Command Line Video Quality Metric (CVQM) Software Release Version 3.0
Release Notes
September, 2011

This file contains information about the above product in the following sections:

1) Release Contents

The CVQM software was developed by the Institute for Telecommunication Sciences (ITS). CVQM performs automated processing on a pair of video files. One contains an original video sequence (e.g., straight from the camera) and the other contains a processed video sequence (e.g., after coding and transmission and decoding). This program runs under the Windows operating system. CVQM performs video calibration and video quality estimation.

2) Package Contents

The CVQM software Version 3.0 package contains the following:

Installation related files:
- MCRInstaller.exe

Software related files:
- cvqm.exe
- rr_original.exe
- rr_processed.exe
- fastlowbw_ref.exe

Video Sequences:
- original.avi
- processed.avi
- rrtv_calmob_original.yuv
- rrtv_calmob_hrc2.yuv
- rrtv_flogar_original.yuv
- rrtv_flogar_hrc1.yuv

Technical documentation:
- cvqm_pc_readme.pdf
- fastlowbw_ref_readme.pdf
- rr_original_readme.pdf

rr_processed_readme.pdf
ntia_tm_10_463.pdf
ntia_tm-11-475.pdf
ntia_tm-11-482.pdf
ntia_tr_02_392.pdf
ntia_tr_06_433a.pdf
ntia_tr_08_433b.pdf
ieee_04.pdf
vpqm_05.pdf
ITUT_COM9_C5.pdf
ITUT_COM9_C6.pdf

If any of these files are missing, you have not received an official distribution of the CVQM software.

3) System Requirements

CVQM software version 3.0 requires the following software and hardware:

Minimum Configuration:

Processor	3.0 GHz Pentium (Quad Core recommended).
RAM	2.0 GB (for SD video), 16.0 GB (for HD video). The RAM requirements are highly dependent on the clip duration, clip resolution, and the user selected calibration and model options. An 8 second HD clip may require up to 32 GB for some calibration and model options.
Software	Microsoft XP (for 32-bit executable), Windows 7 (for 64-bit executable). The software may run under Vista but this has not been tested. Windows 7 64-bit is highly recommended as XP 32-bit does not support usable RAM configurations larger than 2 GB.
Disk	> 4 GB free disk space

4) Technical Support Information

Please send any problems or requests for future improvements to vqm@its.bldrdoc.gov

For information on other video quality NTIA/ITS publications, visit <www.its.bldrdoc.gov/n3/video/documents.htm>. For information on other NTIA/ITS publications, visit the NTIA/ITS web site at <www.its.bldrdoc.gov>. Other video quality measurement software tools may be obtained from <http://www.its.bldrdoc.gov/n3/video/vqmsoftware.htm>.

5) Install/Uninstall Instructions

****
*****Install Instructions
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The CVQM software was developed using MATLAB and its associated toolboxes. It is therefore necessary to install the MATLAB Component Runtime (MCR) library before running CVQM. If a prior version of CVQM was installed, you must first uninstall the old version of the MATLAB Component Runtime Library before

proceeding (see Uninstall Instructions below). Follow this installation procedure for CVQM:

1. Copy the files on the installation CD to a directory on your computer. This directory will be denoted as c:\CVQM for the rest of the installation instructions given below.

2. Double click MCRInstaller.exe in c:\CVQM and follow the instructions to install the MCR library on your computer.

3. After completing installation, check to make sure that the MATLAB Component Runtime library installed properly. From the "Start" menu, select "Control Panel", and in the window that appears, double-click "Add or Remove Programs" and see if the MATLAB Component Runtime library appears in the list of installed programs. If not, repeat step 2.

****
*****Uninstall Instructions
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1. Select "Start", "Control Panel", "Add/Remove Programs". From the list of programs, select "MATLAB Component Runtime", and press "Remove".

2. Delete your installation directory and all files in it.

6) Operating Instructions

Open a command prompt window by selecting "Start", "Program", "Accessories", "Command Prompt". Change to the c:\CVQM installation directory in step 1 of the Installation Instructions by typing "cd c:\CVQM" at the command prompt.

To start the CVQM software, type "cvqm" at the command prompt.

Execute CVQM with no arguments for syntax and brief operating instructions. See also #10 below for details.

7) Product Release Notes

The following changes were made to version 1.1 (from 1.0):

1. Implement 'rrtime' calibration option.

2. Fix a defect that prevented CVQM from running calibration on very short files.

3. If the original and processed files are longer than 15 seconds, only the first fifteen seconds of video will be used for calibration and model calculation. Computers with limited RAM may still run out memory with 15-sec clips. Type-3 warning will be written to the error file.

4. Output a Type 1 error when out-of-memory is encountered, instead of crashing.

The following changes were made to version 2.0 (from 1.1)

1. Implement the 'frcal' and 'frtime' calibration options.

The following changes were made to version 2.1 (from 2.0)

1. Replaced Reduced Reference Luminance Gain/Offset algorithm with a more accurate algorithm (see ntia_tr_06_433a.pdf for documentation on the improved algorithm).

2. Corrected the defect in 'rrcal', 'rrscale' & 'rrtime' temporal registration.

The following changes were made to version 2.2 (from 2.1)

1. Modified 'rrcal' and 'rrscale' to more accurately detect reframing.

2. Warning messages in errors file identify potential calibration problems.

3. Improved the algorithm used to resample iamges when spatial scaling is detected.

The following changes were made to version 2.3 (from 2.2)

1. Changed MATLAB Component Runtime (MCR) library version.

The following changes were made to version 2.4 (from 2.3)

1. Fix defect that caused sequences with reframing to receive very low quality scores (i.e., the reframing was not being performed properly in previous versions - see ntia_tr_02_392.pdf, section 3.1.2 for a definition of reframing).

2. Replace the following quantizers with more efficient, lower bandwidth quantizers: Low Bandwidth model's ATI feature quantizer, Fast Low Bandwidth model's ATI feature quantizer, Temporal Registration feature quantizer, and the Luminance Gain & Offset feature quantizer. These improvements significantly reduce the side channel bandwidth requirements while imposing only a negligible drop in accuracy.

3. Insert missing VQM zero clipping function (activated when VQM < 0.0) and high value crushing function (activated when VQM > 1.0) on the output of General VQM and Developer VQM (see ntia_tr_02_392.pdf, section 6.3 and 6.4). Defect in previous versions would have caused clips with extremely bad quality (greater than 1.0) to be exaggerated; and may have allowed for negative scores (i.e., quality improvement) for the General Model, only.

The following changes were made to version 2.5 (from 2.4)

1. Fix defect that caused sequences with 625-line ("PAL") reframing to receive very low quality scores (i.e., the 625-line reframing was not being performed properly in previous versions).

2. Add options 'rrcal2', 'rrcal2scale', 'frtimemanual', and 'rrtimemanual'.

3. Fix defect in scaling algorithm used by 'rrcalscale' and 'rrcal2scale',that caused scaling algorithm to be less accurate on interlaced video.

4. Changed MATLAB Component Runtime (MCR) library to version R2007b.

The following changes were made to version 2.6 (from 2.5)

1. Fix file & function call names to be consistent with other naming (was "ivqm...")

2. Make quantizers available for calibration. CVQM does not call quantizers, but the appropriate function calls are identified within the code.

3. Updated quantizers for improved accuracy.

4. A few minor tweaks to internally function interface, which allowed CVQM to be split into rr_original and rr_processed. This alternate interface shows how to examine original and processed video on separate computers.

The following changes were made to version 2.7 (from 2.6)

1. Print warning and exit if file is too short (i.e., less than 4 seconds).

2. Remove unnecessary size restriction that was preventing HDTV files from calibrating.

3. Improve quality of image rescaling, when interlaced images are rescaled.

The following changes were made to version 2.8 (from 2.7)

1. Cleaned up spatial registration, temporal registration, and gain/offset code. Changes impact failure cases (i.e., when algorithms cannot accurately estimate calibration values) and these functions' command line arguments. These changes may improve calibration accuracy for some interlaced video sequences.

2. Updated read_avi function to read files larger than 2 GB and expanded the number of uncompressed AVI formats the function can read.

The following changes were made to version 3.0 (from 2.8, there is no version 2.9)

1. Improvements and bug fixes have been made to the read_avi function, including support for the 'YV12' and 'V210' formats (the read times are very slow for the 'V210' 10-bit uncompressed format).

2. Added 3 new calibration options: (1) psnr_search (ITU-T J.340, see ITUT_COM9_C6.pdf), (2) fast_psnr_search1 (ITU-T J.244, then psnr_search), and (3) fast_psnr_search2 (ITU-T J.144, then psnr_search). To compute the ITU-T J.340 PSNR values, one of these new psnr_search calibration options must be selected, followed by the PSNR model (NOT the PSNR_VFD model, which also includes advanced variable frame delay estimation).

3. Added 3 new model options: (1) psnr (peak signal to noise ratio, may be used with new psnr_search calibration options to compute ITU-T J.340 values), (2) psnr_vfd, which is a PSNR metric computed after variable frame delay (VFD) is estimated and removed (see ntia_tm-11-475.pdf), and (3) vqm_vfd, which is a neural network (NN) based video quality metric (VQM) that incorporates VFD processing and VFD quality parameters. The new vqm_vfd model also incorporates viewing distance (in picture heights), which may be set with an optional 'viewing_distance' input argument.

8) Usage, Copyright, and Patent Information

The algorithms contained within the IVQM Software are covered by two U.S. Patents.

U.S. Patent Number 5,446,492, entitled "A Perception-based Video Quality Measurement System," issued on August 29, 1995.

U.S. Patent Number 6,496,2221, entitled "In-Service Video Quality Measurement System Utilizing an Arbitrary Bandwidth Ancillary Data Channel," issued December 17, 2002.

9) Use of VQM Numbers in Outside Reporting

U.S. Department of Commerce policy prohibits NTIA/ITS from endorsing products. However, the NTIA General Model was standardized by ANSI in July of 2003 (ANSI T1.801.03-2003), by ITU-T in March of 2004 (ITU-T J.144), and by ITU-R in June of 2004 (ITU-R BT.1683). The NTIA General Model has been approved for use in performance testing and comparison of digital video systems.

In 2009, the NTIA/ITS Fastlowbw model was a member of the top-performing group in the Reduced-Reference TV (RRTV) tests conducted by the Video Quality Expert Group (VQEG). This model has been included in ITU-T Recommendation J.249 (see ITUT_COM9_C5.pdf).

In 2010, the NTIA/ITS PSNR search algorithm with compensation for constant spatial shifts, constant temporal shift, and constant luminance gain and offset was standardized by ITU-T (ITU-T J.340). This model can be computed by selected one of the psnr_search calibration options, followed by the psnr model (NOT the psnr_vfd model, which also includes advanced variable frame delay estimation).

Therefore, you can reference the VQM numbers in outside reporting of performance as long as you:

1. Use the General, Fastlowbw, or PSNR Models, and
2. Reference the ANSI, ITU-T, or ITU-R standards referenced above, and
3. Do not mention NTIA/ITS.

10) Input and Output Arguments

CVQM performs automated processing on a pair of video files. One contains an original video sequence (e.g., straight from the camera) and the other contains a processed video sequence (e.g., after coding and transmission and decoding). All video sequences must be in uncompressed AVI files, in either the UYVY or RGB color space. Original and processed video sequences must contain the same image size, frames per second and scanning standard.

CVQM compares the original video sequence to the processed video sequence (i.e., the sequence that has been processed by the video system under test). Every original / processed video sequence pair is run through two main steps. First, the requested calibration is run, and results are saved in a file named after the processed video file, with '_calibration.txt' appended. Second, the requested model is run, and results are saved in a file named after the processed video file, with '_model.txt' appended.

Any errors that occur are recorded in a file named after the processed video file, with '_errors.txt' appended. If that file is absent, no errors occurred. Each line on this file will start with a number, indicating error type, and then a string describing the error. Type 1 errors are fatal data input/output issues (e.g., operation cannot continue due to invalid input argument, file read error, or file write error). Type 2 errors are calibration warnings (e.g., still sequence, temporal registration failure, spatial shift beyond search limits). Type 3 errors are non-fatal warnings.

Calibration Options:

The following calibration options are available:

'none' No calibration will be performed. Assume that the first frame in original and processed video files align temporally. Run model with default calibration values which assumes that the processed video file is perfectly calibrated.

'manual' Read the calibration file created on a previous run. The values on the beginning of each line may be manually modified.

'rrcal' Perform reduced reference calibration as given in ntia_tr_06_433a.pdf (except assume no spatial scaling). These algorithms use random processes, which may yield slightly different results from one run to another. It is highly recommended that rrcal results be median filtered across

7 or more different video sequences that have been sent through the same video system (see Calibration Note below).

'rrcalscale' Perform reduced reference calibration as given in ntia_tr_06_433a.pdf , including estimating spatial scaling (e.g., stretch). These algorithms use random processes, which may yield slightly different results from one run to another. It is highly recommended that rrcalscale results be median filtered across 7 or more different video sequences that have been sent through the same video system (see Calibration Note below).

'rrcal2' Improved version of 'rrcal' -- version 2, as specified in ITU-T Recommendation J.244 and ntia_tr_08_433b.pdf (see also 'rrcal2scale'). Includes estimate of Cb and Cr gain and offset; and slightly improved luminance gain & offset algorithm.

'rrcal2scale' Improved version of 'rrcalscale' -- version 2, as specified in ITU-T Recommendation J.244 and ntia_tr_08_433b.pdf (see also 'rrcal2'). Includes estimate of Cb and Cr gain and offset; and slightly improved luminance gain & offset algorithm.

'frcal' Perform full reference bandwidth calibration as given in ANSI T1.801.03-2003, ITU-T J.144 (03/04), and ITU-R BT.1683 (06/04). Preferably, results should be median filtered across several different video sequences that have been sent through the same video system (see Calibration Note below).

'frtime' Performs full reference temporal registration and valid region estimation as given in ANSI T1.801.03-2003, ITU-T J.144 (03/04), and ITU-R BT.1683 (06/04). No other calibration will be performed. Run model with default calibration values. Median filtering is not necessary. Suitable for video systems that are known to never shift, scale, or change the luminance levels.

'rrtime' Performs reduced reference temporal registration and valid region estimation only. No other calibration will be performed. Run model with default calibration values. Median filtering is not necessary. Suitable for video systems that are known to never shift, scale, or change the luminance levels.

'frtimemanual' Read the calibration file created on a previous run. The values on the beginning of each line may be manually modified. Then, ignore delay specification and perform full reference temporal registration as given in ANSI T1.801.03-2003, ITU-T J.144 (03/04), and ITU-R BT.1683 (06/04).

'rrtimemanual' Read the calibration file created on a previous run. The values on the beginning of each line may be manually modified. Then, ignore delay specification and perform reduced reference temporal registration from 'rrcal' and 'rrcal2'.

'psnr_search' Peak Signal to Noise Ratio (PSNR) exhaustive search based on ITU-T J.340, spatial search is +/- 3 pixels, temporal search is +/- 1 second.

'fast_psnr_search1' Reduced Reference Bandwidth Calibration Version 2.0 (ITU-T J.244), then PSNR exhaustive search based on ITU-T J.340 (spatial search is +/- 1 pixel, temporal search is +/- 0.5 seconds).

'fast_psnr_search2' Full Reference Bandwidth Calibration, (ANSI T1.801.03, ITU-T J.144), then PSNR exhaustive search based on ITU-T J.340 (spatial search is +/- 1 pixel, temporal search is +/- 0.5 seconds).

Calibration Search Ranges:

The following calibration search ranges are presumed for 'rrcal', 'rrcalscale', 'rrcal2', and 'rrcal2scale':

Maximum temporal registration uncertainty (1 second)

Maximum spatial shift search (+/- 4 pixels for QCIF, +/- 8 pixels for CIF, and +/- 20 pixels for NTSC & PAL & HDTV)

Maximum spatial scaling (6% for QCIF & CIF, 10% for NTSC & PAL & HDTV)

Calibration Note:

Increased calibration accuracy may be obtained by median filtering results over multiple video sequences. In this case, several video sequences must be run through the exact same system, with all system parameters held constant. Run with 'none' specified for the model, and examine all calibration results produced by these runs. The following values can be median filtered for increased accuracy: Horizontal Shift, Vertical Shift, Luminance Gain, Luminance Offset, Horizontal Scale, and Vertical Scale.

Median Filtering Example:

For each of the above, form a list of the values obtained from each video sequence (e.g., Horizontal Shift = [10 10 11 10 -13 10 9 10 17] -- notice the erroneous horizontal shift values of "-13" and "17"). Calculate the median value by sorting the values and returning the 50% percentile value (e.g., 10 in the previous example). Then, write that value to each processed video sequence's calibration file (e.g., "10 Horizontal Shift") on the correct line. If CVQM is then run with 'manual' specified for calibration, the median filtered calibration values will be used.

Model Options:

The following models options are available:

'none' No model will be calculated - run calibration only.

'general' NTIA General Model, as given in the ANSI T1.801.03-2003, ITU-T J.144 (03/04), and ITU-R BT.1683 (06/04).

'developers' Developer's model, a fast running variant of the General Model, described in ntia_tr_02_392.pdf

'lowbw' Low Bandwidth Model, described in vpqm_05.pdf

'fastlowbw' A fast variant of the low bandwidth model, as given in ITU-T J.249 (see ITUT_COM9_C5.pdf). The fast low bandwidth model differs from the low bandwidth model in the following ways: (1) Each second of video is averaged prior to calculating the spatial information features, (2) The temporal

information features utilize only the luminance image, and (3) The temporal information features use a sub-sampling of pixels rather than the entire image.

'psnr'   Peak Signal to Noise Ratio (PSNR).

'psnr_vfd' Peak Signal to Noise Ratio (PSNR) with variable frame delay (VFD) processing. This model option will recalculate gain and level offset after the VFD correction and the calibration file will be updated accordingly.

'vqm_vfd' Neural Network (NN) based VQM with variable frame delay (VFD) processing.

11) Validation

To validate CVQM, run on the provided video sequences with the following command line:

```
cvqm 'original.avi' 'processed.avi' 'progressive' 'none' 'lowbw'
```

Calibration values will be written file 'processed.avi_calibration.txt' as shown below:

```
none
    0  Horizontal Shift
    0  Vertical Shift
    1  Valid Region Top
    1  Valid Region Left
  144  Valid Region Bottom
  176  Valid Region Right
1.000 Luminance Gain
0.000 Luminance Offset
 1000  Horizontal Scale
 1000  Vertical Scale
    0  Temporal Delay
```

Model values will be written to file 'processed.avi_model.txt' as shown below:

```
0.180958 lowbw
0.002595 hv_loss
0.000000 hv_gain
0.008355 si_loss
0.000000 si_gain
0.169484 color_comb
0.000000 noise
0.000508 error
0.000000 vshift
0.000000 hshift
```

12) Frequently Asked Questions (FAQ)

Question: “Which calibration option should I choose?”

Answer: If you do not know anything about your codec's calibration, here are our suggestions. Run CVQM twice: once with 'rrcalscale2' and once with 'frcal'. Both of these calibration options check everything. 'frcal' is more accurate but does not check for spatial scaling. 'rrcalscale2' will check whether or not your codec is spatially scaling the video.

Remember to save the first output file before you run the second time; CVQM will overwrite the previous results.

Question: "CVQM seems to be doing something but I do not see any results."

Answer: CVQM does not print results to the screen. Output values are written to files. See #10 above.

Question: "Where can I find source video sequences?"

Answer: See the Consumer Digital Video Library (www.cdvl.org). Registered CDVL users have access to high quality uncompressed video scenes that may be used freely for research and development purposes. Users may also contribute their videos to the CDVL database.

Question: "Which model should I choose?"

Answer: Depending on the user's needs, there are several possible recommendations.

The General Model, the Fastlowbw Model, and PSNR were validated by the Video Quality Experts Group (VQEG) and then standardized by the ITU. See #9 above for information on how to run those models in compliance with those Recommendations. This gives legitimacy and credence to your results.

Model VQM_VFD was completed in 2011. Based on ITS training and testing data, VQM_VFD is the most accurate model provided by CVQM. VQM_VFD includes a neural network that achieves 0.9 correlation to subjective quality for subjective datasets at image resolutions from QCIF to HDTV. VQM_VFD was trained on transmission errors. However, this model has not yet been independently validated.

PSNR is a model with wide industry acceptance. PSNR is very sensitivity to calibration errors. If you want to use PSNR on video that may contain a reduced frame rate or variable frame delay and you want this effect removed before PSNR is calculated, we recommend 'psnr_vfd'. PSNR is less accurate than the General Model and the Fastlowbw Model for most applications.

Question: "How do I run the CVQM source code from the MATLAB command line?"

Answer: There is one differences when running CVQM from the MATLAB command line. Arguments on the command line must be surrounded by three (3) single quotes in a

row. Do not use double quotes (“). For example, the validation from #11 becomes:

```
cvqm '''original.avi''' '''processed.avi''' '''progressive''' '''none''' '''lowbw'''
```