# Segmented Time Series Visualization Tool for Additive Manufacturing

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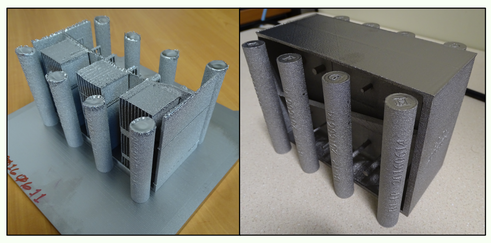
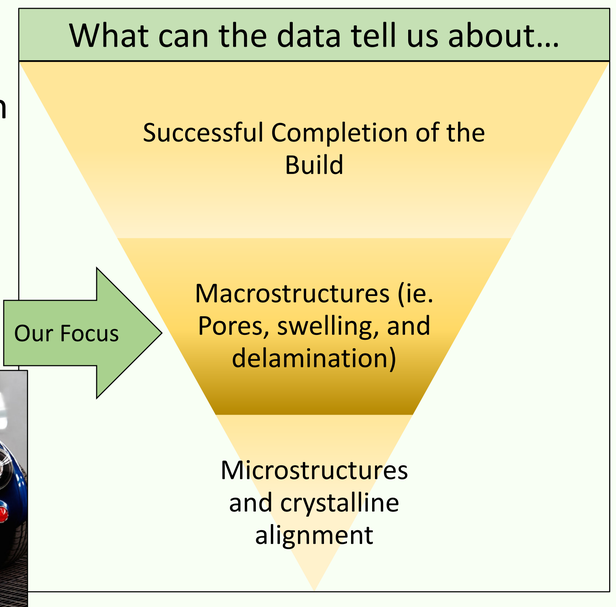
## Objective

The objective of this tool is to provide a means of visualizing heterogeneous data, in the form of near IR images and 3D print log data, for the furtherance of understanding process parameters and their effect on the final quality of printed parts.

## Motivation and Background

- Develop a better understanding of what causes structural flaws in 3D printed parts using only log data (on three different levels)
- Single build has thousands of printed layers and can last for days
- Thousands of variables are recorded asynchronously
- Heterogeneous data types: numerical, categorical, boolean
- Eventually, discovered relationships could be used to predict the success of a build in situ



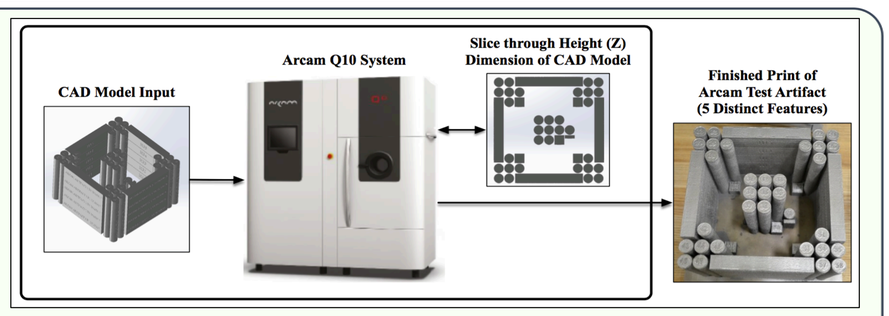


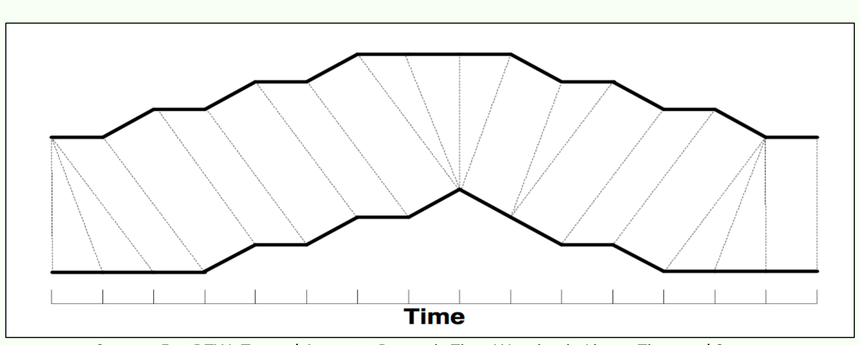

## Qualitative Visual Analytics

- Allow for visual comparison between layers
- Leverage human ability to detect patterns
- Proximal layers can be directly compared
- Distant layers can be compared by choosing a reference segment's time series plot and overlaying the selected plot over the other segments
- Image panel allows for visual correlation between occurrence of undesirable physical macrostructures and sensor data

## Quantitative Time Series Analytics

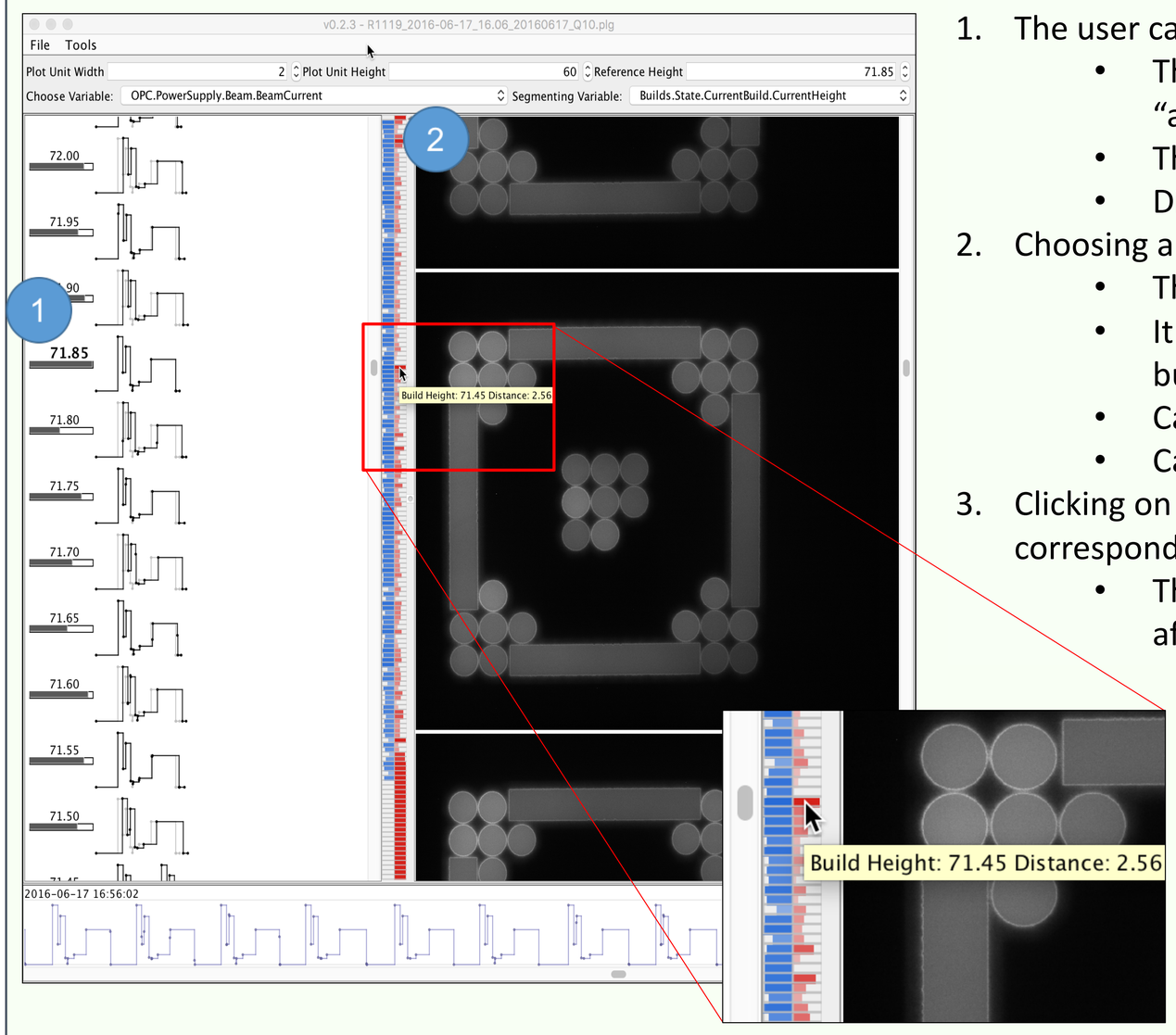
- Fast Dynamic Time Warping (DTW) employed to calculate distance metric
- DTW chosen because it can calculate a distance for time series of different lengths and numbers of data points
- Distance is calculated between every time series segment in the build and the reference segment chosen by the user
- This metric is integrated into the visualization in order to assist with anomaly detection as graphical indicators (see callouts 1, 2, and 3 below)



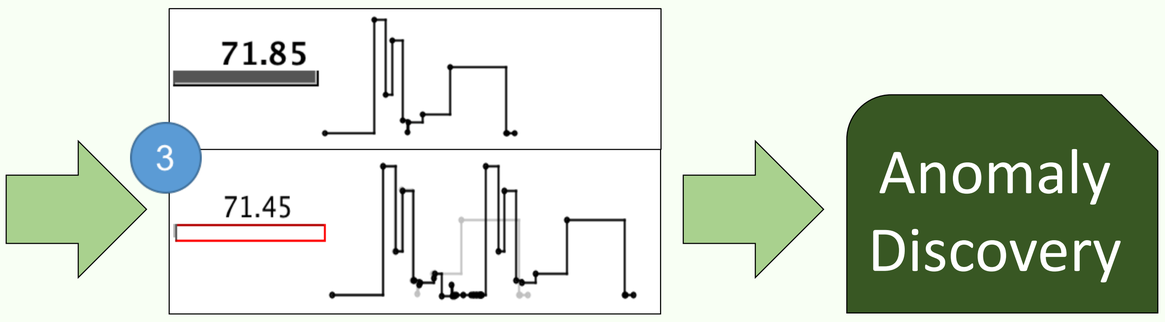




Source: *FastDTW: Toward Accurate Dynamic Time Warping in Linear Time and Space.*

## Employing the Visualization for Anomaly Discovery




1. The user can choose a reference segment that will facilitate knowledge discovery
   - The reference segment can be one that the user deems is "typical" or "anomalous"
   - The reference segment will be visually overlaid on all other segments
   - Distances between each segment and the reference segment are calculated
2. Choosing a reference segment will activate the distance indicator panel
   - This panel shows a summary of the entire build
   - It displays where significantly similar and different segments exist within the build for further investigation
   - Can indicate areas of the build where the geometry is different
   - Can also indicate where anomalous segments occur in the build
3. Clicking on an interesting tick mark in the distance indicator panel pulls the corresponding time series segment into main panel
   - The user can then observe the layer images around the anomaly to see if it affected structural properties of the build

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## References

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[2] S. Salvador and P. Chan, "Fastdtw: Toward Accurate Dynamic Time Warping in Linear Time and Space," in Proceedings of the ACM KDD Workshop on Mining Temporal and Sequential Data, 2004, pp. 70 – 80.

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