From the military to first responders, law enforcement, and security, the ability to transmit high-quality, full-motion video is fast becoming essential. As demand for sharing, downloading, and storing airborne and ground video booms, system designers are hungry for any technology that reduces the required bandwidth, especially on the transmission side. Electronic image stabilization (EIS) is just such a technology. By improving compression efficiency, EIS has the potential to deliver:

- more channels of video in a given bandwidth,
- more video frames per second at a given bandwidth,
- higher video resolution at a given bandwidth, or
- higher picture quality at a given frame rate, resolution, and bandwidth.

We set out to quantify the efficiency gains made possible by current real-time embedded processors.
Electronic image stabilization is primarily designed to correct shaky video, which may be unavoidable when using mobile and pole-mounted cameras. Camera shake is made even worse by the telephoto lenses often required in law enforcement, security, and situational awareness. Cleverly applied, EIS can make it substantially easier to interpret threats, recognize friendlies, read important identifiers such as license plates, and perform mission-critical automated image analysis. Less widely appreciated is the ability of stabilization to increase the efficiency of digital video compression.

EIS processing can be done in computer software or dedicated hardware. SRI Sarnoff manufactures dedicated embedded hardware platforms with optimized stabilization algorithms and H.264 encoding. During stabilization, these platforms compare sequential frames of video and shift each frame to provide a highly stable output. System designers typically feed the stabilized video to a recorder, to a monitor for live viewing by an attendant, or to other image processing applications such as motion detection, object tracking, mosaics, and geo-registration. EIS is particularly important in motion detection and object tracking, because camera motion must be separated from object motion. The frame-to-frame changes computed by EIS (chiefly motion estimation and affine transformation) also provide essential information for building mosaic images.

Stabilization has the ability to increase the efficiency of digital video compression.
To appreciate the effect of EIS on video compression, it helps to review the concepts behind the widely used H.264 compression systems. These systems take advantage of spatial redundancy (the similarity between one pixel of blue sky and the adjacent pixel) and temporal redundancy (the similarity between one frame of video and the following frame). For this reason, compression encoders compare frame-to-frame differences. The systems perform motion estimation to determine what parts of a picture have changed. Rather than transmit the entire frame each time, the system can transmit a “difference” or “inter-coded” frame representing the changes only. On the receiving end, the difference frame is added to the previous complete frame to reconstruct the desired image. Clearly, this type of compression is most efficient when frame-to-frame changes are at a minimum.

Shaky video bloats the difference frames, filling them up with random frame-to-frame motion that must be dutifully computed, coded, and transmitted because the encoder doesn’t know any better. For a given quality level, shaky video causes a noticeable increase in the required bit rate. The shakier the video, the more random the frame-to-frame motion, the bigger impact it will have on video compression. Good, clean, stable video enables better compression than poor, noisy, shaky video.

To quantify the effect of high-quality EIS on video compression, we compressed a wide variety of shaky video content using a recent version of the open-source ffmpeg software encoder. We tested visible light and infrared (IR) content. Table 1 shows the key settings used. We captured shaky video content and either compressed directly with the settings indicated in Table 1 or stabilized first using the ILS-6000 stabilizer and then compressed using identical settings.
To make the comparison as fair as possible, we disabled the encoder rate control and used constant quantization instead. This is similar to the approach used by the committee developing compression standards to evaluate the performance of new tools proposed for inclusion in the standard\(^1\). Two group of pictures (GOP) sizes were tested to evaluate coding structures commonly chosen for greater error resilience/faster recovery time (GOP = 10) or greater coding efficiency (GOP = 30).

The shaky and the stabilized video clips under test are degraded in exactly the same way (by fixing the so-called quantization parameter, or QP, and all other encoding parameters). As a result, the video quality for both clips is identical (corresponding to the same QP and other coding parameters for a given video clip, except for stabilization). We then measure the resulting bit rate for shaky and stabilized video clips and compute the difference.

EIS: Identical encoding parameters yield 10% to 70% lower bit rate

Under these conditions, the measured bit rate of the compressed stabilized video was 10 to 70 percent lower than that of the compressed shaky video. It’s a substantial gain in compression efficiency, a “budget” ready to be spent as additional transmission channels, additional frames per second, or additional resolution, as quantified in Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before EIS, typical performance</th>
<th>After EIS (30% nominal increase in efficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channels of standard-definition video (8 Mbps total bandwidth, TCDL with error correction)</td>
<td>4 channels</td>
<td>5 channels</td>
</tr>
<tr>
<td>Frame rate (1 Mbps channel, e.g., DSL)</td>
<td>15 frames per second</td>
<td>30 frames per second</td>
</tr>
<tr>
<td>Video resolution (at 30 fps, over a 500 kbps channel, e.g., cellular network)</td>
<td>320 H x 240 V</td>
<td>720 H x 480 V</td>
</tr>
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</table>
System designers may also choose to devote the increased efficiency toward better picture quality at the existing bandwidth, frame rate and video resolution. Figure 2 shows a sample decoded frame for the original shaky video and the same frame for the stabilized video sequence. Both the original video and the stabilized video were encoded at 1.3 Mbps, with the actual bit rate difference of less than 3 percent. Notice the loss of detail and the blocky compression artifacts visible in the decoded frame for the original shaky video. The stabilized video is noticeably cleaner and sharper.

Clearly, EIS can render a profound improvement in digital compression efficiency. It’s an improvement that can provide more transmission channels, higher frame rates, higher resolution, or plain old better picture quality. It’s a difference that promises to prove vital to applications as diverse as military, law enforcement, and general video surveillance. And it’s a benefit that comes on top of all the traditional advantages of stabilized video: the enhanced ability to read signs or license plates, recognize people, and otherwise interpret a video picture.
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