Video Error Level Analysis

ABSTRACT
It is increasingly easy to add objects into pre-existing videos, and have those objects correctly interact with the scene's lighting and other objects. Such manipulations can be impossible to detect upon a visual inspection, and previously manipulated videos may have already been given legitimacy by news agencies and the courts. Video Error Level Analysis (VELA) can help the trier of fact identify video content cropping, addition, relocation and alteration.

TARGET AUDIENCE: Video Analysts, Video Technicians

KEYWORDS: Video, Authentication, Detection

LEARNING OBJECTIVES:
1. Document the originality and authenticity of a video recording
2. Identify and quantify video content manipulation
3. Detect and verify video cropping

PROGRAM LEVEL: Advanced

PREREQUISITES: Basic understanding of video

ADVANCED PREPARATION: None

INTRODUCTION
Video content manipulation can be extremely difficult to detect through a visual inspection. One solution is to use specialized software tool to highlight video content alterations. This type of video analysis would also be effective at detecting video cropping. Originally suggested by Dr. Neal Krawetz at the 2007 Black Hat conference in Las Vegas, it was never developed into a forensic tool. That tool is fully developed in this paper.

BASIC PREMIS

Compression and decompression (CoDec) instructions guide a computer on how to store and reconstruct a compacted video. Modern video CoDecs conserve considerable file space by suppressing high-frequency data (pixels with high color or illumination contrast to adjacent pixels) and reducing color details (e.g. merging nearly identical shades of red) in ways that are designed to be minimally perceptive to the human eye (*http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3232547/*). These degradations are performed using quantization tables defined by the standards for each CoDec.

Because the changes are lossy, they result in data errors even in the absence of any intentional editing or content changes. Each successive lossy resave further deviates the video from its original version, but by decreasing amounts. After a nearly infinite number of such compressions, the minimal error level will be reached and the video may appear as a homogeneous blur.

If an object is added to, or relocated within, an already compressed video, it will be at the earlier stages of this process. When an altered video is compressed into a lossy format, the recent viewable manipulations will incur greater quantization changes than the remainder of the video content. These data errors are visually represented as video defects including muted contrast in both color and illumination.

Because any post-production content alterations will have undergone fewer compressions, the pixels located at the points of video alteration will incur greater defects than the remaining pixels. When a test video is compressed in a lossy CoDec, the ensuing defects can be visualized by subtracting the re-compressed video from the video version used to perform that compression. In this way, we can visually analyze the level of video data errors.

The differences between the two video versions can be saved as a results video for later analysis and distribution. Since the video size and duration are not being altered, the results will correspond to the test video. This type of testing is called Video Error Level Analysis (VELA).

Successful VELA requires the test video to have been saved in a lossy CoDec prior to being manipulated. This is a reasonable assumption since nearly all videos are transmitted and shared in lossy formats to reduce their file size. Furthermore, the test video must viewable using the computer’s video player, without requiring special software, so that it can be resaved under the controlled conditions of VELA testing.

INTERPRETATION

If VELA recompression of a test video does not cause new quantization data errors, then the results video will be completely black, regardless of the original video scene. This can only occur after dozens recompressions, thus rendering the video absent of most definable details and nearly useless.

If differences exist between the two video versions, the results video will only display those differences. These differences will appear as visible pixels residing in the exact same frame number and coordinates as where the potential video manipulation exists on the test video.

Brightness depicted within the VELA results video will proportionally denote quantization errors caused by the last lossy compression. Areas of the test video displaying the greatest contrast are expected to incur the largest data errors, and are expected to be the most visible within the results video. If portions of the results video are disproportionally bright and/or colored, when compared to other areas of similar contrast within the test video, then those areas of the test video have the highest probability of being manipulated content.

Once a suspected area of video manipulation has been detected, the colors seen in the VELA results can provide clues as to which software was used to manipulate the test video. Currently, insufficient test data exists to accurately correlate VELA color patterns to specific brands of video editing software.

With video manipulation, the presumption is that an object will be added to a video (e.g. a person or weapon is added to a scene to falsify evidence). Even when an object is removed, it is actually replaced with other pixels, often presumed background details. This process is called in-painting and is common in Hollywood films to change buildings or skylines. However, the manipulation may be as simple as cropping the video to exclude evidence.

Pixels at the perimeter of the video always have fewer adjacent pixels than those located elsewhere. If the test video was cropped in post-production, the quantization errors and motion vectors of the perimeter pixels may be disproportionally affected during the lossy resave of VELA testing. VELA testing can visually display those variances as noticeably brighter lines traversing the perimeter of the newly cropped borders.

VELA can also detect the manipulation of moving objects by exploiting the fact that most modern video CoDecs reduce file size by recognizing moving pixel patterns, and then assigning motion vectors to predict where these non-stationary pixels are to be located in adjacent video frames. These “predictive motion vectors” reduce the CoDec’s need to resave the same pixel pattern for each video frame, which results in smaller file sizes without sacrificing accuracy.

Whether the apparent motion results from a moving object within the camera’s field of view, or a stationary object captured by a camera in motion, predictive motion vectors can be assigned to the group of pixels depicting that object. The faster an object moves across the field of view between adjacent frames, the lower the CoDec’s pixel relationship for the moving object between those frames. Thus, fast motion results in fewer quantization data errors for the object, and reduces the effectiveness of VELA testing.

For example, if two similar objects appear to be traveling across a high contrast scene at different speeds, the faster object may appear brighter in the VELA results video and be interpreted as a false positive. To avoid this, consider an object’s speed when determining if it is a post-production alteration. As VELA testing becomes common place in testing software, threshold settings will help the operator discern between native video scene objects and post-production manipulations.

Nearly all videos representing our three dimensional world are retained as a two dimension recording. As one object within the view of the capturing camera is obscured by another object that is closer, some of the visual characteristics of the background object will be absent in the saved video recording. The motion vectors associated with the background object become disrupted, and different motion vectors are created for the newly merged objects while they overlap on screen. During this interaction, if only one of the objects is an after-the-fact video modification, then the VELA results will become inconsistent until both objects become visually independent again.

Because object speed and overlap can negatively impact VELA testing, VELA results should be taken as advisory and not considered to be an absolute legal assertion.

VELA CODECS

CoDecs based upon the h.264 standard incorporate both quantization and predictive motion vectors. They also segment the video into standardized pixel blocks called “slices”. Each slice is compressed with minimal reference to the adjacent pixels of the neighboring slice. This can cause the motion vectors at the slice boundaries to misalign, and for the boundaries between slices to contain disproportionally high contrast and color shifts. Visually, this is referred to as blockiness, and repeated h.264

compression will severely inhibit any test for manipulated video content, including VELA.

VELA testing relies upon lossy compression that lacks slices, but includes data quantization tables and predictive motion vectors. One class of VELA compatible CoDecs are those that follow the h.263 standard. DIVX is a popular commercially licensed h.263 CoDec and XVID (DIVX spelled backwards) is a popular free open-source alternative. Both DIVX and XVID can be configured to use a specific quantizer, and testing has shown a value of 8 to be a reasonable initial value for the most visual VELA results.

DO-IT-YOURSELF VELA

Begin with a test video named "BEFORE", and then resave it with the name “AFTER” using a h.263 CoDec set to a quantizer value of 8. Subtract the AFTER video from the BEFORE video, and the difference represents the VELA results. This test can be performed in seconds on a Windows™ PC using these free open source tools:
VirtualDub(http://virtualdub.sourceforge.net/)
AVISynth(http://sourceforge.net/projects/avisynth2/)
XVID(http://xvid.org/Downloads.15.0.html)

1. Install the free VirtualDub, AVIsynth, XVID programs.
2. Run VirtualDub and <u>Open</u> (under the FILE menu) a video named "BEFORE.avi".
3. Under the VirtualDub VIDEO menu, set <u>compression</u> to XVID and use the "configure" button to set the quantizer to 8.
4. Use the VirtualDub <u>Save</u> command, located under the FILE menu, to save this new video with the name "AFTER.avi".
5. Create a new text file named “TEST.avs” with the following five tines of text:

```
BEFORE=directshowsource("BEFORE.avi")
AFTER=directshowsource("AFTER.avi")
Overlay(BEFORE,AFTER,mode="Subtract")
Levels(0,5,100,0,255)  # this step amplifies the luminosity of the results
stackhorizontal(BEFORE,last)
```

6. Right mouse click to open this file with VirtualDub, and then save the resulting video as "RESULTS.avi”.

FILES

A test video is available at (http://ForensicProtection.com/VELA.html). That test video displays three moving company logos and was manipulated by adding a fourth moving logo during post-production. As the four logos move across the screen, the after-the-fact logo periodically overlaps the native logos. This interaction stresses the VELA testing and was intentionally encouraged to demonstrate the power of VELA, even under a harsh scenario.

CONCLUSION

The interaction of stationary and moving objects, differentiates VELA from image Error Level Analysis (aka ELA). These differences, and the ability to examine multiple moments in time, empower VELA to detect content manipulations that are undetectable to ELA testing of a single video still. Nearly any post-production scene change becomes obvious under VELA testing, even when such manipulations are impossible to detect by watching the video. With Video Error Level Analysis you gain the power to identify and document video cropping as well as the addition, relocation or alteration of a depicted object, person, vehicle or text.

WEB LINKS

http://www.blackhat.com/html/bh-usa-07/bh-usa-07-speakers.html#Krawetz

TEST YOURSELF (ANSWERS LISTED ON THE NEXT PAGE)

1. Video Error Level Analysis (VELA) works exactly the same as image based ELA:
   A. True
   B. False

2. To maximize results, VELA tests must be based upon the use of:
   A. Lossless compression to preserve details
   B. Any modern CoDec
   C. A lossy CoDec that uses motion vectors without slices
   D. Free software

3. VELA testing is least effective when the altered object(s) in the test video:
   A. Move several pixels between frames
   B. Appear to drift one pixel between frames
   C. Remain stationary for several frames
   D. Are a solid color

4. VELA testing can only be applied to:
   A. Black and white videos
   B. Color videos
   C. Videos created by video surveillance equipment
   D. Videos that can be viewed without proprietary software

5. VELA testing can detect:
   A. Which borders of the test video have been cropped
   B. Which objects of the test video have been added in post-production
   C. Both choices A and B
   D. None of the above

6. The resulting VELA video will typically have a _________ than the test video:
   A. Brighter background
   B. Darker background
   C. Lower resolution
   D. Higher resolution

7. VELA testing requires:
   A. Seconds
   B. Hours
   C. Multiple computers
   D. Years of training

ANSWERS LISTED ON THE NEXT PAGE

ANSWER KEY

1. B
2. C
3. A
4. D
5. C
6. B
7. A

Doug Carner is a forensic multimedia analyst, president of Forensic Protection, and actively donates his time as an industry innovator and educator. He has processed evidence in over a thousand cases worldwide, including the George Zimmerman and Mathew Clark cases. His work has been accepted by courts worldwide, featured in legal and trade publications, and broadcast upon radio and syndicated television.