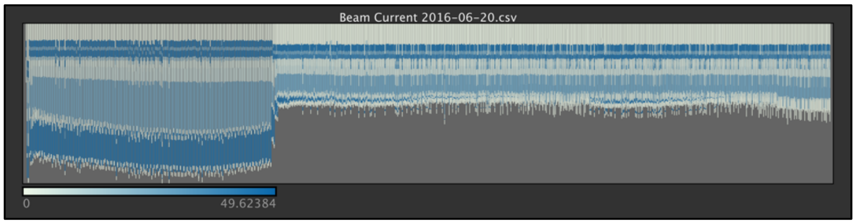
Advancing Additive Manufacturing Through Visual Data Science

Chad A. Steed, Ryan Dehoff, William Halsey, Sean Yoder, Vincent Paquit, and Sarah Powers
Oak Ridge National Laboratory, Oak Ridge, TN

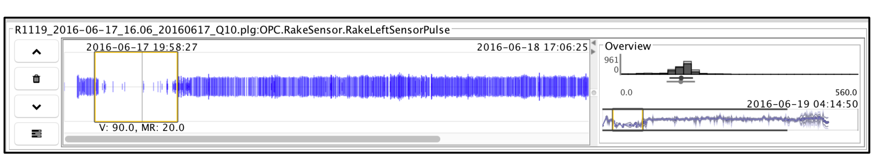


As advances in large-scale 3D printing spark revolutionary ideas in additive manufacturing, visual data science is adding fuel to the fire. With 3D printing, machines synthesize objects layer-by-layer using a variety of materials, such as metal powder, and printing techniques, such as electron beam melting. Technological leaps in this field have given designers an unprecedented degree of geometrical freedom for building complex objects with minimal waste material. Researchers at the Oak Ridge National Laboratory (ORNL) Manufacturing Demonstration Facility (MDF) are at the forefront of this field, contributing new knowledge and creating unique assemblies of 3D printed objects, such as a replica of the 1965 Shelby Cobra sports car shown above. Although the resulting artifacts draw most of the attention, the key to realizing the full potential of large-scale 3D printers lies in acquiring a deep understanding of the printing process—a challenging goal that hinges on the availability of visual data science tools.

In light of this aim, additive manufacturing researchers at the ORNL MDF have partnered with visual analytics researchers to develop new tools that allow interactive hypothesis formulation and confirmation at multiple levels of detail. Freeform investigative techniques are required as the questions that researchers typically ask of their data are too exploratory for a completely automated solution. Furthermore, the scale and complexity of the system log data exceed the capabilities of most general purpose data analysis environments. Indeed, MDF researchers often say their data contain "a zillion data points" as the log files generated from a single build usually contain time series that are hypervariate (thousands of variables), long (many hours over multiple days), fine-grained (sub-second accuracy), large (millions of data values), and irregularly sampled.

Drawing from the expertise of our interdisciplinary team, we are building a new visual analytics system, called Falcon. Falcon offers a variety of linked visualizations that are designed to enable both the discovery and deep examination of patterns hidden within 3D printer log files at multiple scales. One such view, which is shown in the figure above, is the waterfall visualization. This unique visualization segments the entire time series for a variable of interest according to the build layer height. Each vertical line represents a build layer, and the values of the variable are encoded in the color of the line. The layer start times determine the line positions along the x-axis and the lines are aligned along the top. This technique emphasizes the relative time required to print each layer and reveals variations in the main stages performed within each layer. In the figure above, it is clear that the first third of the build (the left side of the plot that corresponds to the bottom of the printed objects) requires more melt time, which translates to more melt area and/or geometric complexity, than the remainder of the build. The visualization gives researchers a unique perspective of a build by showing both broad trends (macro readings) and intricate details (micro readings) in miniature form.

In this talk, we will present the waterfall visualization and other interactive data visualization techniques, like the spectrum plot below, that are available in the Falcon system. We will emphasize examples involving real data analysis scenarios with additive manufacturing experts to highlight some of the discoveries that Falcon has enabled researchers to find. All of these discoveries have helped the researchers develop a more thorough understanding of their data, and many have led to fundamental improvements in the quality and efficiency of the 3D printing process.



Abstract Summary (less than 150 words)

As advances in large-scale 3D printing spark revolutionary ideas in additive manufacturing, visual data science is adding fuel to the fire. Technological leaps in this field have given designers an unprecedented degree of geometrical freedom for building complex objects with minimal waste material. The key to realizing the full potential of large-scale 3D printers lies in acquiring a deep understanding of the printing process using a visual data science approach. To this end, additive manufacturing researchers at the Oak Ridge National Laboratory Manufacturing Demonstration Facility have teamed with visual analytics researchers to develop a new visual analytics system, called Falcon, that allows interactive, multi-scale hypothesis formulation and confirmation for 3D printer log files. In this talk, we will present the interactive data visualization techniques in the Falcon system with an emphasis on examples involving real data analysis scenarios with additive manufacturing experts.

Speaker Bio (less than 150 words)

Dr. Chad A. Steed is a Senior Researcher in the Computational Data Analytics Group at the Oak Ridge National Laboratory (ORNL) and he holds a Joint Faculty Appointment with the University of Tennessee's Electrical Engineering and Computer Science Department. He received the Ph.D. degree in Computer Science from Mississippi State University, where he studied visualization and computer graphics. His research spans the life cycle of data science including interactive data visualization, data mining, human-computer interaction, visual perception, databases, and graphical design. Dr. Steed's work is currently focused on designing systems that combine automated analytics with interactive data visualizations to enhance human exploration and comprehension of complex data. He is the recipient of the 2014 UT-Battelle Early Career Researcher Award, a 2014 ORNL Technology Commercialization Award, a 2013 R&D 100 Award, and a 2013 ORNL Technology Commercialization Award.

Speaker Picture (150 pixels wide and up to 250 pixels tall)