SAFR® Linux ARM Embedded SDK Documentation

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Note: Documentation pertaining to the macOS platform is no longer being actively maintained.

Contents

1 SAFR Embedded SDK Overview

1.1 Purpose

The Embedded SDK is for use when the facial recognition software needs to run on a device with limited resources — RAM, CPU, and memory — without any internet or cloud connectivity. However, the device must still perform, for example, detection and recognition of images with varying conditions with a minimum response time.

Using this SDK, developers can create applications that can:

- Provide information on the total number of known and unknown faces, the relative coordinates of each person detected, the size in pixels for each face, and more.
- Learn new faces through training (labeling).

The SAFR Embedded SDK ships as a `tar.gz` file that contains the necessary libraries, recognizer, and detector model files, and a sample command line tool called Panoptes.

Note: For SAFR Embedded SDK system requirements, go to SAFR.com.

2 Linux ARM eSDK Overview

Download the SAFR Embedded SDK package for Linux ARM from the Developers tab of the SAFR Download Portal. The eSDK is distributed as a set of (native code) shared objects (`.so`) and resource files.

You should copy the library and model files from the SAFR eSDK into the directory which contains your final application. Place the shared object files inside a directory named `lib` and the resource files inside a directory named `model`. Assuming that your application would be called `Example` and that you will ship it inside a directory called `ExampleApp` then the structure of your final application directory would look like this:

```
ExampleApp/
   Example
   lib/
      ...
   model/
      ...
```

The supported architectures are x86_64 and armv8-a. See https://docs.real.com/esdk/linuxx86/Linux_x86_eSDK.html for information about the Linux x86 architecture.

3 Use the Linux ARM eSDK

Use the C API provided by the eSDK by including the `eArgusKit.h` header file into your C files. The following code example shows how to do this and includes basic steps for setting up and using a face detector and face recognizer:

```
#include "eArgusKit.h"

// Detects as many faces as possible in the image 'pBitmap'.
// \param pLicense the SDK license
// \param pBitmap the image description
void detect_faces(const EARLicense* pLicense, const EARBitmap* pBitmap)
{
   EARFaceDetectionInitializationConfiguration initConfig;

   EARFaceDetectorRef pDetector = EARFaceDetectorCreate(pLicense,
      kEARFaceDetectionType_Normal, &initConfig, 0);
   EARFaceDetectionConfiguration config;
   EARDetectedFaceArrayRef pFaces;

   EARFaceDetectionConfigurationInitWithPreset(&config,
      kEARFaceDetectionConfigurationPreset_Generic);

   pFaces = EARFaceDetectorDetect(pDetector, pBitmap, &config);
   for (size_t i = 0; i < EARDetectedFaceArrayGetCount(pFaces); i++) {
      const EARDetectedFace* pFace =
         EARDetectedFaceArrayGetAtIndex(pFaces, i);

      // Process the face data
      ...
   }

   EARDetectedFaceArrayDestroy(pFaces);
   EARFaceDetectorDestroy(pDetector);
}


// Recognizes as many faces as possible out of the set of detected faces
// 'pDetectedFaces'. Expects that the the faces were previously detected
   in the
// image 'pBitmap'.
// \param pLicense the SDK license
// \param pBitmap the image description
// \param pDetectedFaces the previously detected faces
void recognize_faces(const EARLicense* pLicense, const EARBitmap*
   pBitmap, EARDetectedFaceArrayRef pDetectedFaces)
{
   EARPersonStoreRef pStore = EARPersonStoreCreate(<path to the store
      file>, <store file password>);
   EARFaceRecognizerRef pRecognizer = EARFaceRecognizerCreate(pLicense,
      pStore, kEARFaceRecognitionModelType_Regular,
      kEARFaceRecognitionModelPerformance_SpeedOptimized, 0);
   EARFaceRecognitionConfiguration config;
   EARRecognizedFaceArrayRef pFaces;
```

```
   EARFaceRecognitionConfigurationInitWithPreset(&config,
      kEARFaceRecognitionConfigurationPreset_Recognize);

   pFaces = EARFaceRecognizerRecognizeDetectedFaces(pRecognizer,
      pDetectedFaces, pBitmap, &config, kEARAllowRecognition);
   for (size_t i = 0; i < EARRecognizedFaceArrayGetCount(pFaces); i++) {
      const EARRecognizedFace* pFace =
         EARRecognizedFaceArrayGetAtIndex(pFaces, i);

      // Process the face data
      ...
   }

   EARRecognizedFaceArrayDestroy(pFaces);
   EARFaceRecognizerDestroy(pRecognizer);
   EARPersonStoreDestroy(pStore);
}
```

Note: This sample code does not check for errors. As you should always check for errors in your code, use the `EARGetLastError()` function to get the most recent error.

Your code should create the face detector, face recognizer, and person store objects once and reuse them. Do not recreate these objects for every single detection and recognition operation.

4 Use Linux ARM eSDK Detection and Recognition

Execute the following steps to detect and recognize faces:

1. Create a person store object. You specify a file system location and file name. A new and empty person store is created if none already exists.
2. Create a face detector object.
3. Create a face recognizer object and pass it a reference to the person store.
4. Use the face detector to find faces in an image. This returns an array of detected faces. Each face has a bounding box and information about the quality of the detected face.
5. Use the face recognizer on the faces returned by the face detector. You can attempt to recognize all faces but more typically you should first filter the array of detected faces down to the set that you want to attempt recognition on given your use case constraints.
6. Save the updated person store to disk.

Execute Steps 1 to 3 once in a typical application. The person store, face detector, and recognizer objects should be reused whenever possible.

Note: The face detector and recognizer objects are not thread safe. Make sure only one face detection/recognition operation is executed on a single detector/recognizer object at any given time. However, you may create multiple separate detector/recognizer objects and use them in parallel from different threads.

When processing a video file, execute Step 4 on every frame or every other frame of the video file. Inspect the detected faces and decide which ones are of sufficient quality to attempt recognition on. Face recognition should be rate limited to approximately one (1) recognition per face since it is significantly more costly than face detection.

Note: Changes to a person store are not automatically saved. The changes are applied in memory and you must explicitly save the person store when it makes sense for your application.

5 Understand Linux ARM eSDK Object Detection and Recognition

This page describes the SAFR Embedded SDK objects you use to detect and recognize objects.

5.1 EARFaceDetector

A face detector instance allows you to detect faces in an image. All face detector APIs are synchronous. Parallelism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the detector instance to that thread. This thread should then listen to detection requests and process them with the help of the face detector object.

5.1.1 Threading

A face detector instance is owned by a single thread. Only this thread may use the face detection services.

5.1.2 EARFaceDetection Types

Two face detector types are supported.

- **kEARFaceDetectionType_Normal**: Normal is the default face detector. It's faster, but less accurate than HighSensitivity face detector.
- **kEARFaceDetectionType_HighSensitivity**: HighSensitivity face detector has better accuracy compared to Normal, especially when detecting faces wearing masks. Because the input resolution is fixed, it's faster than Normal on higher resolution images.

Similar face attribute values are expected for both face detectors.

5.1.3 kEARFaceDetectionHighSensitivityResolutions Property

You can configure the resolution of the HighSensitivity face detector by setting the `kEARFaceDetectionHighSensitivityResolu` property. This property is similar to the `minFaceSearchSize` configuration parameter of the Normal face detector in that it depends on expected face resolutions. Unlike `minFaceSearchSize`, however, it's set when the face detector is initialized and can't be changed later on.

The default value for the HighSensitivity face detector resolution is 640x480: `kEARFaceDetectionHighSensitivityResolution`

5.2 EARFaceRecognizer

A face recognizer instance allows you to recognize faces/persons in an image. All face recognizer APIs are synchronous. Parallelism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the recognizer instance to that thread. This thread should then listen to recognition requests and process them with the help of the face recognizer object.

5.2.1 Threading

A face recognizer instance is owned by a single thread. Only this thread may use the face recognizer services.

5.2.2 EARFaceRecognition Model Type Options

The face recognizer supports two recognition models,

- **kEARFaceRecognitionModelType_Regular**: Regular model is the default, performs well on variety of use cases.
- **kEARFaceRecognitionModelType_MaskOptimized**: MaskOptimized recognition model has similar performance to Regular model, but performs better on faces wearing masks.

5.2.3 EARRecognition Model Performance Options

The face recognizer model has 2 options for optimizing performance.

- **kEARFaceRecognitionModelPerformance_SpeedOptimized**: Speed optimized model has slightly lower accuracy due to loss of precision from 32-bit to 8-bit. It is the default option and recommended to use since the loss of accuracy is in most cases not as important compared to gain in speed.
- **kEARFaceRecognitionModelPerformance_AccuracyOptimized**: Accuracy optimized model is recommended to use when enough computational resources are available and when the database contains significant number of persons and the extra bit of accuracy can help.

5.3 EARObjectDetector

An object detector instance allows you to detect objects and persons in an image. All object detector APIs are synchronous. Parallelism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the detector instance to that thread. This thread should then listen to detector requests and process them with the help of the face detector object.

5.3.1 Threading

An object detector instance is owned by a single thread. Only this thread may use the object detector services.

5.4 EARPersonStore

A person store persistently stores information about a person. Every person is identified by a globally unique ID (UUID). Each person also has a signature the face recognizer generates. This signature property is an internal property that is not exposed to the user.

The user of the API may add arbitrary key-value pairs to a person. A key is always represented by a string, while a value is a sequence of arbitrary bytes. The person store does not interpret these bytes.

5.4.1 Threading

A single person store instance may be accessed from multiple threads at the same time.

6 Understand Linux ARM eSDK Object Face Estimation and Signature Compositing

This page describes the SAFR eSDK objects you use to estimate certain characteristics of detected faces as well as the signature compositor object which can be used to create a composite signature from a set of source signatures.

6.1 EARAgeEstimator

An age estimator instance allows you to estimate the age of detect faces in an image. All face estimator APIs are synchronous. Parallism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the estimator instance to that thread. This thread should then listen to estimation requests and process them with the help of the face estimator object.

6.1.1 EARAgeEstimator Threading

An estimator instance is owned by a single thread. Only this thread may use the estimator services.

6.2 EAREmotionEstimator

An emotion estimator instance allows you to estimate the expressed emotion of detect faces in an image. All face estimator APIs are synchronous. Parallism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the estimator instance to that thread. This thread should then listen to estimation requests and process them with the help of the face estimator object.

6.2.1 EAREmotionEstimator Threading

An estimator instance is owned by a single thread. Only this thread may use the estimator services.

6.3 EAROcclusionEstimator

An occlusion estimator instance allows you to estimate the amount of occlusion of detect faces in an image. All face estimator APIs are synchronous. Parallism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the estimator instance to that thread. This thread should then listen to estimation requests and process them with the help of the face estimator object.

6.3.1 EAROcclusionEstimator Threading

An estimator instance is owned by a single thread. Only this thread may use the estimator services.

6.4 EARGenderDetector

A gender detector instance allows you to detect the gender of detect faces in an image. All face detector APIs are synchronous. Parallism/asynchronous behavior can be achieved by the caller by creating a thread and assigning the detector instance to that thread. This thread should then listen to detection requests and process them with the help of the face detector object.

6.4.1 EARGenderDetector Threading

A detector instance is owned by a single thread. Only this thread may use the detector services.

6.5 EARMaskEstimator

A mask estimator instance allows you to estimate the probability of a face being covered by a mask. All face detector APIs are synchronous. Parallism/asynchronous behavior can be achieved by creating a thread and

assigning the estimator instance to that thread. This thread should then listen to estimation requests and process them with the help of the face estimator object.

6.5.1 EARMaskEstimator Threading

An estimator instance is owned by a single thread. Only this thread may use the estimator services.

6.6 EARSignatureCompositor

A signature compositor is used to create a composite signature from a set of source signatures. The source signatures should all represent the same physical person. For example you may have a set of person objects in the person store which all representthe same physical person. In this case you could create a singular merged person object in the person store for all the existing person objects by doing the following:

1. Create a signature compositor.
2. Get the signatures of all the person objects which represent the same physical person. (These are the input person objects.)
3. Use the signature compositor to create the composite signature.
4. Apply whatever algorithms are necessary to generate a correct merged representation of the metadata key-value pairs of the input persons.
5. Create a new person in the person store from the composite signature.
6. Add the merged metadata key-value pairs to the newly create composite person.
7. Remove the input person objects from the person store.

7 Mask Detection and RGB Liveness Detection

7.1 Recognition of Faces with Masks

The same `EARFaceRecognitionModelType` used for face registration should be used for face recognition.

When registering a face without a mask that is to be matched with faces with and without masks, register the face with `kEARFaceRecognitionModelType_Regular` and `kEARFaceRecognitionModelType_MaskOptimized` into two separate person stores.

When recognizing a face, first determine if the face is wearing a mask by using mask detection. If the face is masked, recognize it with `kEARFaceRecognitionModelType_MaskOptimized` and the corresponding person store. If a face does not have a mask, recognize it with `kEARFaceRecognitionModelType_Regular` and the corresponding person store.

If also registering faces with a mask, register the faces with masks with `kEARFaceRecognitionModelType_MaskOptimized` into a third, separate person store. When recognizing a face, first determine if the face has a mask using mask detection. If the face does have a mask, recognize it with `kEARFaceRecognitionModelType_MaskOptimized` and the corresponding person store containing masked faces. If this fails, attempt to recognize it with `kEARFaceRecognitionModelType_MaskOptimized` and the person store containing unmasked faces.

If a face does not have a mask, recognize it with `kEARFaceRecognitionModelType_Regular` and the corresponding person store. If this fails, attempt to recognize it with `kEARFaceRecognitionModelType_MaskOptimized` and the person store containing masked faces.

7.2 RGB Liveness Detection

RGB liveness detection is calculated internally within the face detector (`EARFaceDetector`) as part of the face detection operation. It's only supported on high sensitivity face detectors (`kEARFaceDetectionType_HighSensitivity`).

RGB liveness detection is disabled by default. To enable it, set the `enableLiveness` parameter in the face detection configuration object (`EARFaceDetectionConfiguration`) to `true`.

Using the `EARFaceDetectorDetect` API will result in computing both face detection and RGB liveness detection on a single low resolution image. For best results, the `EARFaceDetectorDetectHighRes` API should be used if both low resolution and high resolution images can be obtained. Low resolution images (e.g. 480p) should be used for face detection while high resolution images (e.g. 1080p) should be used for RGB liveness detection, which improves the RGB liveness detection accuracy.

Detected face info (`EARDetectedFace`) returned by the face detection operation contains four liveness-related parameters:

- **liveness**: The RGB liveness score of the detected face. This value ranges from 0.0 (i.e. definitely fake) to 1.0. (i.e. there's a real person in front of the camera). We recommend that you use a liveness threshold of 0.6.
- **livenessStatus**: Status of the RGB liveness detection.
  - *kEARLivenessOK*: RGB liveness has been successfully calculated.
  - *kEARLivenessLowQuality*: The image quality of the detected face is below the required quality level.
  - *kEARLivenessModelNotLoaded*: RGB liveness could not be evaluated. This is either because the `EARFaceDetector` instance wasn't initialized with RGB liveness support (i.e. the platform doesn't support RGB liveness detection) or because the `enableLiveness` parameter was set to `false`.
  - *kEARLivenessError*: An unspecified error occurred.
- **livenessStage1**: The RGB liveness score of a detected face on a texture model. This value ranges from 0.0 (i.e. definitely fake) to 1.0. (i.e. there's a real person in front of the camera).
- **livenessStage2**: The RGB liveness score of a detected face on a context model. This value ranges from 0.0 (i.e. definitely fake) to 1.0. (i.e. there's a real person in front of the camera).

7.2.1 Parameters

The face detection configuration object (`EARFaceDetectionConfiguration`) contains multiple liveness-related parameters. Some parameters are used to define the minimum required image quality of the detected face image for RGB liveness to be evaluated. When the image quality is too low, the RGB liveness value is set to 0.0 and **livenessStatus** is set to *kEARLivenessLowQuality*. The following parameters are used as thresholds for low image quality.

- **liveness_minFaceSize**: Minimum face size, in pixels, required for the RGB liveness model to be evaluated. The default value for this parameter is 150.
- **liveness_minCPQ**: Minimum center pose quality for the RGB liveness model to be evaluated. This parameter ranges from 0.0 (worst) to 1.0 (best). Its default value is 0.2.
- **liveness_minSharpness**: Minimum sharpness required for the RGB liveness model to be evaluated. This parameter ranges from 0.0 (worst) to 1.0 (best). Its default value is 0.45.
- **liveness_minContrast**: Minimum contrast required for the RGB liveness model to be evaluated. This parameter ranges from 0.0 (worst) to 1.0 (best). Its default value is 0.45.
- **liveness_minFaceContext**: Minimum context required around the detected face for the RGB liveness model to be evaluated. This parameter ranges from 0 to 1000. Its default value is 1.0.

Two additional parameters can be configured: **liveness_mode** and **liveness_initial_threshold**.

The **liveness_mode** parameter is used to select the mode used to calculate the liveness response in multi-model setup. The following modes are allowed:

- *kEARLivenessModeNone*: Only the texture-based model value is returned.
- *kEARLivenessModeLast*: Only the context-based model value is returned.
- *kEARLivenessModeAverage*: The average liveness value of both models is returned.
- *kEARLivenessModeMin*: Minimum liveness value from both models is returned. This is the default mode.
- *kEARLivenessModeMax*: Maximum liveness value from both models is returned.

The **liveness_initial_threshold** parameter is used to short-circuit stage 2 liveness. It ranges from 0.0 to 1.0. Its default value is 0.19.

7.2.2 Additional Info

7.2.2.1 Improve Accuracy We recommended you calculate liveness score on multiple consecutive frames (e.g. 10 frames) to confirm that the face is live or fake.

7.2.2.2 Recommended Camera Settings To ensure reliable RGB liveness detection, the following camera settings are recommended.

- High color saturation. (i.e. vibrant colors)
- Low contrast. (i.e. no grain)
- Focus into the distance with a reasonable focus in target range.
- Exposure setting should yield properly exposed faces.

7.3 Sample Code

```
#include "eArgusKit.h"

// Detects as many faces as possible in the image 'pBitmap' and calculate
   liveness score for each detected face.
// \param pLicense the SDK license
// \param pBitmap the image description
void detect_faces(const EARLicense* pLicense, const EARBitmap* pBitmap,
   const EARBitmap* pBitmapHighRes)
{
```

```
   EARFaceDetectionInitializationConfiguration initConfig;
   //Enable liveness detection as it is disabled by default
   initConfig.enableLiveness = true;

   EARFaceDetectionConfiguration config;
   EARFaceDetectionConfigurationInitWithPreset(&config,
      kEARFaceDetectionConfigurationPreset_Generic);

   //Adjust some default liveness parameters
   config.liveness_initial_threshold = 0.25;
   config.liveness_mode = kEARLivenessModeAverage;

   //Only HighSensitivity face detector type supports liveness detection
   EARFaceDetectionType FDType = kEARFaceDetectionType_HighSensitivity;

   EARFaceDetectorRef pDetector = EARFaceDetectorCreate(pLicense, FDType,
      &initConfig, 0);

   EARDetectedFaceArrayRef pFaces;

   pFaces = EARFaceDetectorDetectHighRes(pDetector, pBitmap,
      pBitmapHighRes, &config);
   for (size_t i = 0; i < EARDetectedFaceArrayGetCount(pFaces); i++) {
      const EARDetectedFace* pFace =
         EARDetectedFaceArrayGetAtIndex(pFaces, i);

      // Process the face data
      ...
   }

   EARDetectedFaceArrayDestroy(pFaces);
   EARFaceDetectorDestroy(pDetector);
}
```

Additional liveness instructions can be found in Panoptes sample documentation, with liveness sample images in panoptes/sample_images directory.

8 Panoptes Command Line Tool

The panoptes command line tool allows you to learn and recognize persons in images. It also provides you with tools to manage persons in a person directory.

Panoptes stores person-related information in a database file named `safr_person.db` that is by default stored in your home directory.

To install panoptes:

1. Decompress the `tar.gz` file you have received. The result is a directory with the name `panoptes` in your current directory.
2. Push this directory and all its subdirectories with `adb push` to a suitable home folder on your device. The Panoptes tool can be found inside the `panoptes` folder.

Note: Many embedded Linux versions set home directory to `/`.

Panoptes automatically creates the database file if it doesn't already exist, and it updates the database file if it does already exist. You can point panoptes to a database file stored in a different location by setting the environment variable `PANOPTES_DB_PATH` before you invoke panoptes. The value of this variable should be an absolute path to the desired database location.

You invoke panoptes with an *action* and *action specific parameters*. You can see what commands panoptes supports by running `panoptes --help`, as shown below.

```
> panoptes --help
panoptes <action>

Where <action> is one of:
analyze   <path to image(s)> [-Ckey=value ...]
analyze-highres <path to low-res image> <path to high-res image>
   [-Ckey=value ...]
learn     <path to image(s)> [-Dkey=value ...] [-Ckey=value ...]
recognize <path to image(s)> [-Ckey=value ...]
benchmark <path to image(s)> [-Dkey=value ...] [-Ckey=value ...]\n
remove    <person id>
list      [person id]
edit      <person id> [-Dkey=value ...] [-Rkey ...]
encrypt   <new password>

-Dkey=value       define person metadata key-value pair
-Rkey             remove person metadata key-value pair

-Cmin-cpq=value          the required minimum center pose quality [0 - 1]
-Cmin-cq=value           the required minimum contrast quality [0 - 1]
-Cmin-sq=value           the required minimum sharpness quality |0 - 1]
-Cmin-confidence=value   the required minimum confidence [0 - 1]
-Cmin-search-size=value  the minimum face width/height in pixels for
   detection
-Cmin-size=value         the minimum face width/height in pixels for
   acceptance
-Cselect=value           the face selection policy: 'any', 'largest' or
   'at-location'
-Cloc-x=value            the X coordinate of the location if selection
   policy is at-location
-Cloc-y=value            the Y coordinate of the location if selection
   policy is at-location
```

```
-Cmax-threads=value      the maximum number of threads to process
   detection and recogniton (0 - auto detect, 1-100 actual number of
   threads)
-Cfr-model=value         face recognition model (regular, masked).
   regular - default
-Cfr-optimization=value  face recognition variant optimized for speed vs
   accuracy (speed, accuracy). speed - default
-Cfd-type=value          face detector type (normal, high_sensitivity).
   normal - default
-Cfd-enable-liveness=value  use liveness detection (true / false),
   default - false
-Cfd-liveness-mode=value liveness detection mode (none, last, avg, min,
   max), default - min
-Cfd-high-sensitivity-resolution=value  high sensitivity face detector
   model input resolution. 640x480 - default
    Available resolutions:  1280x720, 720x1280, 640x480, 640x640,
       480x640, 480x480, 480x320, 320x480, 320x240, 320x320, 240x320,
       240x240, 128x128

-b                       generate benchmark output (used with learn or
   recognize actions)
-do                      Run detection only (used only with benchmark
   action)
-wo                      Write output of all models to stdout (used only
   with benchmark action)
-Brd=N                   Repeat detection (and recognition if applicable)
   N times per image.
-Omodel-size=(n|t)       Model size for object/person detector (benchmark
   action only) (n - normal, t - tiny)
-Oinput-size=(s|n|l)     Input size for object/person detector (benchmark
   action only) (s - small, n - normal, l - large)
-Omodel-precision=(fp32|fp16|int8)       Model precision for
   object/person detector (benchmark action only)

Environment variables:
PANOPTES_DB_PATH         if set, specifies the path and file name for the
   person store file
PANOPTES_DB_PWD          if set, specifies the password for the person
   store file
PANOPTES_LICENSE         if set, specifies the panoptes license
```

Important: You have to set the `PANOPTES_LICENSE` environment variable to the license key you have received from RealNetworks before you invoke panoptes. On a POSIX comparability system, you can do this by executing the following command in a shell window:

```
export PANOPTES_LICENSE=<license key>
```

This command should be added to your shell startup script to ensure it is executed for every new shell window you open.

9 Panoptes Actions

9.1 Analyze Action

The *Analyze* action instructs panoptes to run a face recognition action on an image or a set of images for the purpose of finding out what kind of center pose quality, contrast, and sharpness values can be expected for faces. Notethat panoptes does not learn those faces. Neither does it attempt to match those faces against face information stored in an Identity Database. It tries to find as many faces as it can in the images, and it prints information about the found faces to the console.

Use this action on a set of images you have never processed before to get an idea about what center pose quality (cpq), contrast (cq), sharpness (sq) and face size values you can expect. You can then use those values as a basis for choosing the `min-cpq`, `min-cq`, `min-sq`, and `min-size` values for the *Learn* and *Recognize* actions.

If the `fd-enable-liveness` parameter is set to `true`, RGB liveness detection is enabled and the face detector will produce two additional values for the detected face: a liveness score and a liveness status. RGB liveness detection can be used only with high sensitivity face detector. (i.e. with *-Cfd-type=high_sensitivity*)

Panoptes uses the settings below in analyze mode which can be overridden via the -C command line options. (e.g. *-Cmin-search-size*, *-Cfd-enable-liveness*, etc.)

Setting	Default	Range	Description
fd-type	normal	normal, high_sensitivity	Face detector to use. *high_sensitivity* is slower than *normal*, but has better accuracy, especially on masked faces.
fd-enable-liveness	false	true, false	When enabled, RGB liveness detection will be used. (Available only with high_sensitivity face detector.)
fd-liveness-mode	min	none, last, avg, min, max	Liveness detection mode used to calculate liveness response in multi-model setup.
min-search-size	40	15 - 720	Minimum face width/height, in pixels, used for face search with the normal face detector.
fd-high-sensitivity-resolution	640x480	1280x720, 720x1280, 640x480, 640x640, 480x640, 480x480, 480x320, 320x480, 320x240, 320x320, 240x320, 240x240, 128x128	Resolution used for face search with the *high_sensitivity* face detector.

Below is an invocation of panoptes that instructs it to analyze an image and print recognition information about every person found in the image:

```
> panoptes analyze image_with_person.jpeg
```

Note: The path to the image file/image directory must immediately follow the action word.

Invocation of panoptes that will analyze and image and additionally calculate liveness score for every person found in the image. Liveness mode is changed to the average of the *Texture* and *Context* models:

```
> panoptes analyze image_with_person.jpeg -Cfd-type=high_sensitivity
   -Cfd-enable-liveness=true -Cfd-liveness-mode=avg
```

9.1.1 Examples

The directory *sample_images* contains sample images that can be used to test RGB liveness detection.

RGB liveness detection achieves best results if a high resolution image is provided for liveness detection. Invocation of panoptes that will provide low resolution image for face detection and high resolution image for RGB liveness detection:

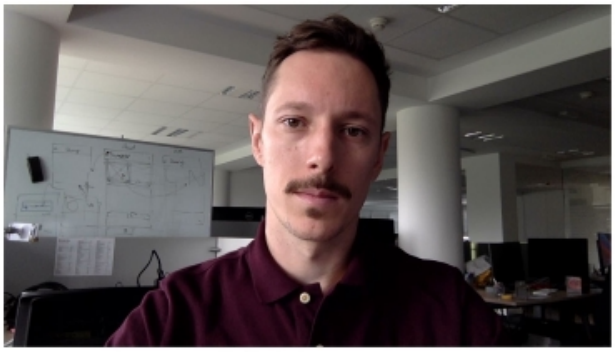
```
> panoptes analyze-highres ../sample_images/Live_LowRes_240x320.jpg
   ../sample_images/Live_HighRes_1920x2560.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
```

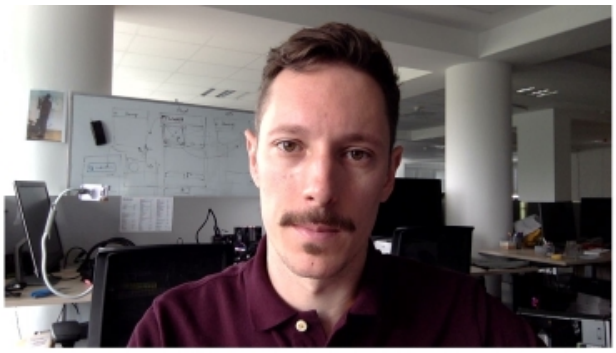
If only *Live_LowRes_240x320.jpg* was provided to the *Analyze* action, RGB liveness would not be calculated because the face size wouldn't satisfy the default requirements. For all of the following examples, RGB liveness detection and face detection are done on a single image, but if possible RGB liveness detection should be provided with a higher resolution image.

Live person images are expected to return:

- liveness: 1.00 (or close to 1)
- livenessStatus: 0 (liveness detection has completed successfully)

```
> panoptes analyze ../sample_images/Live_1.jpg -Cfd-type=high_sensitivity
   -Cfd-enable-liveness=true
> panoptes analyze ../sample_images/Live_2.jpg -Cfd-type=high_sensitivity
   -Cfd-enable-liveness=true
```



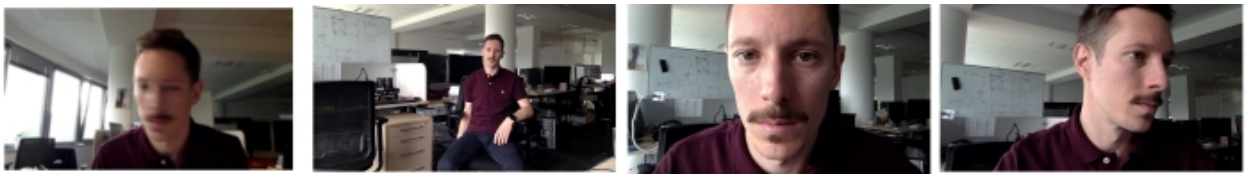


Live person images that don't satisfy face image quality requirements:

- liveness: 0.00
- livenessStatus: 1 (image does not satisfy quality requirements - low quality)
- sq/cpq/cq/face context - below given threshold

```
> panoptes analyze ../sample_images/Live_Blur.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
> panoptes analyze ../sample_images/Live_MinFaceSize.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
> panoptes analyze ../sample_images/Live_FaceContext.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
```

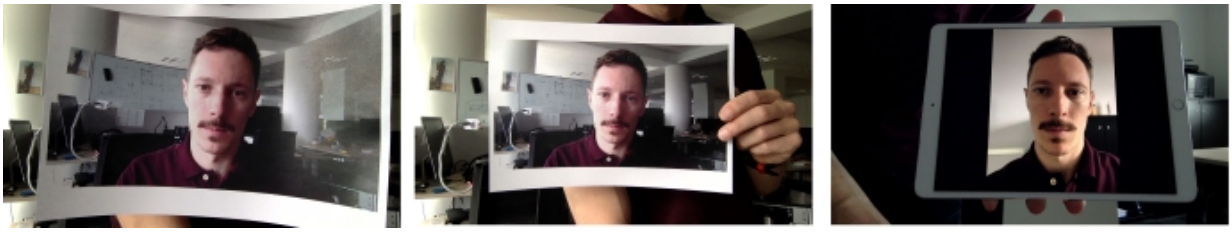
```
> panoptes analyze ../sample_images/Live_CPQ.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
```



Fake person images:

- liveness: 0.00 (or close to 0)
- livenessStatus: 0

```
> panoptes analyze ../sample_images/Fake_Paper_1.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
> panoptes analyze ../sample_images/Fake_Paper_2.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
> panoptes analyze ../sample_images/Fake_Device_1.jpg
   -Cfd-type=high_sensitivity -Cfd-enable-liveness=true
```



9.2 Learn Action

This action instructs panoptes to learn a face/person/identity from a JPEG image or a set of persons from a directory with JPEG images. Panoptes focuses on the person with the largest projected face in the image and learns only this person. You may specify metadata for the person. This metadata is stored together with the person's face signature in the person database. Panoptes assigns a unique identifier (GUID) to the person. This GUID can be used with other actions to refer to this person.

Panoptes uses a default set of face recognizer settings, but you can override the settings via `-C` command line argument described previously. The following table lists the supported settings and their default values:

Setting	Default	Range	Description
min-cpq	0.59	0 - 1	Required minimum center pose quality.
min-cq	0.45	0 - 1	Required minimum contrast quality.
min-sq	0.45	0 - 1	Required minimum sharpness quality.
min-confidence	1	0 - 1	Required minimum confidence.
min-search-size	40	15 - 720	Minimum face width/height in pixels used for face search during detection.

Setting	Default	Range	Description
min-size	146	1 - 720	Minimum face width/height in pixels for recognition acceptance.
select	largest	any, largest, at-location	Face selection policy.
loc-x	0.5	0 - 1	X-coordinate of the location if selection policy is at-location.
loc-y	0.5	0 - 1	Y-coordinate of the location if selection policy is at-location.
fd-type	normal	normal, high_sensitivity	Face detector to use. *high_sensitivity* is slower than *normal*, but has better accuracy, especially on masked faces.
fd-enable-liveness	false	true, false	When enabled, RGB liveness detection is used. (Only available with *high_sensitivity* face detector.)
fd-high-sensitivity-resolution	640x480	1280x720, 720x1280, 640x480, 640x640, 480x640, 480x480, 480x320, 320x480, 320x240, 320x320, 240x320, 240x240, 128x128	Resolution used for face search with the *high_sensitivity* face detector.
fr-model	regular	regular, masked	Face recognition model to use. The *masked* model is optimized for recognition on masked faces.
fr-optimization	speed	speed, accuracy	Face recognition model optimized for either speed or accuracy.

Below is an invocation of panoptes, instructing it to learn the person visible in the image and to add the metadata `name` with the value `Foo` to the person.

```
> panoptes learn image_with_person.jpeg -Dname=Foo
```

Note: As mentioned previously, the path to the image file/image directory must immediately follow the action word.

9.3 Recognize Action

This action instructs panoptes to recognize a person or a set of persons. You may pass a path to a single JPEG image or a path to a directory containing one or more JPEG images. Panoptes runs a face recognition operation on every image to extract person information, and matches up this person information with the person information stored in the person database. It then lists the unique person ID (GUID) and metadata for every recognized person.

Panoptes uses a default set of face recognizer settings, but you can override the settings. The following table lists the supported settings and their default values:

Setting	Default	Range	Description
min-cpq	0.0	0 - 1	Required minimum center pose quality.
min-cq	0.0	0 - 1	Required minimum contrast quality.
min-sq	0.0	0 - 1	Required minimum sharpness quality.
min-confidence	0.93	0 - 1	Required minimum confidence.
min-search-size	40	15 - 720	Minimum face width/height in pixels used for face search during detection.
min-size	0	1 - 720	Minimum face width/height in pixels for recognition acceptance.
select	largest	any, largest, at-location	Face selection policy.
loc-x	0.5	0.5	X-coordinate of the location if selection policy is at-location.
loc-y	0.5	0.5	Y-coordinate of the location if selection policy is at-location.
fd-type	normal	normal, high_sensitivity	Face detector to use. *high_sensitivity* is slower than *normal*, but has better accuracy, especially on masked faces.
fd-enable-liveness	false	true, false	When enabled, RGB liveness detection is used. (Only available with *high_sensitivity* face detector.)
fd-high-sensitivity-resolution	640x480	1280x720, 720x1280, 640x480, 640x640, 480x640, 480x480, 480x320, 320x480, 320x240, 320x320, 240x320, 240x240, 128x128	Resolution used for face search with the *high_sensitivity* face detector.
fr-optimization	speed	speed, accuracy	Face recognition model optimized for either speed or accuracy.
fr-model	regular	regular, masked	Face recognition model to use. The *masked* model is optimized for recognition on masked faces.

Below is an invocation of panoptes, instructing it to print out all recognized persons visible in the given JPEG image. This invocation also shows how to override one of the recognizer settings with a custom value:

```
> panoptes recognize image_with_person.jpeg -Cmin-confidence=0.86
```

Below is an invocation of panoptes which instructs it to print out all recognized persons visible in the given JPEG image. This invocation also shows how to override face detector and face recognition default settings:

```
> panoptes recognize image_with_person.jpeg -Cfd-type=high_sensitivity
   -Cfd-high-sensitivity-resolution=128x128 -Cfr-model=masked
   -Cfr-optimization=accuracy -Cfd-enable-liveness=true
```

If a person was learned using the regular/masked face recognition model, the same model should be used when attempting to recognize the face. Different face recognition models produce different facial signatures for the same face and should not be compared. If a different model is used when attempting to recognize a face, no error will be returned but the person is unlikely to be recognized.

When using the *high_sensitivity* face detector, this message can occur:

```
ERROR: OpenCL library not loaded - dlopen failed: library
   "libOpenCL-pixel.so" not found
ERROR: Falling back to OpenGL
```

This error is actually only a warning and can be ignored.

9.4 Benchmark Action

This action instructs panoptes to instantiate all eSDK capabilities (i.e. face detection, face recognition, emotion estimation, age estimation, gender detection, and object/person detection), measure the duration of each process, and generate a benchmark output before ending execution. You may pass a path to a single JPEG image or a path to a directory which contains one or more JPEG images.

Face recognition is configurable in the same way as it is in the *Recognize* action, described above. In addition, the object/person detector can be configured by specifying the model type (object detector or person detector), model size (normal or tiny), input size (normal, large, or small) and precision.

When running panoptes benchmark for the first time, it may take a while (depending on the device, up to 10 minutes) for benchmark to start as all the models have to be optimized before the first run.

Setting	Default	Options	Description
model-size	Normal	Normal, Tiny	Model size. The tiny model is smaller and faster but has lower accuracy.
input-size	Normal	Small, Normal, Large	Size to which the input image is resized to. Normal = 416px Small = 320px Large = 608px
model-precision	Half	Float, Half, Int8	Precision of the model. The "Float" value represents "float32", while the "Half" value represents "float16".

Below is an invocation of panoptes which will benchmark the eSDK on a single image with a person detector

using fp16 precision:

```
> panoptes benchmark image_with_person.jpeg -Omodel-type=p
   -Omodel-precision=fp16
```

9.4.1 Interpreting Confidence Values

Confidence Value	Interpretation
>= 1.0	Certain match. (Values > 1.00 are possible indicating even greater certainty.)
[0.93 1.0>	Close match.
[0.86 0.93>	Possible match with low confidence.
[0.82 0.86>	Similar face with no confidence of match.
[0.00 0.82>	Different face.

Note: As mentioned previously, the path to the image file/image directory must immediately follow the action word.

9.5 List Action

The *List* action instructs panoptes to display the person ID and metadata of all persons in the person database. You can optionally specify a known person ID to limit the display to just this person.

9.6 Remove Action

The *Remove* action takes a person ID and instructs panoptes to delete all information about this person from the person database.

9.7 Edit Action

The *Edit* action instructs panoptes to edit the metadata of a person, specified by their person ID. Metadata key-value pairs can be added or updated with the `-D` switch. A metadata key-value pair may be deleted with the `-R` switch.

9.8 Encrypt Action

The *Encrypt* action instructs panoptes to encrypt the person store database file with the provided password. This action also allows you to change the password of an existing database file. Note that the `PANOPTES_DB_PWD` environment variable must be set to the old password so that panoptes is able to decrypt the existing database file before encrypting it with the new password.

Important: Don't forget to update the `PANOPTES_DB_PWD` environment variable with the new password after the *Encrypt* action has completed and before you try to execute a *Learn* or *Recognition* action.

10 Panoptes Benchmark Output

The **Learn** and **Recognize** actions support the generation of benchmark output. You enable this mode by passing the `-b` switch to panoptes.

Below is an invocation of panoptes instructing it to print out benchmark data into a tab-delimited file for all recognized persons visible in all JPEG images in a specified directory:

```
> panoptes recognize <path to image(s)> -b [-Ckey=value ...]
```

The format of the benchmark output is:

```
<image file name> <person ID> <confidence percentage> <recognition time>
```

where:

- Fields are tab delimited.
- **image file name**: The file name of the JPEG image.
- **person ID**: The person ID.
- **confidence percentage**: The recognition confidence expressed as a percentage.
- **recognition time**: The time in milliseconds it took to run recognition on the image expressed.

Note: Confidence percentage can range from 0 to approximately 180. A value of 100 indicates near certainty of a match.

You can redirect the benchmark output to a file as shown below to open it in a spreadsheet application. The data is stored as a tab-separated list.

```
> panoptes recognize directory_with_jpegs -b > my_data.tsv
```