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
[3] Research described in this paper is part of the Analysis in Motion Initiative at Pacific Northwest National Laboratory and was conducted under the Laboratory Directed Research and Development Program at PNNL. In-situ TEM work was primarily supported by Joint Center for Energy Storage Research (JCESR), an Energy Innovation Hub funded by the Department of Energy, Office of Science, Basic Energy Sciences. The development of the operando stage was supported by the Chemical Imaging Initiative, a Laboratory Directed Research and Development Program at Pacific Northwest National Laboratory (PNNL). PNNL is a multi-program national laboratory operated by Battelle for the U.S. Department of Energy (DOE) under Contract DE-AC05-76RL01830. A portion of the research was performed using EMSL, a national scientific user facility sponsored by the Department of Energy’s Office of Biological and Environmental Research and located at PNNL.

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