VRWORKS 360 VIDEO CALIBRATION

PG-08666-001_v01.1 | December 2017

Programming Guide

DOCUMENT CHANGE HISTORY

PG-08666-001_v01.1

Version	Date	Description of Change
01	2017-08-04	Initial release
01.1	2017-12-08	Release 1.1

TABLE OF CONTENTS

Chapter 1. INTRODUCTION TO 360 VIDEO CALIBRATION

In computer vision, most applications that process images from cameras require the mathematical relationship between points in the 3D world and points in the 2D image space. This relationship is represented by the parameters of the camera model, also called the intrinsics and the extrinsics.

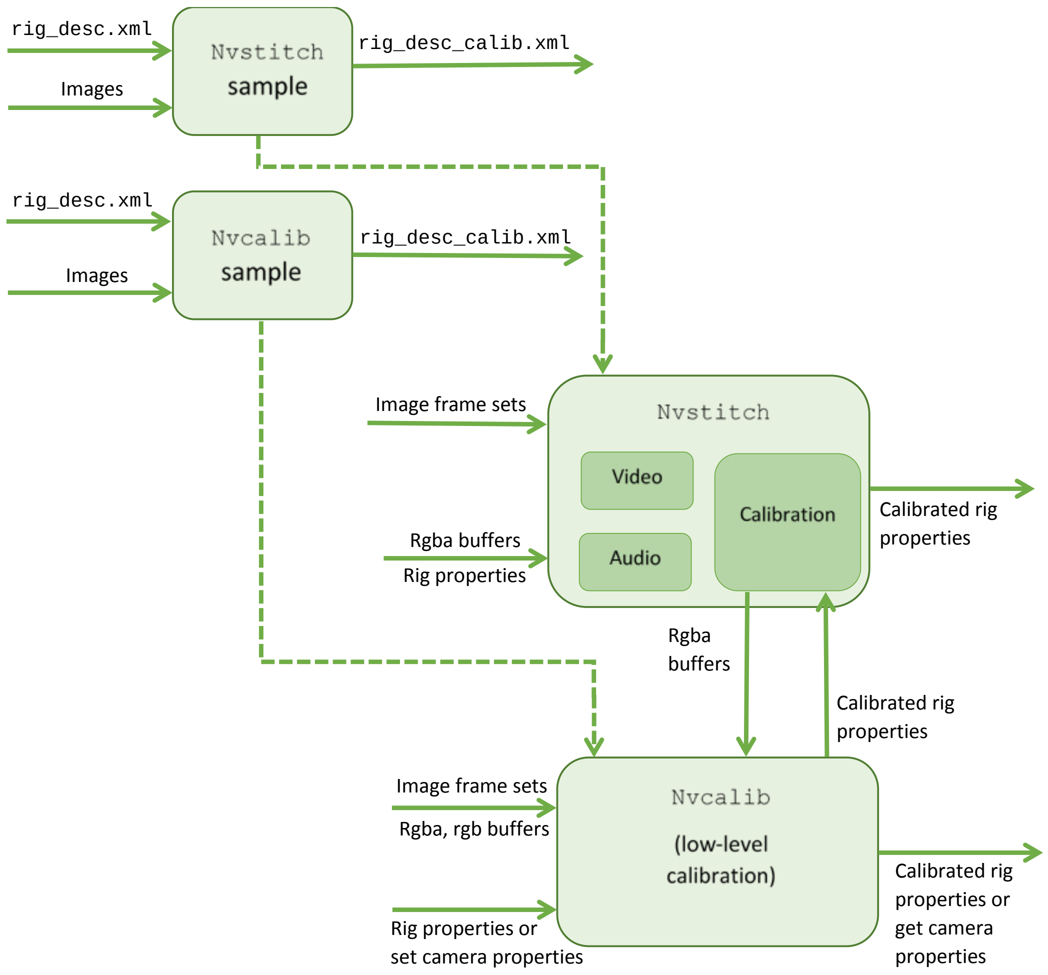
- The intrinsics represent the mapping between the camera coordinate system and the pixel coordinate system. They comprise focal length, principal point, and distortion coefficients.
- The extrinsics represent the orientation of the camera relative to the world. They comprise rotation and translation.

Camera calibration is the process of deriving and tuning these intrinsics and extrinsics for a camera. The NVIDIA VRWorks™ 360 Camera calibration SDK allows developers to calibrate camera systems to achieve this goal.

1.1 FEATURES OF THE VRWORKS 360 CAMERA CALIBRATION SDK

- Can be customized to any camera system and any number of iterations
- Allows calibration with partial/no parameter estimates
- Outputs a cross-correlation based quality metric
- Accepts simple input XML format
- Provides setter and getter functions for individual parameters in the API.
- Calibrates for fish-eye and perspective lenses.
- Supports up to five distortion coefficients with checks for nonmonotonic curves

1.2 STRUCTURE OF THE VRWORKS 360 CAMERA CALIBRATION SDK



Chapter 2. GETTING STARTED WITH 360 VIDEO CALIBRATION

Before performing a calibration, obtain a set of images from each camera and the input estimates for camera properties. You can then use the `nvcalib` API to perform calibration as explained in this chapter.

For detailed reference information about the `nvcalib` API, see Chapter 3. The functions and data types in this API are defined in the header file `calibration_api.h`.

2.1 BEFORE YOU BEGIN

For best video stitching and camera calibration results, follow the guidelines in this section for camera rig setup and input images. Also ensure that you have values or estimates for the camera input parameters that you'll need to complete the calibration.

The `nvcalib_sample` application provides command-line arguments for specifying the file format of the input images and the input camera parameters.

2.1.1 Camera Rig Guidelines

For best video stitching, following these guidelines for setting up your camera rig:

- Place the cameras in the rig close together.
- Maintain good overlap between adjacent cameras.
- Use wider field of view (FOV) cameras for better overlap.
- Use higher resolution cameras for better feature extraction.

- Use many cameras for better 360-degree coverage and overlap.

Note: All cameras must overlap with at-least one other camera and no groups of cameras can be isolated.

Heterogeneous rigs (rigs with different cameras) are supported. Input camera parameter estimates are required for heterogeneous rigs.

Rigs that have a large translation (greater than 30 cm) between cameras are not supported.

2.1.2 Input Image Guidelines

For best camera calibration results, follow these guidelines:

- Provide input images captured at the same time from each camera, or captured from a scene with no movement.
- Although one calibration image per camera is sufficient, try to provide more frames for better calibration.
- Capture calibration images of scenes with objects far away.

The `nvcalib_sample` application supports PNG, JPEG, and BMP image formats.

The following `nvcalib_sample` command-line argument specifies the file format of the input images:

```
--ext {png | jpg | bmp}
```

2.1.3 Input Camera Parameters

Input camera parameter estimates are optional for most scenes and rigs. However, for best performance, provide input parameter estimates if possible.

Note: Some rigs and scenes require input parameter estimates. For example, for heterogenous rigs, you **must** provide input parameter estimates.

2.1.3.1 Required Parameters

Lens Type

The lens type of the camera, which is either wide angle (fisheye) or normal angle (brown).

The following `nvcalib_sample` command-line argument specifies the lens type:

```
--lens {fisheye | brown}
```

2.1.3.2 Optional Parameters

Focal Length

The distance in pixels between the optical center and the sensor plane.

The focal length is computed automatically during calibration. If calibration fails to compute the focal length, provide either an estimate of the focal length or the field of view of the cameras.

The focal length is typically found in camera manufacturers' data sheets, in mm. To convert the value in mm to pixels, use the following formula:

$$Focal\ length\ in\ pixels = (focal\ length\ in\ mm \div camera\ sensor\ width\ in\ mm) \times image\ width\ in\ pixels$$

The following `nvcalib_sample` command-line argument specifies the focal length:

```
--fl focal-length-in-pixels
```

Field of View

The horizontal and vertical angle covered by the camera. Provide the field of view if focal length is not known.

The field of view is typically available in camera manufacturers' data sheets as HFOV (horizontal field of view) and VFOV (vertical field of view).

The following `nvcalib_sample` command-line arguments specify the HFOV and VFOV:

```
--hfov horizontal-field-of-view
--vfov vertical-field-of-view
```

Fisheye Radius

The radius of the valid pixels for fisheye images. Specify this parameter only for fisheye-lens cameras.

The fisheye radius is detected automatically from the image. Issues such as lens flare and dark or low light scenes can impair the ability to detect the fisheye radius.

The following `nvcalib_sample` command-line argument specifies the fisheye radius:

```
--radius radius-in-pixels
```

Principal Point

The optical center of the cameras, which is typically the center of the image. This parameter is optional, and an estimate is not required.

Rotation

The orientation of each camera in yaw, pitch, roll angles, or rotation matrix.

This parameter is optional, and an estimate is typically not required.

Translation

The translation in cm along the X, Y, and Z direction from the center of the rig.

This parameter is optional. Calibration currently does not support rigs with translation greater than 20-30 cm.

Note: Translation calibration is highly dependent on the scene and may not converge for all scenes.

The following `nvcalib_sample` command-line argument specifies the translation:

```
--trans translation-in-cm
```

2.2 CREATE INSTANCE

Create an `nvcalibInstance` by calling the `nvcalibCreateInstance()` function, passing in the following parameters:

- `framesCount` as the number of image sets that will be fed for calibration
- `camerasCount` as the number of cameras in the rig

The call to `nvcalibCreateInstance()` provides a handle to the calibration instance.

2.3 SET CAMERA PROPERTIES

Set all required camera properties before calling the function to perform the calibration.

You can set properties for a rig and individual cameras in a rig or set individual properties of a camera:

- To set properties for a rig and individual cameras in a rig, call the `nvcalibSetRigProperties()` function.

  The structures `nvstitchVideoRigProperties_t` and `nvstitchCameraProperties_t` are defined in the header file `nvstitch_common_video.h`.

- To set individual properties of a camera, call the `nvcalibSetCameraProperty()` function.

If you do not supply initial estimates for camera properties, the calibration SDK attempts to determine the properties solely from the input images. In many instances, the images will contain sufficient information for the calibration to succeed.

2.4 SET IMAGES

Provide input images as RGBA, RGB, BGR, BGRA buffers by calling the `nvcalibSetImages()` function. Call this function with the set of images `framesCount` number of times.

Each call to this function provides pointer to a single set of image buffers from all cameras.

2.5 CALIBRATE

After setting the input camera properties and images, call the `nvcalibCalibrate()` function to perform the calibration. This function checks if all camera parameters and input images have been provided and, if so, proceeds with the calibration. The call to `nvcalibCalibrate()` takes several seconds to several minutes depending on the number of cameras.

2.6 GET CAMERA PROPERTIES

After successful calibration, get the calibrated camera properties. The camera properties obtained can then be used for stitching.

You can get properties for a rig and individual cameras in a rig or set individual properties of a camera:

- To get properties for a rig and individual cameras in a rig, call the `nvcalibGetRigProperties()` function. Get the properties in the structure `nvstitchVideoRigProperties_t`.

  The structures `nvstitchVideoRigProperties_t` and `nvstitchCameraProperties_t` are defined in the header file `nvstitch_common_video.h`.
- To get individual properties of a camera, call the `nvcalibGetCameraProperty()` function.

2.7 OPTIONAL: GET CALIBRATION ACCURACY

Get the accuracy of the results of camera calibration by calling the `nvcalibGetResultParameter()` function.

Chapter 3. 360 VIDEO CALIBRATION API REFERENCE

3.1 ENUMERATIONS

3.1.1 nvcalibCameraLensModelType

This enumeration defines the model type of the camera lens. It is used in `nvcalibSetCameraProperty()` and `nvcalibGetCameraProperty()`.

Enumerator	**Description**
`NVCALIB_LENS_MODEL_BROWN = 0`	Brown model, suitable for normal-angle perspective lenses. 5 coefficients.
`NVCALIB_LENS_MODEL_FISHEYE`	Fisheye f·theta model with coefficients, suitable for wide-angle camera lenses. 4 coefficients.
`NVCALIB_LENS_MODEL_FISHEYE_EQUIDISTANT`	Fisheye with f·theta fixed projection (no optimization on distortion). 0 coefficients.
`NVCALIB_LENS_MODEL_FISHEYE_STEREOGRAPHIC`	Fisheye with 2f·tan(theta/2) fixed projection (no optimization on distortion). 0 coefficients.
`NVCALIB_LENS_MODEL_FISHEYE_EQUISOLID`	Fisheye with 2f·sin(theta/2) fixed projection (no optimization on distortion). 0 coefficients.
`NVCALIB_LENS_MODEL_FISHEYE_ORTHOGRAPHIC`	Fisheye with f·sin(theta) fixed projection (no optimization on distortion). 0 coefficients.

3.1.2 nvcalibCameraProperties

This enumeration defines the properties of a camera.

Use the extrinsics properties as follows:

- For rotation, you must specify one of the following sets of properties:
  - `NVCALIB_CAM_PROP_EXTR_ROT_YPR`

  - NVCALIB_CAM_PROP_EXTR_AXES and NVCALIB_CAM_PROP_EXTR_ROT_MATRIX
- For translation, you can optionally specify NVCALIB_CAM_PROP_EXTR_AXES and NVCALIB_CAM_PROP_EXTR_TRANSLATION.

Enumerator	Description
NVCALIB_CAM_PROP_WIDTH = 0	Type: NVCALIB_DATATYPE_UINT32 Camera width. Required.
NVCALIB_CAM_PROP_HEIGHT	Type: NVCALIB_DATATYPE_UINT32 Camera height. Required.
NVCALIB_CAM_PROP_INPUT_IMAGE_FORMAT	Type: nvcalibInputImageFormat, NVCALIB_DATATYPE_UINT32 The format of the input image data. Required.
NVCALIB_CAM_PROP_INPUT_IMAGE_PITCH	Type: NVCALIB_DATATYPE_UINT32 The pitch of the input image data, that is, the byte stride between pixels vertically. Optional. Default = NVCALIB_CAM_PROP_WIDTH * 4
Intrinsics	
NVCALIB_CAM_PROP_INTR_PRINCIPAL_POINT	Type: NVCALIB_DATATYPE_FLOAT32 array[2] The (X,Y) coordinates in pixels, relative to the upper-left corner, that specify the location of the principal point. Note that the Y-coordinates increase downward. Optional. Default = (Width-1)/2, (Height-1)/2
NVCALIB_CAM_PROP_INTR_FOCAL_LENGTH	Type: NVCALIB_DATATYPE_FLOAT32 The focal length of the camera in pixels. Optional.
Extrinsics	
NVCALIB_CAM_PROP_EXTR_ROT_YPR	Type: NVCALIB_DATATYPE_FLOAT32 array[3] Extrinsic rotation in radians, specified in aircraft principal axes: yaw, pitch, and roll. They are applied in this order: **1.** Roll – increases clockwise **2.** Pitch – increases tilting upward **3.** Yaw – increases toward the right Optional.
NVCALIB_CAM_PROP_EXTR_AXES	Type: CalibExtrinsicsMatrixAxes, NVCALIB_DATATYPE_UINT32 The coordinate system axes in which the rotation matrix and translation are specified. The standard coordinate system has Y-up. All coordinate systems have X to the right. Other coordinate systems have Z-up or Y-down. In any event, all coordinate systems are right-handed.

Enumerator	Description
NVCALIB_CAM_PROP_EXTR_ROT_MATRIX	Type: NVCALIB_DATATYPE_FLOAT32 array[9] The extrinsic rotation transformation, which places the camera into the world. In the standard coordinate system with Y-up, the vector {array[3], array[4], array[5]} aligns with the camera's Y axis (up) when placed into the world. Likewise, {array[6], array[7], array[8]} is the camera's Z-axis, which is opposite the camera's look-at direction. Specify NVCALIB_CAM_PROP_EXTR_AXES to choose a different coordinate system than Y-up. Optional
NVCALIB_CAM_PROP_EXTR_TRANSLATION	Type: NVCALIB_DATATYPE_FLOAT32 array[3] Translation X,Y,Z from the rig center in axes. Typically, a negative multiple of elements 6-8 of the rotation transform. Default = {0,0,0}. Optional.
Distortion	
NVCALIB_CAM_PROP_DISTORTION_TYPE	Type: CameraLensModelType, NVCALIB_DATATYPE_UINT32 The lens type of the camera. Default=fisheye. Required.
NVCALIB_CAM_PROP_DISTORTION_COEFFS	Type: NVCALIB_DATATYPE_FLOAT32 array[1-5] Coefficients of the camera lens distortion model Optional. Default = (0,0,0,0,0). Optional.
NVCALIB_CAM_PROP_FISHEYE_RADIUS	The circular clipping radius in pixels for fisheye lens cameras. The clipping circle is centered on the principal point. Zero implies no circular clipping. Optional.
NVCALIB_CAM_PROP_LAYOUT	Type: nvstitchCameraLayout, NVCALIB_DATATYPE_UINT32 The layout of the camera in the rig. Default = Equatorial. Optional.

3.1.3 nvcalibDataType

This enumeration defines the calibration API data types. It is used in `nvcalibGetCameraProperty()`, `nvcalibSetCameraProperty()`, `nvcalibGetResultParameter()`.

Enumerator	Description
NVCALIB_DATATYPE_UINT32 = 0	32-bit unsigned integer.

Enumerator	Description
`NVCALIB_DATATYPE_FLOAT32`	32-bit single-precision IEEE floating-point.
`NVCALIB_DATATYPE_CSTRING`	C-string, null terminated.

3.1.4 nvcalibExtrinsicsAxes

This enumeration defines the axes of the extrinsics coordinate system. It is used in `nvcalibGetCameraProperty()` and `nvcalibSetCameraProperty()`. All coordinate systems are right handed with X increasing to the right. Therefore, only the orientation of the Y or Z axis need be specified.

Enumerator	Description
`NVCALIB_AXES_Y_UP = 0`	Right hand system with Y up: •X = Right •Y = Up •Z = Inward, which is opposite to the look-at direction
`NVCALIB_AXES_Y_DOWN`	Right hand system with Y down: •X = Right •Y = Down •Z = Outward, which is the look-at direction
`NVCALIB_AXES_Z_UP`	Right hand system with Z up: •X = Right •Y = Outward, which is the look-at direction •Z = Up

3.1.5 nvcalibInputImageFormat

This enumeration defines the supported input image types. It is used in `nvcalibGetCameraProperty()` and `nvcalibSetCameraProperty()`. In this release, only the following image types are supported:

- RGBA8
- RGA8
- BGR8
- BGRA8

Enumerator	Description
`NVCALIB_IN_FORMAT_RGBA8 = 0`	4-byte pixels, arranged as {R,G,B,A} in memory.
`NVCALIB_IN_FORMAT_RGB8`	3-byte pixels, arranged as {R,G,B} in memory.
`NVCALIB_IN_FORMAT_BGRA8`	4-byte pixels, arranged as {B,G,R,A} in memory.
`NVCALIB_IN_FORMAT_BGR8`	3-byte pixels, arranged as {B,G,R} in memory.
`NVCALIB_IN_FORMAT_GRAY8`	1-byte grayscale pixels.

Enumerator	Description
`NVCALIB_IN_FORMAT_PNG`	PNG (unimplemented).
`NVCALIB_IN_FORMAT_JPG`	JPEG (unimplemented).

3.1.6 nvcalibOption

This enumeration defines calibration options. It is used in `nvcalibSetOption()`.

Enumerator	Description
`NVCALIB_OPTION_USE_TRANS = 0`	Type: `NVCALIB_DATATYPE_UINT32` Whether to use rig translation parameters for triangulation-based calibration. • 0=Don't Use (Default) • 1=Use
`NVCALIB_OPTION_OPTIMIZE_PARAMS`	Type: `nvcalibOptionOptimizeParams (uint32_t)` Camera parameters to be optimized. `NVCALIB_OPTION_OPTIMIZE_PARAMS_ALL` (Default).
`NVCALIB_OPTION_MODE`	Type: `NVCALIB_DATATYPE_UINT32` The calibration mode. • 0= High Quality Mode (Default) • 1=Fast Mode.
`NVCALIB_OPTION_CORRESPONDENCE_DIRECTORY`	Type `NVCALIB_DATATYPE_CSTRING` Write images with feature points and correspondence overlaid to the specified directory. Set to `""` or `NULL` to clear.
`NVCALIB_OPTION_PANORAMA_ORIENTATION`	Type `NVCALIB_DATATYPE_UINT32` or `NVCALIB_DATATYPE_FLOAT32` The orientation of the panorama: • `NVCALIB_ORIENT_PANO_AUTO_BALANCE` (default) • `NVCALIB_ORIENT_PANO_FREEZE_FIRST_CAMERA` • `NVCALIB_ORIENT_PANO_APPLY_TRANSFORM` • `NVCALIB_ORIENT_PANO_APPLY_YPR`

3.1.7 nvcalibOptionOptimizeParams

This enumeration defines the sets of camera parameters to be optimized. It is used in `nvcalibSetOption()`.

Enumerator	Description
`NVCALIB_OPTION_OPTIMIZE_PARAMS_ALL = 0`	Optimize all parameters (intrinsics, extrinsics and distortion).

Enumerator	**Description**
NVCALIB_OPTION_OPTIMIZE_PARAMS_EXTRINSICS	Optimize only extrinsic parameters.

3.1.8 nvOrientationOption

This enumeration is used to indicate the desired orientation of the panorama. It is used in `nvcalibSetOption()`.

Some enumerators require extra arguments. The data type of enumerators that require extra arguments should be declared as `NVCALIB_DATATYPE_FLOAT32`. If no extra arguments are needed, `NVCALIB_DATATYPE_UINT32` can be used.

The `APPLY` enumerators can be used to level the horizon if the rig was not upright when the material was captured.

Enumerator	**Description**
NVCALIB_ORIENT_PANO_AUTO_BALANCE	Type NVCALIB_DATATYPE_INT32 or NVCALIB_DATATYPE_FLOAT32. Count 1. Balance the panorama on the dominant axis of the rig, as determined from the camera poses.
NVCALIB_ORIENT_PANO_FREEZE_FIRST_CAMERA	Type NVCALIB_DATATYPE_INT32 or NVCALIB_DATATYPE_FLOAT32. Count 1. Maintain the orientation of the first camera.
NVCALIB_ORIENT_PANO_APPLY_TRANSFORM	Type NVCALIB_DATATYPE_FLOAT32. Determine the pose of the panorama from a linear transformation. This enumerator must be followed by 9 additional single-precision floating-point numbers that comprise the desired pose of the panorama expressed as a linear transformation. For example, if the pose of the fourth camera is supplied, the fourth camera will be in the center of the stitched panorama. The total count is 10, and the data is float[10].
NVCALIB_ORIENT_PANO_APPLY_YPR	Type NVCALIB_DATATYPE_FLOAT32. Determine the pose of the panorama from yaw, pitch, and roll angles. This enumerator must be followed by 3 additional single-precision floating-point numbers that comprise the desired pose of the panorama expressed using the yaw, pitch and roll angles in radians. The total count is 4, and the data is float[4].

3.1.9 nvcalibResultParameter

This enumeration is used to indicate the computation of the accuracy of a calibration. It is used in `nvcalibGetResultParameter()`.

Enumeration	Description
NVCALIB_RESULTS_ACCURACY	Type NVCALIB_DATATYPE_FLOAT32 Accuracy indication of results from [0-1].

3.2 COMMON TYPES

3.2.1 nvcalibInstance

```
typedef uint32_t nvcalibInstance;
```

3.3 FUNCTIONS

3.3.1 nvcalibCalibrate

```
nvcalibResult NVCALIBAPI nvcalibCalibrate(
    nvcalibInstance hInstance
);
```

3.3.1.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance on which to run the calibration.

3.3.1.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if `nvcalibInstance` is invalid
- `NVCALIB_ERROR_ARGUMENT_INVALID` if an argument is invalid
- `NVCALIB_ERROR_ARGUMENT_MISSING` if required properties are not set
- `NVCALIB_ERROR_ADD_IMAGES_COUNT_MISMATCH` if the frames added do not match the frames

- NVCALIB_ERROR_INSUFFICIENT_FEATURES if the camera does not have enough features
- NVCALIB_ERROR_FAILED_CONVERGENCE if the calibration failed to converge to optimum values

3.3.1.3 Remarks

This function runs the main calibration process.

3.3.2 nvcalibCreateInstance

```
nvcalibResult NVCALIBAPI nvcalibCreateInstance(
    [in]    cons uint32_t    framesCount,
    [in]    const uint32_t   camerasCount,
    [out]   nvcalibInstance* hInstance
  );
```

3.3.2.1 Parameters

`framesCount [in]`

Type: `uint32_t`

The number of frames to be used for calibration.

`camerasCount [in]`

Type: `uint32_t`

The number of cameras in the rig to calibrate.

`hInstance [out]`

Type: `nvcalibInstance*`

Pointer to the `nvcalibInstance` instance created.

3.3.2.2 Return Value

Returns one of the following values:

- NVCALIB_SUCCESS on success
- NVCALIB_ERROR_HANDLE_INVALID if the handle nvcalibInstance is invalid
- NVCALIB_ERROR_ARGUMENT_INVALID if input arguments are invalid

3.3.2.3 Remarks

This function creates the calibration instance.

3.3.3 nvcalibDestroyInstance

```
nvcalibResult NVCALIBAPI nvcalibDestroyInstance(
    nvcalibInstance hInstance);
```

3.3.3.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance to destroy.

3.3.3.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid

3.3.3.3 Remarks

This function destroys the calibration instance, freeing the memory that was allocated to it.

3.3.4 nvcalibGetCameraProperty

```
nvcalibResult NVCALIBAPI nvcalibGetCameraProperty(
    nvcalibInstance          hInstance,
    uint32_t                 cameraIndex,
    nvcalibCameraProperties cameraProperty,
    nvcalibDataType          propertyDataType,
    uint32_t                 dataCount,
    void*                    propertyData
  );
```

3.3.4.1 Parameters

`hInstance [in]`

Type: `nvcalibInstance`

The calibration instance from which to get a camera property.

`cameraIndex [in]`

Type: `uint32_t`

The index of the camera from which to get a property.

`cameraProperty`

Type: `nvcalibCameraProperties`

The name of the camera property to get, which must be one of the properties defined in "nvcalibCameraProperties" on page 9: width, height, pitch, format, rotation, principal point, focal length, translation, axes, lens type, distortion coefficients, fisheye radius, layout.

`propertyDataType`

Type: `nvcalibDataType`

The data type of the option to get, which must be one of the data types defined in "nvcalibDataType" on page 11. If this parameter is set to any other data type, an error occurs.

`dataCount`

Type: `uint32_t`

The number of data elements.

`propertyData`

Type: `void*`

A pointer to the destination data buffer. The destination must have the appropriate data size.

3.3.4.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid
- `NVCALIB_ERROR_ARGUMENT_UNSUPPORTED` if `cameraProperty` specifies an unsupported property
- `NVCALIB_ERROR_ARGUMENT_COUNT_INVALID` if the number of property data elements is invalid
- `NVCALIB_ERROR_ARGUMENT_DATATYPE_INVALID` if the data type of the property is invalid

3.3.4.3 Remarks

This function gets an individual camera property.

3.3.5 nvcalibGetLastErrorString

```
nvcalibResult NVCALIBAPI nvcalibGetLastErrorString(
    nvcalibInstance hInstance,
    const char**    errorStringPtr
);
```

3.3.5.1 Parameters

`hInstance [in]`

Type: `nvcalibInstance`

The calibration instance from which to get the last error string.

`errorStringPtr [in]`

Type: `const char**`

A pointer to a `NULL`-terminated C-string. This string provides more detail about the most recently received error code. Both the pointer and the string should be considered to be ephemeral, and will change the next time a call to a function in this API returns an error. Typically, the string is immediately printed and discarded. The string would need to be copied to be retained for a longer period.

3.3.5.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid

3.3.5.3 Remarks

After a result other than `NVCALIB_SUCCESS` is received, call this function to get additional information about the error.

3.3.6 nvcalibGetResultParameter

```
nvcalibResult NVCALIBAPI nvcalibGetResultParameter(
    nvcalibInstance        hInstance,
    nvcalibResultParameter resultParameter,
    nvcalibDataType        resParamDataType,
    uint32_t               dataCount,
    void*                  resultParameterData
);
```

3.3.6.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance for which to get the result parameter.

`resultParameter`

Type: `nvcalibResultParameter`

The name of the result parameter to get, which must be one of the parameters defined in “nvcalibResultParameter” on page 14.

`resParamDataType`

Type: `nvcalibDataType`

The data type of the parameter to get, which must be one of the data types defined in “nvcalibDataType” on page 11. If this parameter is set to any other data type, an error occurs.

`dataCount`

Type: `uint32_t`

The number of data elements.

`resultParameterData`

Type: `void*`

A pointer to the destination data buffer.

3.3.6.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid
- `NVCALIB_ERROR_ARGUMENT_UNSUPPORTED` if `resultParameter` specifies an unsupported property
- `NVCALIB_ERROR_ARGUMENT_COUNT_INVALID` if the number of property data elements is invalid
- `NVCALIB_ERROR_ARGUMENT_DATATYPE_INVALID` if the data type of the property is invalid

3.3.6.3 Remarks

This function gets the result parameters after calibration. Call this function after call to `nvcalibCalibrate()`.

Result parameters that can be retrieved are specified in in "nvcalibResultParameter" on page 14.

3.3.7 nvcalibGetRigProperties

```
nvcalibResult NVCALIBAPI nvcalibGetRigProperties(
    nvcalibInstance               hInstance,
    nvstitchVideoRigProperties_t* cameraProperties
);
```

3.3.7.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance for which to get the camera rig properties.

`cameraRigProperties`

Type: `nvstitchVideoRigProperties_t*`

A pointer to the destination data buffer.

3.3.7.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid

3.3.7.3 Remarks

This function gets all the camera rig properties in the structure `nvstitchVideoRigProperties_t` defined in `nvstitch_common_video.h`.

3.3.8 nvcalibSetCameraProperty

```
nvcalibResult NVCALIBAPI nvcalibSetCameraProperty(
    nvcalibInstance         hInstance,
    uint32_t                cameraIndex,
    nvcalibCameraProperties cameraProperty,
    nvcalibDataType         propertyDataType,
    uint32_t                dataCount,
    const void*             propertyData
);
```

3.3.8.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance for which to set the camera property.

`cameraIndex`

Type: `uint32_t`

The index of the camera for which set a property.

`cameraProperty`

Type: `nvcalibCameraProperties`

The name of the camera property to set, which must be one of the properties defined in “nvcalibCameraProperties” on page 9: width, height, pitch, format, rotation, principal point, focal length, translation, axes, lens type, distortion coefficients, fisheye radius, or layout.

`propertyDataType`

Type: `nvcalibDataType`

The data type of the option to set, which must be one of the data types defined in “nvcalibDataType” on page 11. If this parameter is set to any other data type, a typecasting error occurs.

`dataCount`

Type: `uint32_t`

The number of data elements.

`propertyData`

Type: `void*`

A pointer to the source data buffer.

3.3.8.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid
- `NVCALIB_ERROR_ARGUMENT_UNSUPPORTED` if `cameraProperty` specifies an unsupported property
- `NVCALIB_ERROR_ARGUMENT_COUNT_INVALID` if the number of property data elements is invalid
- `NVCALIB_ERROR_ARGUMENT_DATATYPE_INVALID` if the data type of the property is invalid

3.3.8.3 Remarks

This function sets an individual camera property.

3.3.9 nvcalibSetImages

```
nvcalibResult NVCALIBAPI nvcalibSetImages(
    [in]    nvcalibInstance hInstance,
    [in]    const void*     imageData[]
  );
```

3.3.9.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance to which to add the images.

`imageData`

Type: `void*`

An array of pointers to image data. The size of the array should be the number of cameras passed. Each pointer points to a buffer, the size of which is the product of the following values:

- `NVCALIB_CAM_PROP_HEIGHT`
- `NVCALIB_CAM_PROP_INPUT_IMAGE_PITCH (`or computed from `NVCALIB_CAM_PROP_WIDTH` if not supplied)
- The number of bytes corresponding to `nvcalibInputImageFormat`

3.3.9.2 Return Value

Returns `NVCALIB_SUCCESS` on success.

3.3.9.3 Remarks

This function adds images to a calibration instance and adds a single set of frames from all cameras. The number of calls to this function to add each frameset this must match `framesCount`.

3.3.10 nvcalibSetOption

```
nvcalibResult NVCALIBAPI nvcalibSetOption(
    nvcalibInstance hInstance,
    nvcalibOption   optionName,
    nvcalibDataType optionDataType,
    uint32_t        dataCount,
    void*           optionData
  );
```

3.3.10.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance for which to set the options.

`optionName`

Type: `nvcalibOption`

The name of the option to set, which must be one of the options defined in “nvcalibOption” on page 13: whether to use translation, the parameters to optimize, quality mode, correspondence image directory, or panorama orientation.

`optionDataType`

Type: `nvcalibDataType`

The data type of the option to set, which must be one of the data types defined in “nvcalibDataType” on page 11.

`dataCount`

Type: `uint32_t`

The number of data elements.

`optionData`

Type: `void*`

A pointer to the source data buffer.

3.3.10.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid
- `NVCALIB_ERROR_ARGUMENT_UNSUPPORTED` if `optionName` specifies an unsupported option
- `NVCALIB_ERROR_ARGUMENT_COUNT_INVALID` if the number of option data elements is invalid
- `NVCALIB_ERROR_ARGUMENT_DATATYPE_INVALID` if the data type of the option is invalid

3.3.10.3 Remarks

This function sets a particular calibration option from `nvcalibOption`. Call this function before a call to `nvcalibCalibrate()`.

3.3.11 nvcalibSetRigProperties

```
nvcalibResult NVCALIBAPI nvcalibSetRigProperties(
    nvcalibInstance                    hInstance,
    const nvstitchVideoRigProperties_t* cameraRigProperties
  );
```

3.3.11.1 Parameters

`hInstance`

Type: `nvcalibInstance`

The calibration instance for which to set the camera rig properties.

`cameraRigProperties`

Type: `nvstitchVideoRigProperties_t*`

A pointer to the source data buffer.

3.3.11.2 Return Value

Returns one of the following values:

- `NVCALIB_SUCCESS` on success
- `NVCALIB_ERROR_HANDLE_INVALID` if the handle `nvcalibInstance` is invalid

3.3.11.3 Remarks

This function sets all the camera rig properties from the structure `nvstitchVideoRigProperties_t` defined in `nvstitch_common_video.h`. Call this function after a call to `nvcalibCalibrate()` to get calibrated properties.

3.4 RETURN CODES

In addition to the common and general NVAPI return status codes, the 360 Video Calibration interfaces may return the following more specific values:

Return Code	Value	Description
`NVCALIB_SUCCESS`	0	The function call succeeded.
`NVCALIB_ERROR_UNSUPPORTED`		The function call is not supported.
`NVCALIB_ERROR_ARGUMENT_INVALID`		An argument passed to the function is invalid.
`NVCALIB_ERROR_ARGUMENT_MISSING`		One or more required properties is not provided.
`NVCALIB_ERROR_ARGUMENT_UNSUPPORTED`		The argument passed is unsupported.
`NVCALIB_ERROR_ARGUMENT_COUNT_INVALID`		The argument count is invalid.
`NVCALIB_ERROR_ARGUMENT_DATATYPE_INVALID`		The data type of an argument is incorrect.
`NVCALIB_ERROR_ARGUMENT_DATA_INVALID`		The data provided as argument is invalid.
`NVCALIB_ERROR_HANDLE_INVALID`		The handle `nvcalibInstance` is invalid.
`NVCALIB_ERROR_ADD_IMAGES_COUNT_MISMATCH`		The number of image frame sets added does not match `framesCount`.
`NVCALIB_ERROR_CAMERA_COUNT_INVALID`		The `camerasCount` parameter is invalid.
`NVCALIB_ERROR_INSUFFICIENT_FEATURES`		One or more frames has too few features to perform a calibration.
`NVCALIB_ERROR_FAILED_CONVERGENCE`		Calibration failed to converge to optimum values