SLAC NATIONAL ACCELERATOR LABORATORY

Visual Jet Detection for Automated Jet Tracking

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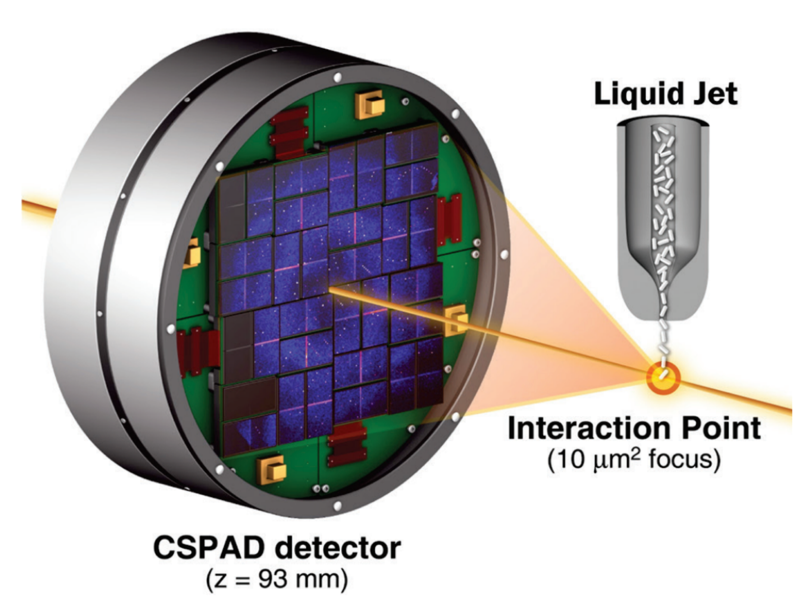
Introduction

Liquid jets are used in X-ray diffraction experiments at LCLS for injecting crystals to the beam. Given the small (~ 5 μm) radius of the jet, aligning it with the beam is challenging. Due to unwanted shifts in nozzle position and jet angle, this alignment also has to be actively sustained.

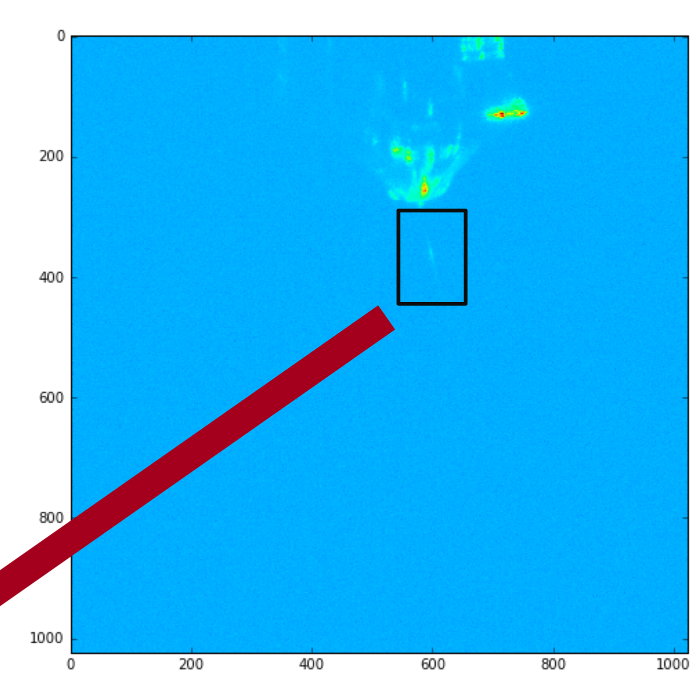
So far, this has been done manually, but automating the process has the potential to both save time and increase accuracy.

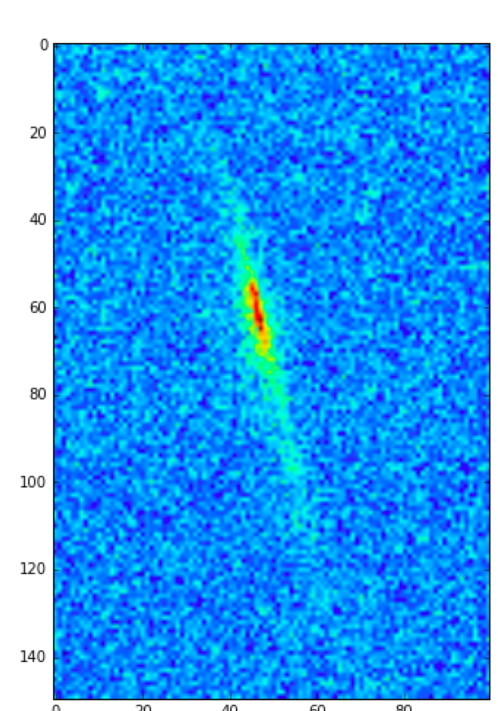


(Credit: Sébastien Boutet et al.)

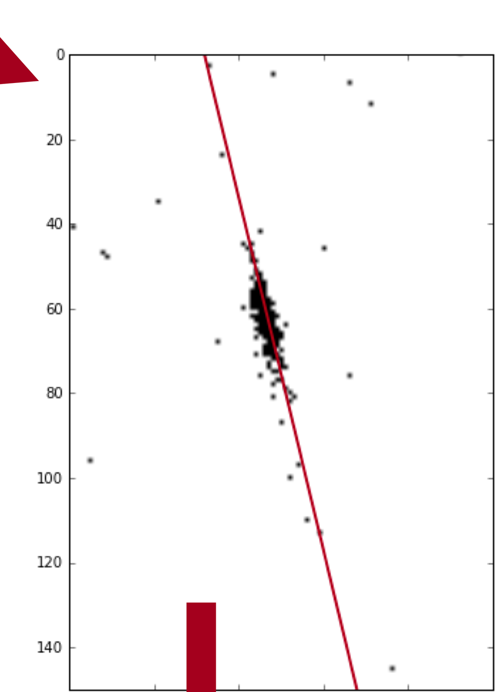
Methods

We use the on-axis Questar camera, functioning at the rate of 30 Hz, to automatically analyze the jet. From this camera image, we extract a region of interest (ROI) where the jet is visible. Choosing this area can be either done manually or automatically, using the brightness difference between the nozzle and the rest of the image.





The image of the ROI is converted into a binary image, using a threshold calculated from the mean and standard deviation of the image. This threshold is automatically decreased if the algorithm is unable to find the jet.



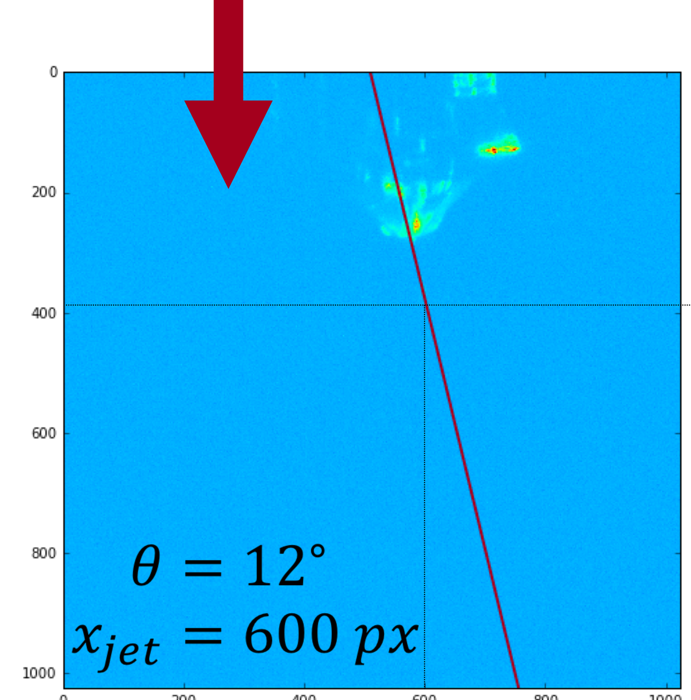
This binary image is analyzed using the Hough Line Transform. For each point in the image, the algorithm finds the space of lines passing through that point (x_0, y_0) :

$$r_\theta = x_0 \cos\theta + y_0 \sin\theta$$

Plotting these equations for each point in the image, the pair (r_θ, θ) with the highest number of lines intersecting represents the best fit for a line in the image.

The last step is to convert the angle and position back to the coordinate system we're interested in and to find the jet's x-position at the beam height.

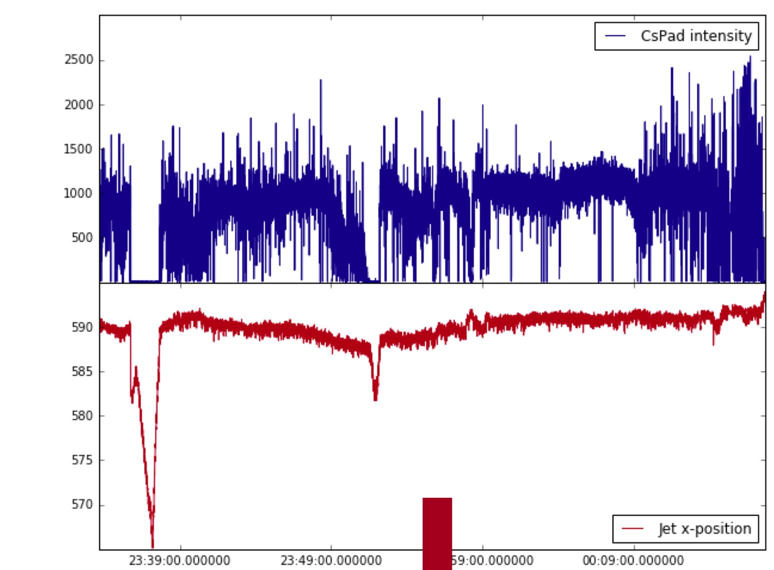
This distance between the jet and the beam can then be used to move the motors in the x-direction.

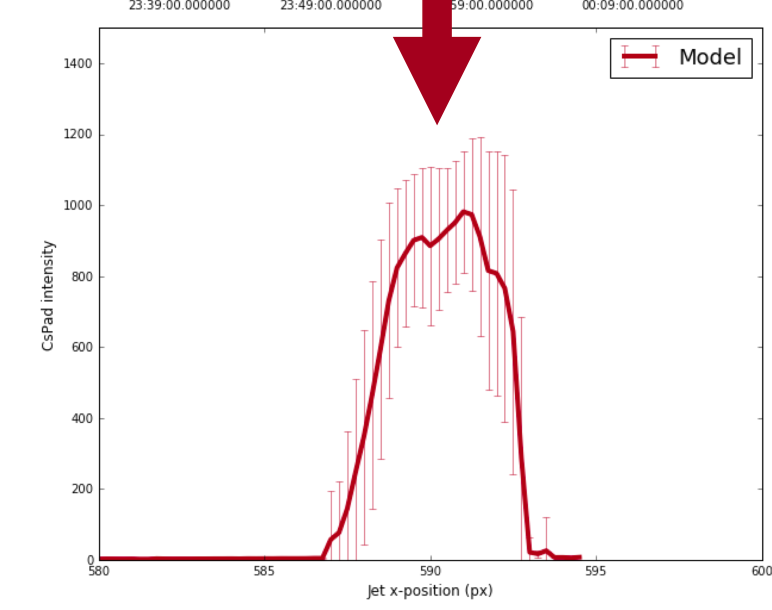


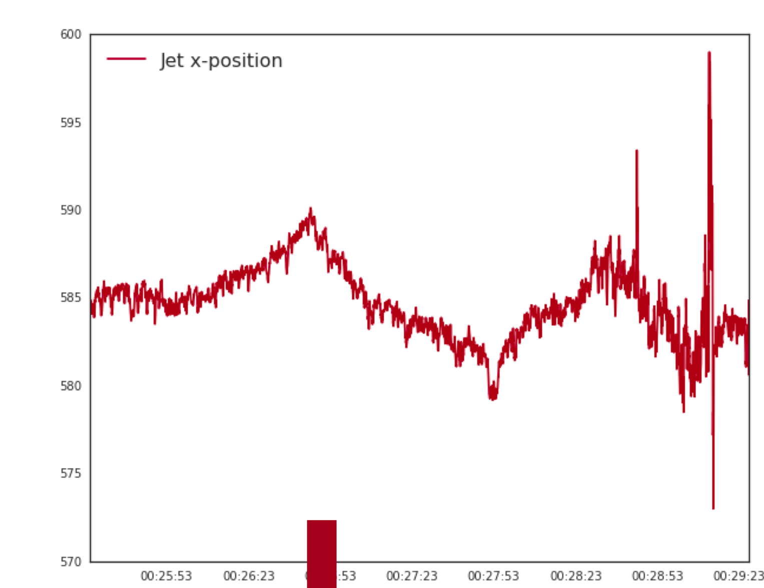
Results

For testing the method we used an experimental run where the jet had been moved across a long distance, and analyzed the relationship between the position and the total sum on the CSPAD.

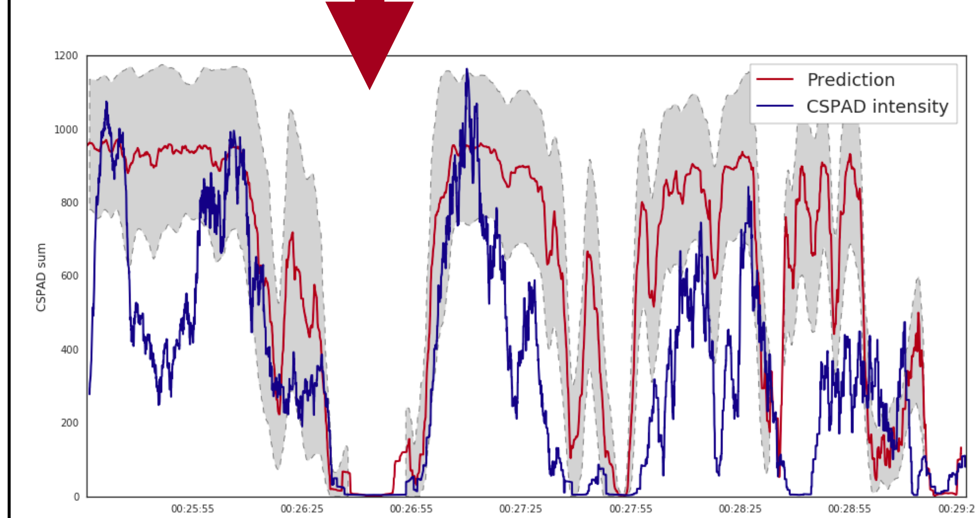
To account for error caused by fluctuations in beam intensity, we normalized the CSPAD sum by dividing by the total beam intensity. This resulted in a clear Gaussian-like peak at the X-ray interaction point, showing a correlation between the jet position and CSPAD intensity.







We then used this data to predict the CSPAD intensity for other runs using only the jet position and total beam intensity. Sufficiently close to the original run, the prediction was accurate and also capable of showing when the jet was moved in the wrong direction.



The prediction works well as an upper bound for the intensity, but sometimes jet instability causes drops below the prediction. We found that this instability can also be automatically predicted by frequency analysis.

Conclusions

Whenever available, the on-axis camera proved to be a promising way of tracking the jet. However, since most experiments did not have this data recorded, more data needs to be gathered to generalize the method to different situations and jets.

There is still plenty of noise in the jet finding algorithm. Given that the nature of the problem is image analysis, future research with neural networks might be necessary to achieve better results.

When the camera is not available, monitoring the CSPAD intensity and scanning over a range of injector positions when the intensity drops is a way to achieve the same goal of making sure the jet stays in an optimal position.

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