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Compression Algorithm Analysis of *In-Situ* (S)TEM Video: Towards Automatic Event Detection and Characterization

Jeremy R. Teuton[1], Richard L. Griswold[2], B. Layla Mehdi[1] and Nigel D.Browning[1]

[1.] Fundamental and Computational Sciences, Pacific Northwest National Laboratory, Richland, WA 99352, USA
[2.] National Security Division, Pacific Northwest National Laboratory, Richland, WA 99352, USA

Precise analysis of both (S)TEM images and video are time and labor intensive processes. As an example, determining when crystal growth and shrinkage occurs during the dynamic process of Li dendrite deposition and stripping involves manually scanning through each frame in the video to extract a specific set of frames/images. For large numbers of images, this process can be very time consuming, so a fast and accurate automated method is desirable. Given this need, we developed software that uses analysis of video compression statistics for detecting and characterizing events in large data sets. This software works by converting the data into a series of images which it compresses into an MPEG-2 video using the open source "avconv" utility [1]. The software does not use the video itself, but rather analyzes the video statistics from the first pass of the video encoding that avconv records in the log file. This file contains statistics for each frame of the video including the frame quality, intra-texture and predicted texture bits, forward and backward motion vector resolution, among others. Avconv records 15 statistics for each frame. By combining different statistics, we have been able to detect events in various types of data. We have developed an interactive tool for exploring the data and the statistics that aids the analyst in selecting useful statistics for each analysis. Going forward, an algorithm for detecting and possibly describing events automatically can be written based on statistic(s) for each data type.

Next, we applied this process to the series of (S)TEM images and videos from an *in-situ* liquid electrochemical stage for (scanning) transmission electron microscopes (*in-situ* liquid ec-(S)TEM) demonstrating dynamic changes at the Pt working electrode surface during Li dendrite growth and dissolution process in liquid $LiPF_6$ in PC electrolyte used in state-of-the-art Li-ion battery systems [2]. The electrochemical stability of electrolytes in the new generation of high energy densities Li-ion batteries is disturbed by both the oxidizing nature of the cathode and reducing nature of the anode, resulting often in the accumulation of insulating side products (thick insulating layer or crystal growth on the anode/cathode surface) which leads to capacity fading. After selecting the appropriate statistics, we were able to identify distinct changes such as the beginning of the crystals growth at the Pt surface, plateau of growth, and/or shrinking. Comparing our first pass algorithm to manually scoring the data, our algorithm typically found the events within ±13 frames of the actual event. In one data set where the algorithm detected crystal growth much earlier than the human analyst (21 frames early), further investigation showed that the human analyst had missed the actual start of the crystal growth, due to the very subtle changes not readily apparent to the human eye. With further optimization on a larger data set, we hope to improve the identification accuracy of dynamic changes during electrochemical processes at the electrolyte/electrode interface during *in-situ* liquid ec-(S)TEM measurements, which would enhance time consuming video analysis and potentially replace traditional time and effort intensive techniques [3].

References:
[1] Libav team, “Libav: Open source audio and video processing tools”, libav.org
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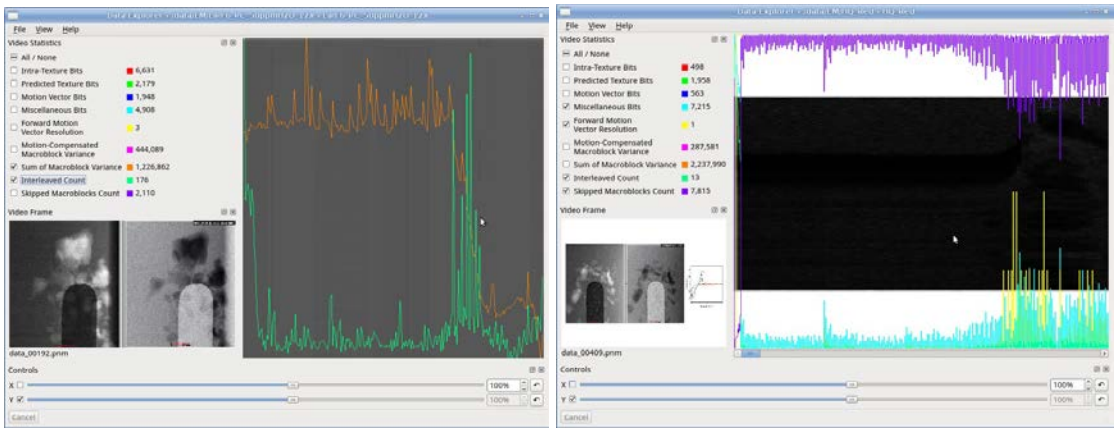

Figure 1. Interactive data explorer tool, showing selected statistics from two different data sets.

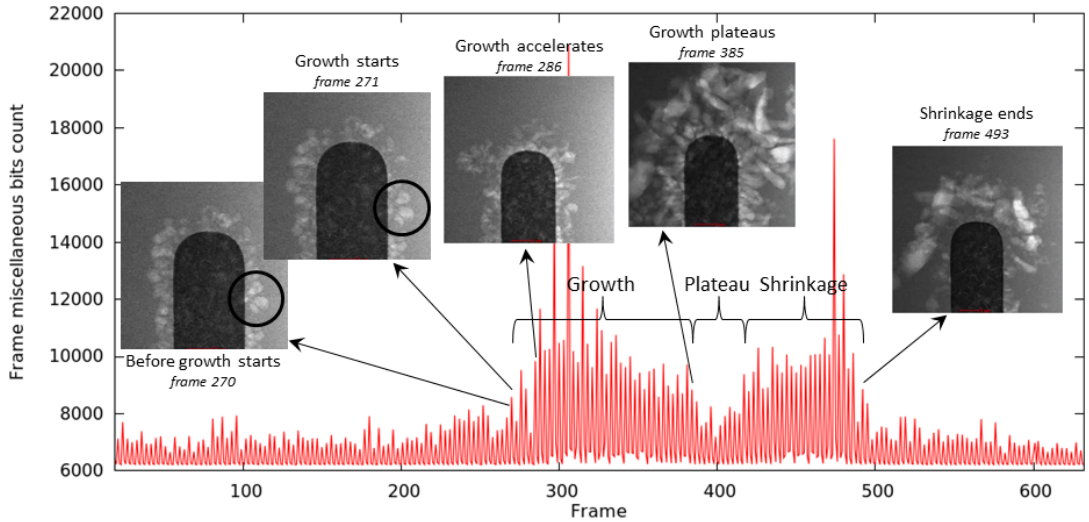

Figure 2. Annotated plot of the Miscellaneous Bits video compression statistic

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