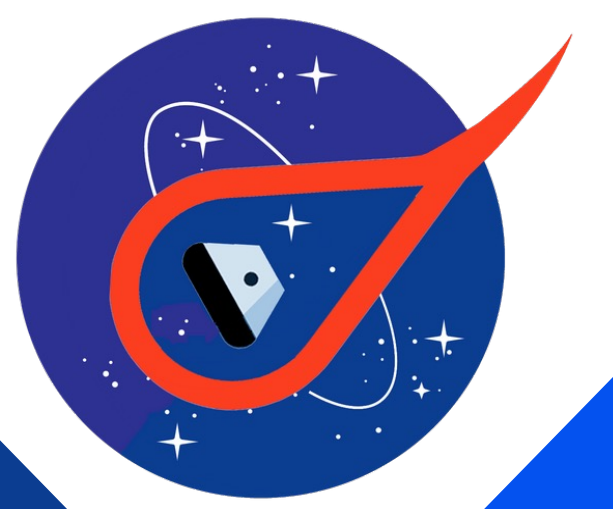


arcjetCV: automating recession tracking

Magnus A. Haw¹, Alexandre M. Quintart^{2,3}

¹NASA Ames Research Center ²Flying Squirrel ³Analytical Mechanics Associates Inc.



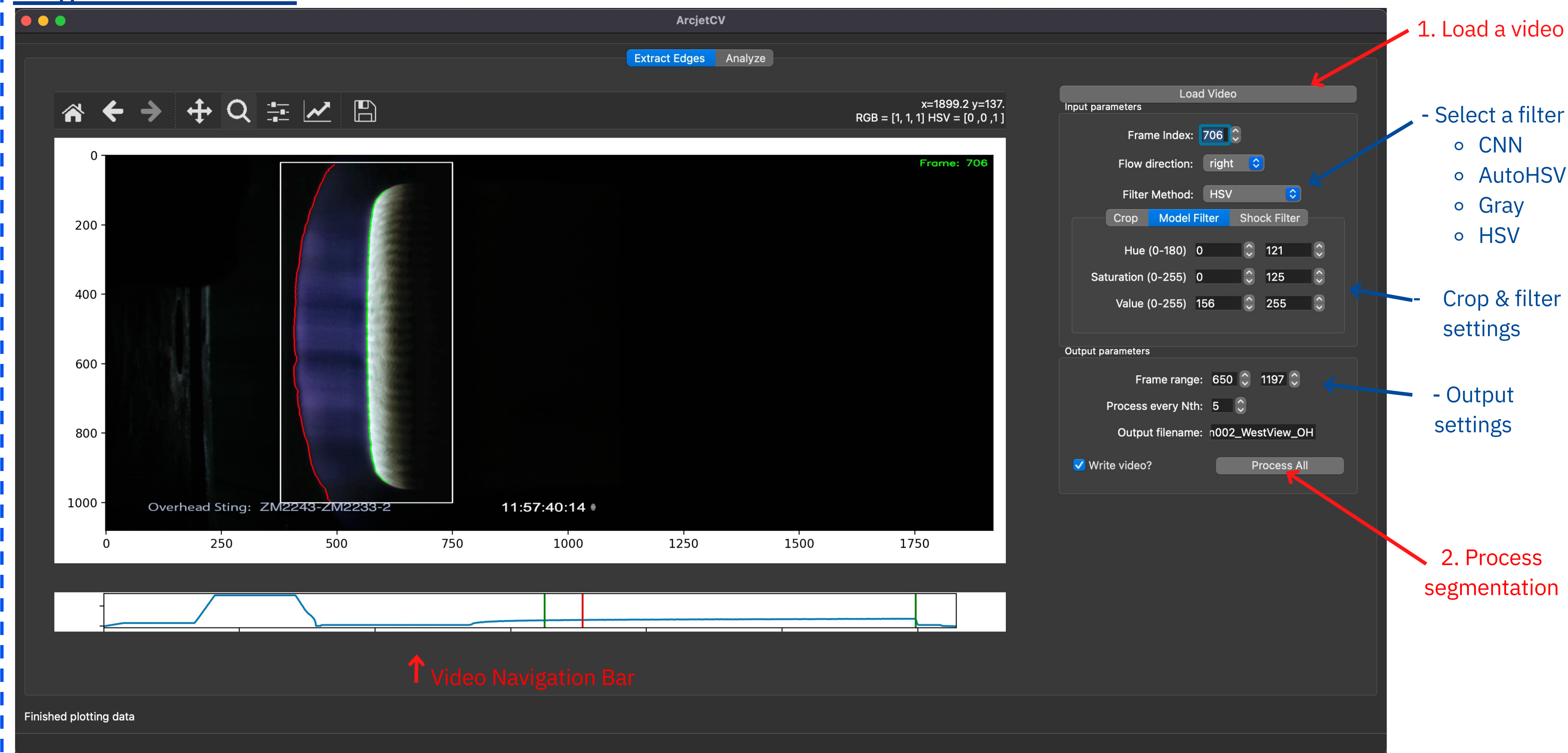
Abstract

arcjetCV is a software application that automates time-resolved recession tracking in test videos, specifically for material recession and shock-material standoff analysis. This tool enables the resolution and validation of new physics associated with non-linear processes, reducing uncertainties in heatshield material performance testing, modeling, and validation. arcjetCV employs machine learning techniques, including 1D CNN for segment inference, 2D CNN and DT for recession measurement, and KM for data cleaning. The software also offers a user-friendly graphical interface. Application to arc jet videos reveals insights into non-linear time-dependent effects and material failure modes.

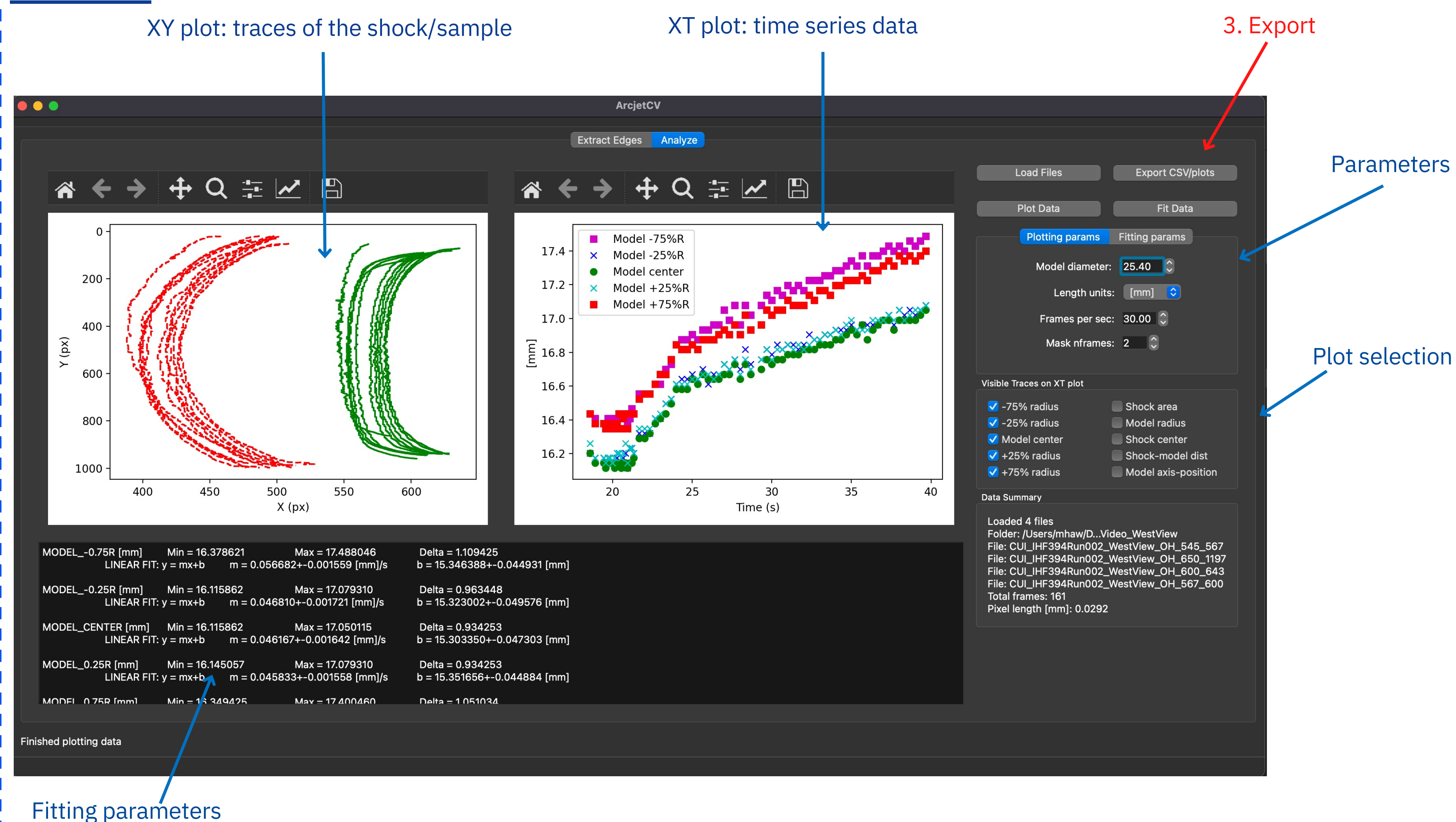
Keywords: Recession tracking, machine learning, arc jet, porous ablator, open source

Graphical User Interface

Edge Extraction Tab



Results Tab



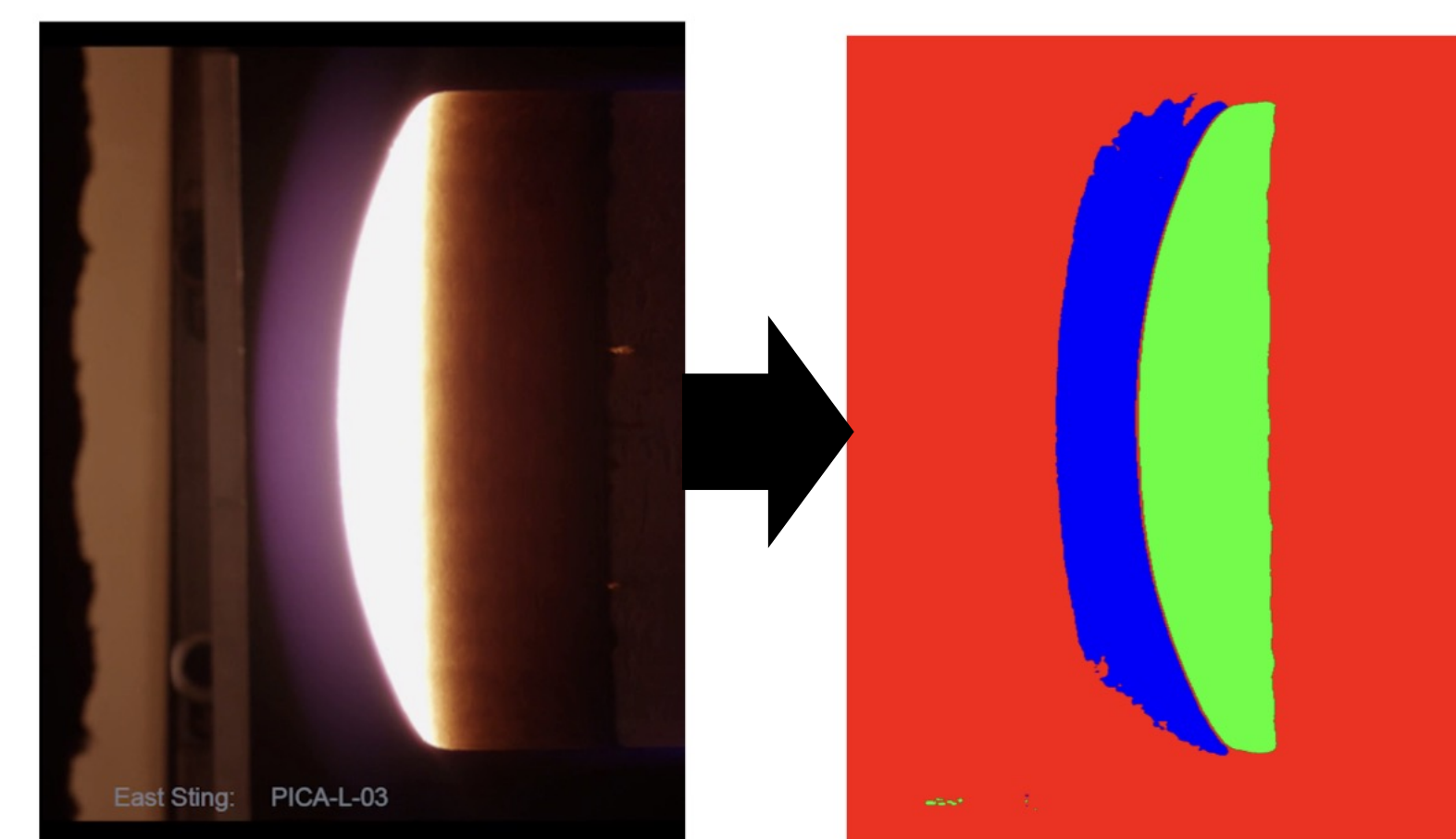
Installation

arcjetCV will be released as an opensource software in the near future. To get updates about the release and installation **scan** the code:



Machine Learning Models

2D CNN: robust image segmentation



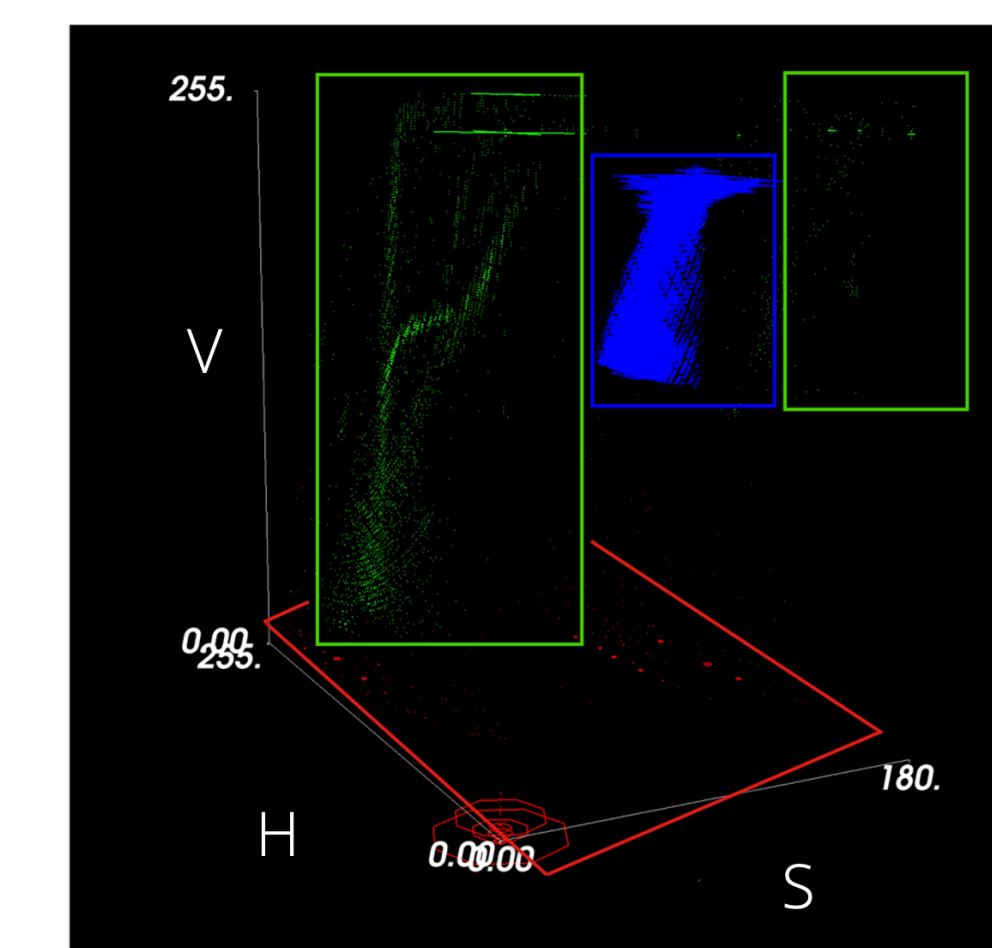
A 2D convolutional neural net (CNN) was developed to automate image segmentation for tracking sample and shock leading edges. The images above show a typical segmentation into 3 classes (Green: sample, Blue: shock, Red: background).

The model was trained using a manually labeled dataset of about 200 frames from 20 videos. The resulting neural net has robust performance and eliminates the need for manual inputs for most videos.

Decision Tree: fast image segmentation

To complement the CNN model, a decision tree model was trained to recognize pixel colors corresponding the main classes of interest (Sample, Shock, Background).

The plot on the right shows a 3D histogram of the pixels from the training set and show the classes are reasonably well separated in the HSV color space. This separation enables a simple decision tree to perform fast image segmentation suitable for real-time processing.

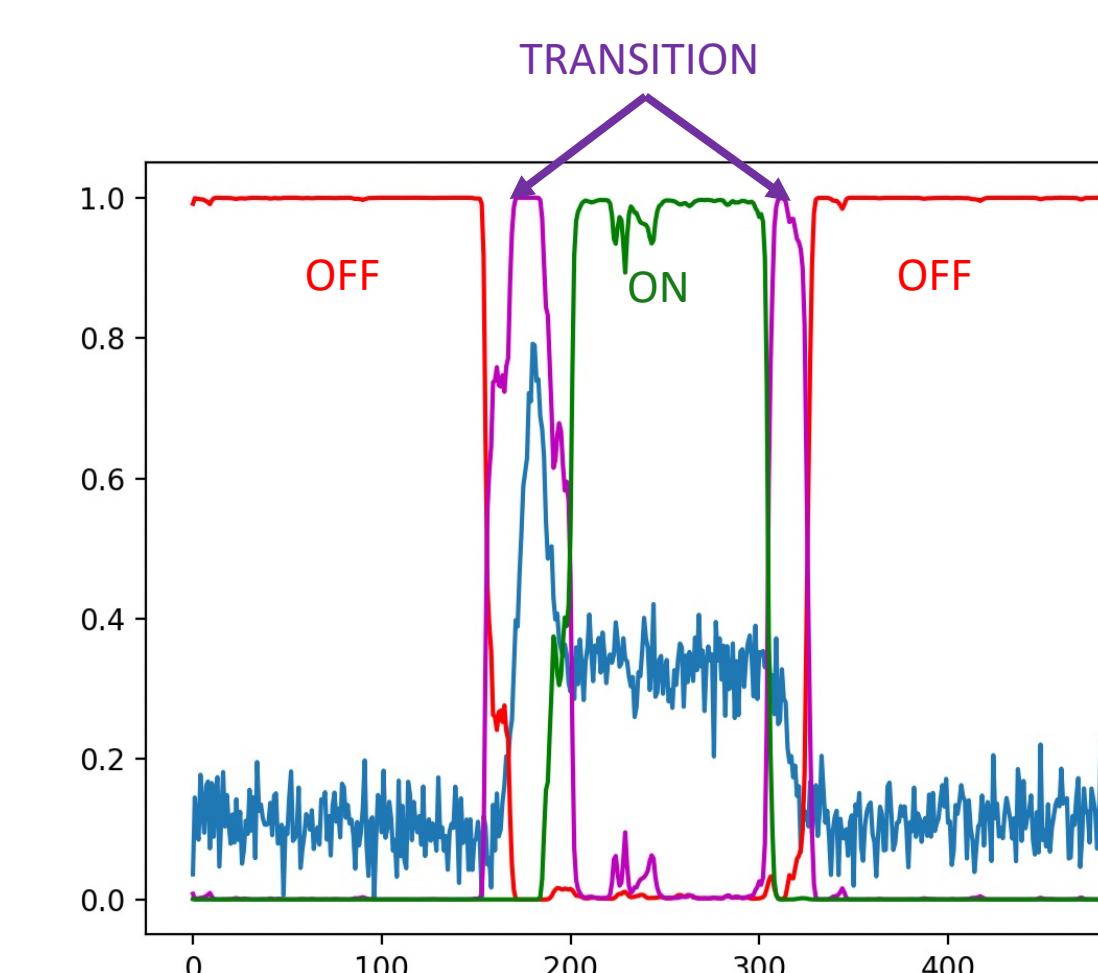


1D CNN: automating time segmentation

Time segmentation of the time intervals of interest is automated using a custom 1D CNN trained on synthetic intensity data. The model extracts a normalized time series of the integrated video frame intensity and classifies the data into 3 classes (OFF, TRANSITION, ON). This automates one of the primary manual inputs needed to process the video.

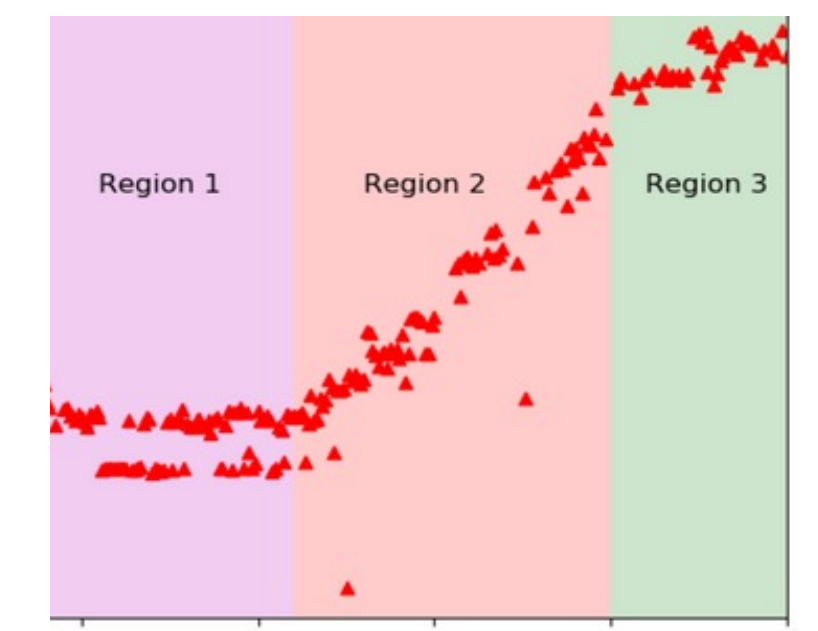
F1 scores:

OFF:0.99, TRANSITION:0.93, ON:0.97



Results

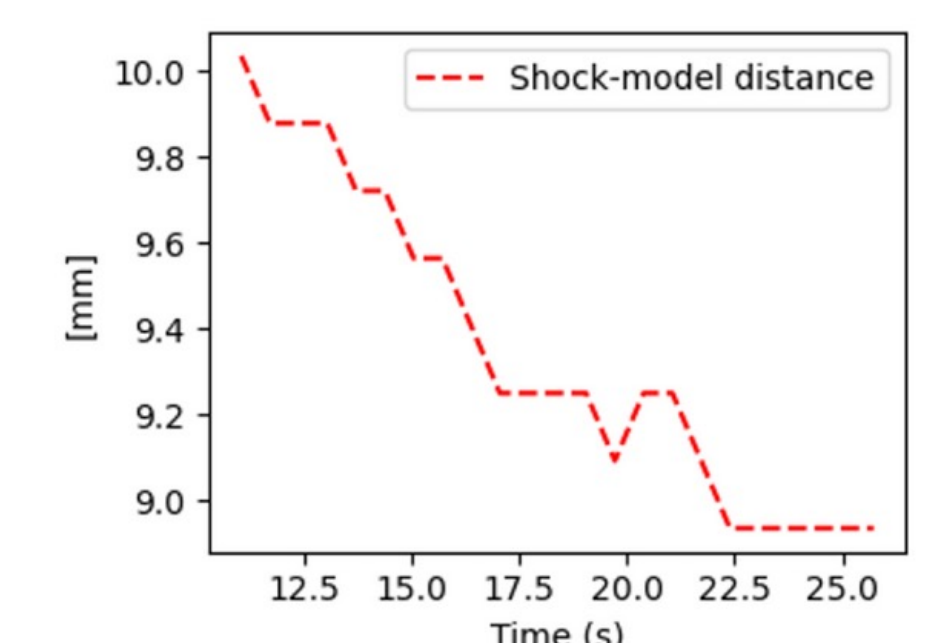
Non-linear Recession



Before: Recession considered linear
With arcjetCV: 3 Regions:

- Region 1: Nearly no recession
- Region 2: Constant recession rate
- Region 3: reduced recession rate

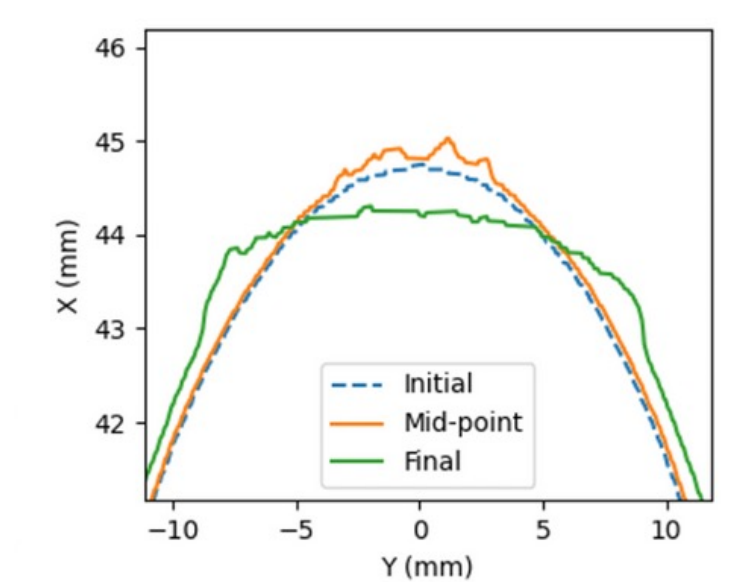
Changing Shock Standoff



- Validation metric for coupled aerothermal + radiation simulations
- Shock-sample distance decrease implies that the pressure at the sample surface is changing with time:

→ Aerothermal conditions are changing
→ The sample is becoming more porous

Shape Change



- Sample shape deforms/flattens at the nose and develops millimetre scale ripples/bubbles
- The entire sample is expanding (e.g. negative recession at the edges).

→ Provide first validation for 3D material simulations

References
[1] Alexandre Quintart and Magnus A. Haw, "ArcjetCV: a new machine learning application for extracting time-resolved recession measurements from arc jet test videos," AIAA SCITECH 2023 Forum, January 2023.
[2] Magnus A. Haw, Megan E. MacDonald and Sebastian V. Colom, "Big-data Efficient and Automated Science Transfer (BEAST): an open-source software architecture for arc jet data management, modeling, and automation," AIAA SCITECH 2023 Forum, January 2023.

Funding for this work was provided by the NASA Ames TSM branch IRAD funds, the MSR project, and the Orion project.

