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Face Detection HW Hybrid Version 4.0

80-P9301-134 A

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Revision history

Revision	Date	Description
A	November 2017	Initial release

Note: There is no Rev. I, O, Q, S, X, or Z per Mil. standards.

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1 Introduction

1.1 Purpose

This document provides a high-level description of the face detection (FD) HW hybrid version 4.0 for SDM845 and SDM670 with face detection HW 4.1 IP core.

1.2 Conventions

Function declarations, function names, type declarations, attributes, and code samples appear in a different font, for example, `#include`.

Code variables appear in angle brackets, for example, `<number>`.

1.3 Technical assistance

For assistance or clarification on information in this document, submit a case to Qualcomm Technologies, Inc. (QTI) at https://createpoint.qti.qualcomm.com/.

If you do not have access to the CDMATech Support website, register for access or send email to support.cdmatech@qti.qualcomm.com.

2 Overview

The face detection feature analyzes a scene and detects the faces within the scene during preview and video operation. When detecting the faces, FD sends relevant information to the other features as shown in the following image:
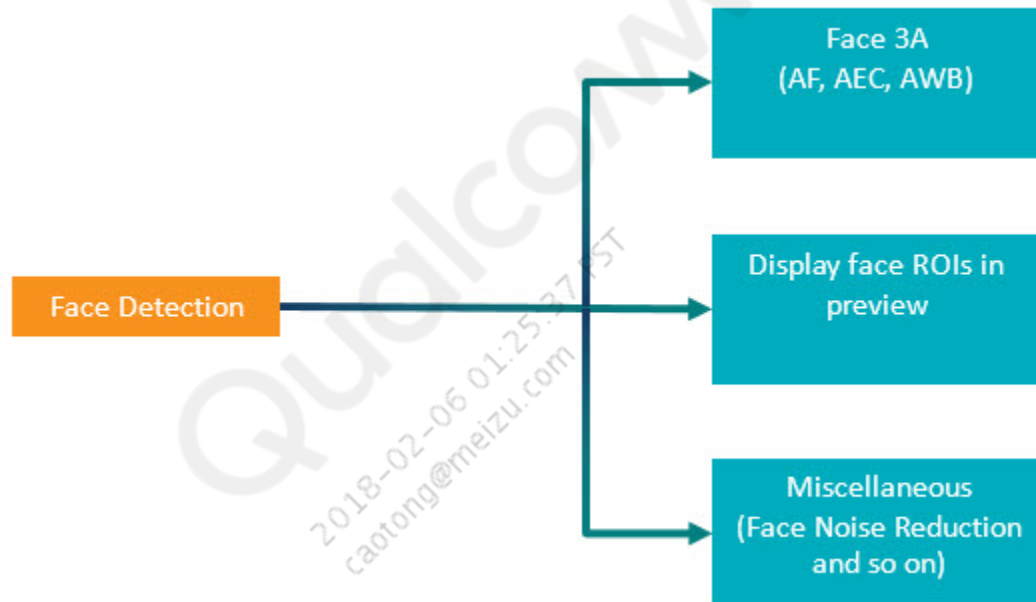
FD can be configured to detect faces in the following angles:

- 360° of roll angles
- -90° to 90° of yaw angles
- -30° to 30° of pitch angles

FD is typically configured to run continuously during preview for both front and rear cameras. It can also be configured to run during video preview and/or recording.

The FD HW hybrid version 4.0 improves on the following areas compared to the previous version 3.0:

- Detection latency
- Better stabilization with reduced motion lag
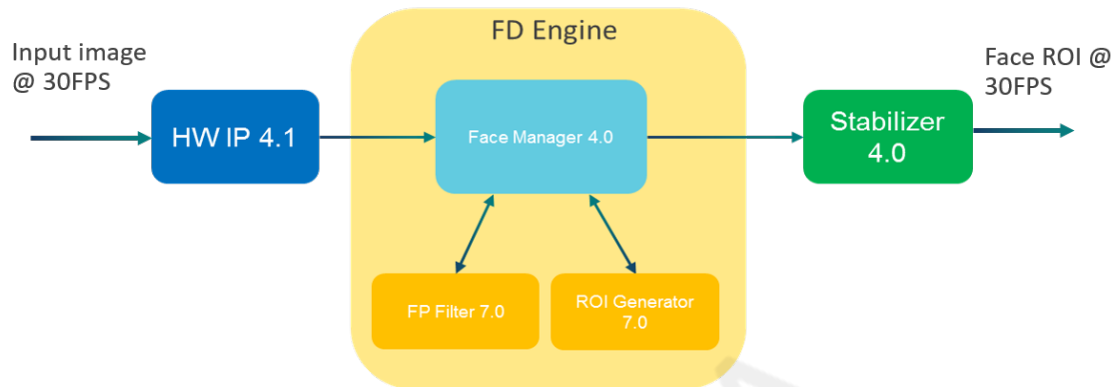
Figure 2-1 HW Hybrid 4.0 functional flow diagram

- HW IP - fast detecting typical faces

- Face Manager - tracking already detected and new detected faces

- False Positive (FP) filter - filtering out non-faces

- Region-of-interest (ROI) generator - retrieving lost faces during blurry frames or illumination changes

- Stabilizator - stabilizing the output face ROIs from FD Engine

3 Tuning parameters

Table 3-1 General

| Parameter Name	Description	Default	Range	Impact
maxNumberOfFaces	The maximum number of faces that can be detected.	10	1 - 10	N/A
maxFPS	The maximum fps at which FD can run.	30	15 or 30	Increasing this value will reduce detection latency and increase face ROI stability and smoothness, but result in higher power consumption.
lockDetectedFaces	Lock the detected faces for tracking. When the number faces detected are greater than maxNumberOfFaces, the old faces that are being tracked are accepted and the new faces are rejected.	TRUE	TRUE or FALSE	N/A
initialNoFrameSkipCount	First n number of frames which are always skipped before executing face detection. If the first several frames are dark or black, no need to run FD.	15	greater than 0	Increasing this value will increase the detection latency.
maxPendingFrames	Max allowed frames in pending queue.	2		
delayCount	Frame count to show only the face which is detected in a number of consecutive frames higher than the delay count.	1	0 - 10	This value can be used to suppress false positive detection like these which appear in the frames less than the delay count, but faces will be detected slower by the frames specified by delay count.
holdCount	Frame count to keep outputting face info when the face is lost during tracking.	2	0 - 2	Increasing the hold count will improve the stability and tracking during small disruptions like occlusion or out of focus, but will result in wrong result info displayed.
accuracy	Search accuracy during tracking.	FDAccuracyNormal	FDAccuracy Normal or FDAccuracy HIGH	High tracking accuracy will improve the face following accuracy, but will increase the processing time.

Table 3-2 HW

Parameter Name		Description	Default	Range	Impact
enable		Flag to enable or disable HW face detection.	TRUE	TRUE or FALSE	Face detection will be disabled if it's set to FALSE.
minFaceSize	type	Mode to control minimum face size specification in fixed pixels or ratio of image height.	FDFaceAdjFixed	FDFaceAdjFixed or FDFaceAdjFloating	N/A
	size	The minimum face size in pixels can detected.	32	20, 25, 32 or 40	Decreasing this value will result in smaller faces be detected, but also increase the overall processing time.
enableUpFrontAngles		Flag to enable up-front angles detection only.	FALSE	TRUE or FALSE	Enable this feature will reduce the processing time and suppress the false positive detection, but it may also reduce the face detection rate.
angle		Flag to enable up-front angles detection only.	FDAngleAll	FDAngleNone, FDAngle45, FDAngle90, FDAngle135 or FDAngleAll	Enable this feature will reduce the processing time and suppress the false positive detection, but it may also reduce the face detection rate.
threshold		Detection threshold to determine a face.	0	0 - 10	Increasing this value will reduce detection rate but will result in less false positive detection.
noFaceFrameSkip		Frame skip count when no faces detected.	0		
newFaceFrameSkip		Frame skip count when at least one face is detected.	0		

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Table 3-3 FP Filter

Parameter Name	Description	Default	Range	Impact
enable	Flag to enable or disable false positive filter.	TRUE	TRUE or FALSE	FP filter will be bypassed if it's set to FALSE.
baseThreshold	SW detection threshold. Faces with confidence below this threshold are discarded while executing FP filter.	500	0 - 1000	As the value decreases, more the chances to detect faces, but more the chances to detect false positives.
innerThreshold		750		
expandFaceSizePerce ntage	Face size percentage to calculate min, max face sizes while calling FP filter.	25	0 - 100	As the value increases, more the chances to detect faces, but processing time increases.
expandBoxBorderPerc entage	Frame box rectangle percentage to calculate the crop region to search for while false positive filtering. Used when HW find the face.	25	0 - 100	As the value increases, more the chances to detect faces, but processing time increases.
faceSpreadTolerance	If the displacement is greater than the tolerance, face is rejected. Used when HW finds the face.	0.3	0 - 1	As the value increases, moving faces are tracked, also there is a possibility of tracking a wrong face.
searchDensity	SW face detection search density.	FDSearchD ensityHigh	FDSearchDensityHighest, FDSearchDensityHigh, FDSearchDensityNormal, FDSearchDensityLow or FDSearchDensityLowest	As the value increases, more faces can be detected; more the chances of false positives, and processing time increases.

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Table 3-4 ROI Generator

Parameter Name	Description	Default	Range	Impact
enable	Flag to enable or disable ROI generator.	TRUE	TRUE or FALSE	ROI generator will be bypassed if it's set to FALSE.
baseThreshold	SW detection threshold. Faces with confidence below this threshold are discarded while executing ROI generator.	500	0 - 1000	As the value decreases, more the chances to detect faces, but more the chances to detect false positives.
innerThreshold	SW confidence threshold. Face output from ROI generator is confident up to this value.	800	0 – 1000 (Must be higher than all FaceConfidence values in FaceManager)	
expandFaceSizePercentage	Face size percentage to calculate min, max face sizes while calling FP filter.	25	0 - 100	As the value increases, more the chances to detect faces, but processing time increases.
expandBoxBorderPercentage	Frame box rectangle percentage to calculate the crop region to search for while false positive filtering. Used when HW find the face.	100	0 - 100	As the value increases, more the chances to detect faces, but processing time increases.
faceSpreadTolerance	If the displacement is greater than the tolerance, face is rejected. Used when HW finds the face.	0.9	0 - 1	As the value increases, moving faces are tracked, also there is a possibility of tracking a wrong face.
searchDensity	SW face detection search density.	FDSearchDensityNormal	FDSearchDensityHighest, FDSearchDensityHigh, FDSearchDensityNormal, FDSearchDensityLow or FDSearchDensityLowest	As the value increases, more faces can be detected; more the chances of false positives, and processing time increases.

Table 3-5 Face Manager

Parameter Name	Description	Default	Range	Impact
enable	Flag to enable or disable face tracking.	TRUE	TRUE or FALSE	Face tracking will be bypassed if it's set to FALSE.
newGoodFaceConfidence	Confidence threshold to treat the face as a high confidence good face. When a face with confidence above this value is detected for delayCount times in subsequent frames, then the face is accepted and given as output.	750	baseThreshold to 1000	As the value decreases, the detection rate increases, and false positive rate also increases.
newNormalFaceConfidence	Confidence threshold to accept the face for entry. When a face with confidence above this value is detected for 2 x delayCount times in subsequent frames, then the face is accepted and given as output.	665	newGoodFaceConfidence to 1000	As the value decreases, the detection rate increases, and false positive rate also increases.
existingFaceConfidence	Confidence threshold to accept the face while tracking.	500	newNormalFaceConfidence to 1000	As the value decreases, the tracking rate increases, and false positive rate increases.
angleDiffForStrictConfidence	Angle in each direction to consider the zone as upfront. Used only when device orientation is available.	55	Up to 90	if strictNewGoodFaceConfidence are different (greater) than newGoodFaceConfidence and this value is set, upfront faces will be easily detected compared to other angle faces. This will help in de-prioritizing other angle faces and thus restricting false positives.
strictNewGoodFaceConfidence	Same as newGoodFaceConfidence. Used for processing the faces that are in angles other than upfront. Used only when device orientation information is available.	740	baseThreshold to 1000	As the value decreases, the detection rate increases, and false positive rate also increases.
strictNewNormalFaceConfidence	Same as newNormalFaceConfidence. Used for processing the faces that are in angles other than upfront. Used only when device orientation information is available.	700	strictNewGoodFaceConfidence to 1000	As the value decreases, the detection rate increases, and false positive rate also increases.
strictExistingFaceConfidence	Same as existingFaceConfidence. Used for processing the faces that are in angles other than upfront. Used only when device orientation information is available.	500	strictNewNormalFaceConfidence to 1000	As the value decreases, the tracking rate increases, and false positive rate increases.
faceLinkMoveDistanceRatio	Move distance ratio threshold to link a face.	1.1	Default recommended	Impacts linking face in current frame to previous frame
faceLinkMinSizeRatio	Minimum size ratio threshold to link a face.	0.666666	Default recommended	Impacts linking face in current frame to previous frame

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Parameter Name	Description	Default	Range	Impact
faceLinkMaxSizeRatio	Maximum size ratio threshold to link a face.	1.5	Default recommended	Impacts linking face in current frame to previous frame
faceLinkRollAngleDifference	Roll angle difference threshold to link a face.	60.0	Default recommended	Impacts linking face in current frame to previous frame

Table 3-6 Stabilization Filter

Parameter Name		Description	Default	Range	Impact
enable		Flag to enable or disable stabilization filter.	TRUE	TRUE or FALSE	Stabilization filter will be bypassed if it's set to FALSE.
historyDepth		Stabilization history length.	10	greater than minStableState	N/A
position	enable	Flag to enable or disable face position stabilization.	TRUE	TRUE or FALSE	Face position stabilization will be bypassed if it's set to FALSE.
	mode	Criteria used in Stabilize state to determine if the face ROI position is marked as stable. Options are: Equal – checks whether the new received face ROI position is equal to the current stable face ROI position. Smaller – checks whether the new received face ROI position is smaller than the current stable face ROI position. Bigger – checks whether the new received face ROI position is bigger than the current stable face ROI position. WithinThreshold – checks whether the difference between the new received face ROI position and current stable face ROI position is within the threshold.	WithinThreshold	Equal, Smaller, Bigger, CloserToReference or WithinThreshold	Mode impacts stabilization for static faces and motion lag for moving faces. WithinThreshold is recommended.
	minStableState	Minimum number of frames checked in Stabilize state before switching to Stable state.	6	1 to historyDepth	Increasing this value makes face ROI position more stable, but this may result in inaccurate ROI being displayed for a moving face.

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Parameter Name		Description	Default	Range	Impact
	stableThreshold	Threshold value used in Stabilize state when the mode is set to WithinThreshold.	20	5 to 30	Increasing this value improves face following accuracy but may cause the ROI position to be less stable
	threshold	Threshold value used in Stable state which is used to determine unstable state transition.	120	50 to 200	Increasing this value make the face ROI more stable for static faces
	stateCount	Number of frames checked in Stable state before switching to Unstable state.	6	1 to historyDepth	Increasing this value suppresses small disruptions in face ROI position, but this may result in inaccurate ROI being displayed for a moving face.
	useReference	Reference to monitor whether values are stable or not.	FALSE	TRUE or FALSE	
	filterType	Ways to evaluate stability based on the next frame or a sequence of frame history. Options are: NoFilter – denotes that the filter is disabled. Average – denotes that the output face ROI positions is the average of frames with average.history_length. Median – denotes that the output face ROI positions are the median of frames with average.history_length.	Average	NoFilter, Temporal, Hysteresis, Average or Median	
	movingThreshold		65		
	movingInitStateCount		4		
	movingLinkFactor		1.5f		
	averageFilter.historyLength		5		
size	enable	Flag to enable or disable face size stabilization.	TRUE	TRUE or FALSE	Face size stabilization will be bypassed if it's set to FALSE.

Parameter Name		Description	Default	Range	Impact
	mode		WithinThreshold	Equal, Smaller, Bigger, CloserToReference or WithinThreshold	
	minStableState		6		
	stableThreshold		20		
	threshold		200		
	stateCount		6		
	useReference		FALSE	TRUE or FALSE	
	filterType		Average	NoFilter, Temporal, Hysteresis, Average or Median	
	movingThreshold		65		
	movingInitStateCount		4		
	movingLinkFactor		1.5f		
	averageFilter.historyLength		5		

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4 Typical FD issues

This chapter provides information on what some of the typical FD issues are and how they can be resolved.

Certain faces are not detected

Occasionally, the FD feature fails to detect some faces.

- Potential causes

  □ FD tuning parameters may not be configured to detect the current face. For example, the face size may be smaller than `minFaceSize` or the face in scene may be a at a roll angles not configured by `angle` parameter.

  □ Some challenging types of face images, such as backlit, wearing glasses, certain hairstyles, partial or occluded faces, or low-light faces, are often not detected. These faces have characteristics that are atypical of normal faces and are challenging for the FD algorithm to detect them at a high probability.

- Resolutions

  □ Modify tuning parameters as described in Chapter 3 starting with reducing `newNormalFaceConfidence` in decrements of 20.

  □ Detection of challenging categories can be improved by following the tuning guidelines in Chapter 3. Lowering the FaceConfidence parameter in FaceManager section helps to improve detection in a statistical sense, which may help resolve the issue. For example, a lower threshold could improve detection on a large set (30 or more) of faces with glasses compared to a higher threshold. There may be a side effect of increased false positives with a lower FaceConfidence values. It is recommended to check false positive increase with a large false positive dataset of at least 100 non-face images.

NOTE: FD algorithm cannot detect all challenging faces and improvement is measured statistically.

False positives are detected

Occasionally, the FD feature may detect a non-face as a face. For example, a doll or car wheel may be classified as a face. False positives that are rarely visible are to be expected with the FD feature. Current tuning guideline is to achieve less than 2% false positives per image/scene.

- Potential Cause

  □ For the FD feature, a challenging face and a false positive may seem similar in terms of confidence. A typical tuning goal of detecting challenging faces at a high probability may result in more false positives being detected.

- Resolution

  □ Select tuning parameters to match the detection requirements. For example, setting a lower min_face_size value than necessary may result in higher false positives. The false

positive rate or probability can be reduced by increasing the *FaceConfidence* parameters in Face Manager section of Chapter 3. It is recommended that the false positive increase be checked with a large false positive dataset of at least 100 non-face images.

NOTE: A higher threshold may result in reduced detection rate. It is recommended that the detection rate change be checked by testing on a representative dataset with at least 50 face images.

Face ROI is not stable

For a stationary face, face ROI may fluctuate for a long duration (more than two seconds).

- Potential cause
  - □ Stabilization filter may not have the right tuning parameters.
- Resolution
  - □ Assign a higher value to the `minStableState` or increase *average.history_length* for size and/or position in Stabilization section of Chapter 3. This may result in a delay in the display of face ROI for a moving face.

High Detection Latency: New faces are detected slower than expected

When a new face appears in the scene, it is detected after a few frames. This FD latency may be higher than expected.

- Potential causes
  - □ All faces including typical faces take longer to detect
  - □ Challenging faces take longer to detect.
- Resolutions
  - □ Reduce `delayCount` in general section of Chapter 3 to improve detection lag of any detected face
  - □ Lower the *FaceConfidence* values in Face Manager section of Chapter 3 to detect challenging faces with higher probability and with lower latency. There may be a side effect of increased false positives with a lower FaceConfidence values. For information on how to check FD latency through logs, please refer to Debugging info of Chapter 5.

High Motion Lag: ROI lags the faces when moving

When an already detected faces starts moving in the scene, the ROI may lag the actual face significantly.
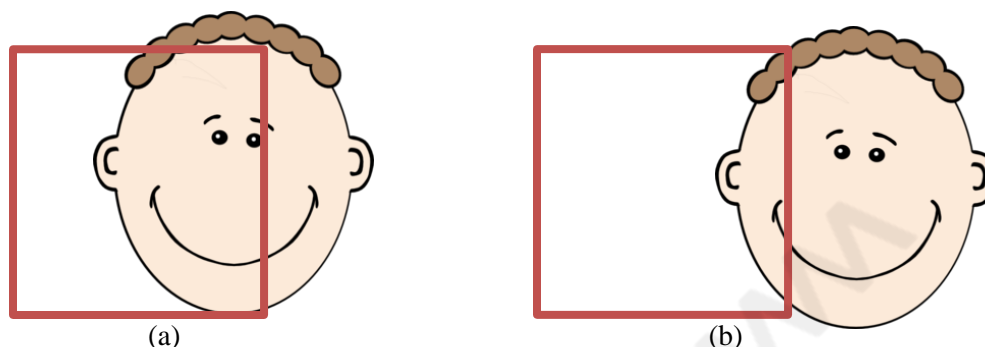

Figure: (a) Acceptable motion lag for moving face from left to right in the scene (b) High motion lag for moving face from left to right.

- Potential causes

  □ Aggressive stabilization for static faces may cause ROI lag during face motion due to temporal ROI filtering

  □ FD processing time may be high due to tuning parameters which is causing a latency of

- Resolutions

  □ Reduce *threshold, stateCount, movingThreshold, averageFilter.historyLength* values of position in stabilization filter Chapter 3. In addition increasing *movingInitStateCount* to be closer to stateCount may reduce the motion lag. There may be side effect of Face ROI being unstable for static face. It is recommended to balance the stabilization filter tuning by monitoring impact on both motion lag and static faces.

Table 4-1 Typical issues

| Issue	Resolution
Certain faces are not detected	Assign a lower detection threshold value.<Add specific params> **Note:** This may cause more false positive detections.
False positive is detected	Assign a higher detection threshold value. **Note:** This may result in fewer faces being detected.
Face ROI is not stable	Assign a higher value to min_count_for_stable_state or average.history_length. **Note:** This may cause inaccurate ROI being displayed for a moving face.
High FD latency	Check current FD latency and assign a lower new face search cycle value. **Note:** This may increase the processing time per frame and it may cause FDFPS values to drop.
Small faces are not detected	Assign a lower minimum face size value so that faces of sizes above the assigned value are detected. **Note:** This will increase the processing time per frame and it may cause FDFPS values to drop.

5 Debugging information

Enable logs

Enable Camx FD logs by enabling CAMX_LOG_VERBOSE and searching for tag "[FD   ]" for all FD logs

View FD log information

- View Input face information to face manager

  Search string: **HWFDResults**

- View FD output face information after face manager.

  Search string: **FDEngineResults**

- View FD performance information after stabilization.

  Search string: **AfterSorting**

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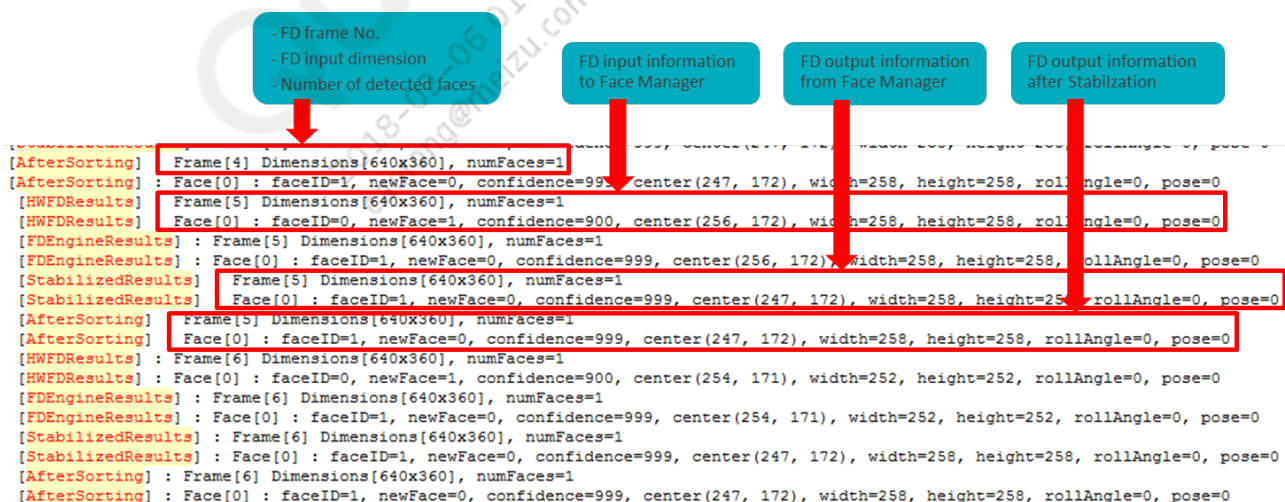
A References

A.1 Related documents

Title	Number
Qualcomm Technologies, Inc.	
Face Detection Tuning Overview	80-NV077-1

A.2 Acronyms and terms

Acronym or term	Definition
FD	Face Detection
FOV	Field of View
FP	False positive
ROI	Region of interest
FPS	Frames per Second