updating the tracking history. In cases where the pixel data is missing or invalid the filter uses a user-defined persistency mode to decide whether the missing value should be rectified with stored data. Note that due to its reliance on historic data the filter may introduce visible blurring/smearing artefacts, and therefore is best-suited for static scenes.

5.3.3.1 Filter Controls

Controls	Operation	Range	Default
Smooth Alpha	The Alpha factor in an exponential moving average with Alpha=1 - no filter . Alpha = 0 - infinite filter	[0-1]	0.4
Smooth Delta	Step-size boundary. Establishes the threshold used to preserve surfaces (edges)	Discrete [1-100]	20
Persistency index	A set of predefined rules (masks) that govern when missing pixels will be replace with the last valid value so that the data will remain persistent over time: ***Disabled*** - Persistency filter is not activated and no hole filling occurs. ***Valid in 8/8*** - Persistency activated if the pixel was valid in 8 out of the last 8 frames ***Valid in 2/last 3*** - Activated if the pixel was valid in two out of the last 3 frames ***Valid in 2/last 4*** - Activated if the pixel was valid in two out of the last 4 frames ***Valid in 2/8*** - Activated if the pixel was valid in two out of the last 8 frames ***Valid in 1/last 2*** - Activated if the pixel was valid in one of the last two frames ***Valid in 1/last 5*** - Activated if the pixel was valid in one out of the last 5 frames ***Valid in 1/last 8*** - Activated if the pixel was valid in one out of the last 8 frames ***Persist Indefinitely*** - Persistency will be imposed regardless of the stored history (most aggressive filtering)	[0-8] enumerated	3 (***Valid in 2/last 4***)

5.3.4 Holes Filling Filter

The filter implements several methods to rectify missing data in the resulting image. The filter obtains the four immediate pixel "neighbors" (up, down, left, right), and selects one of them according to a user-defined rule.

5.3.4.1 Filter Controls

Controls	Operation	Range	Default
Hole Filling	Control the data that will be used to fill the invalid pixels	[0-2] enumerated: ***fill_from_left*** - Use the value from the left neighbor pixel to fill the hole ***farest_from_around*** - Use the value from the neighboring pixel which is furthest away from the sensor ***nearest_from_around*** - - Use the value from the neighboring pixel closest to the sensor	1 (Farest from around)

5.4 Using Filters in Application Code

The post-processing blocks are designed and built for concatenation into processing pipes. There are no software-imposed constrains that mandate the order in which the filters shall be applied. At the same time the recommended scheme used in librealsense tools and demos is elaborated below:

Depth Frame >> Decimation Filter >> Depth2Disparity Transform -> Spatial Filter >> Temporal Filter >> Disparity2Depth Transform** >> Hole Filling Filter >> Filtered Depth.**

** Applicable for stereo-based depth cameras (D4XX).

Note: Even though the filters order in the demos is predefined, each filter is controlled individually and can be toggled on/off at run-time.

Demos and tools that have the post-processing code blocks:

1. [RealSense-Viewer]()
2. [Depth Quality Tool]()
3. [Post-Processing]()

Filter initialization and activation flows:

```
// Establishing a frame_queue object for each processing block that
will receive the processed frames
rs2_frame_queue* decimated_queue = rs2_create_frame_queue(1, NULL);
rs2_frame_queue* spatial_queue = rs2_create_frame_queue(1, NULL);
...
// Creating processing blocks/ filters
rs2_processing_block* decimation_filter =
rs2_create_decimation_filter_block(NULL);
rs2_processing_block* spatial_filter =
rs2_create_spatial_filter_block(NULL);
...

// Direct the output of the filters to a dedicated queue
rs2_start_processing_queue(decimation_filter, decimated_queue, NULL);
rs2_start_processing_queue(spatial_filter, spatial_queue, NULL);
...
// Get depth frame from the device
rs2_frame* depth_frame = ...

// Apply decimation filter
rs2_process_frame(decimation_filter, depth_frame, NULL);
rs2_frame* decimated_frame = rs2_wait_for_frame(decimated_queue, 5000,
NULL);
// Inject the decimated frame to spatial filter
rs2_process_frame(spatial_filter, decimated_frame, NULL);
// Get the filtered frame
rs2_frame* spatial_filter_frame = rs2_wait_for_frame(spatial_queue,
5000, NULL);
// Use the filtered data
...

// Control filter options
rs2_set_option((rs2_options*)decimation_filter,
RS2_OPTION_FILTER_MAGNITUDE, 3, NULL);
rs2_set_option((rs2_options*)spatial_filter,
RS2_OPTION_FILTER_SMOOTH_ALPHA, 0.5f, NULL);
```

Using C++ API

```
// Streaming initialization
    rs2::pipeline pipe;
```

```
    ...
    // Declare filters
    rs2::decimation_filter dec_filter;
    rs2::spatial_filter spat_filter;

    // Configure filter parameters
    decimation_filter.set_option(RS2_OPTION_FILTER_MAGNITUDE, 3);
    ...
    spatial_filter.set_option(RS2_OPTION_FILTER_SMOOTH_ALPHA, 0.55f);
    ...


    // Main Loop
    while (true) {
       rs2::frameset data = pipe.wait_for_frames();
       rs2::frame depth_frame = data.get_depth_frame();
       ...
       rs2::frame filtered = depth_frame;
       // Note the concatenation of output/input frame to build up a
chain
       filtered = dec_filter.process(filtered);
       filtered = spatial_filter.process(filtered);

    }
```

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6 Advanced Control

6.1 Overview

The user can modify the settings via the Advanced Mode menu and save a customized user preset. All the settings can be saved and loaded via the tool's menu. Intel® use machine learning algorithms and capture of ground truth datasets to optimize preset for certain conditions, and we may add more presets in the future. The developers can do this too, or just start adjusting the parameters by hand, but Intel® does not provide guidance on this. The key to good depth is to start from our recommended defaults:

- D435: Use 848x480 resolution @30fps, with auto-exposure. Use post processing with downsample 2.
- D415: Use 1280x720 resolution @30fps, with auto-exposure. Use post processing with downsample 3.

If you have bad depth, first try to use manual exposure and adjust exposure. Keep gain as low as possible (preferably 16).

For further information, refer to:

BKMs-For-Tuning-RealSense_D4xx_Cameras_WP

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7 Additional Reference

- **RealSense Website:**

https://realsense.intel.com/

- **RealSense White Paper:**

https://realsense.intel.com/intel-realsense-downloads/#whitepaper

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