A Machine Learning based approach for the Process Optimization of Silicon Crystal Growth

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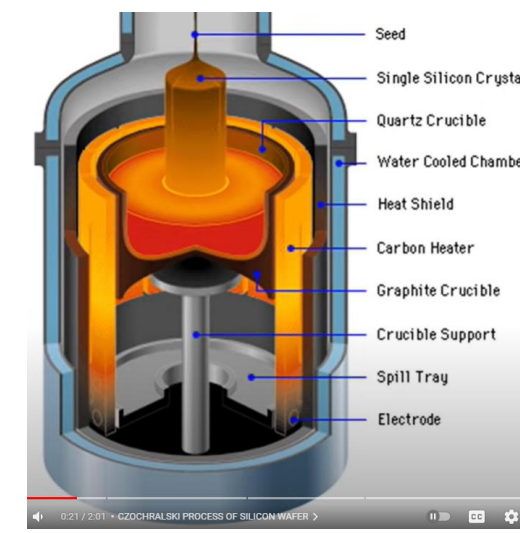**RIT** Golisano Institute for Sustainability

Background

- First step: Silicon Crystal Growth known as (*Czochralski*) *cz* process.
- Complex phenomenon with a monitoring of many process parameters with growth time of around 2-3 days.
- Quality and rate of growth are the important profit measures.
- Any defect during the growth phase, is detected only after at least 15 hours.

Silicon crystal

Czochraski Method

Prepare high purity molten silicone

Dipping Seed Crystal

Large Crystal will start growing

Large Crystal

Wafer after grinding and slicing

Project Goals

- Selecting the right parameters.
- Early detection of quality defects.
- Classifying good and bad crystals.
- Forecasting future values for the output.
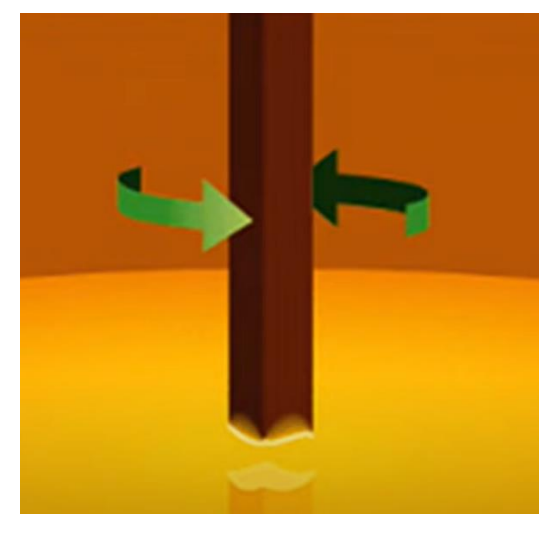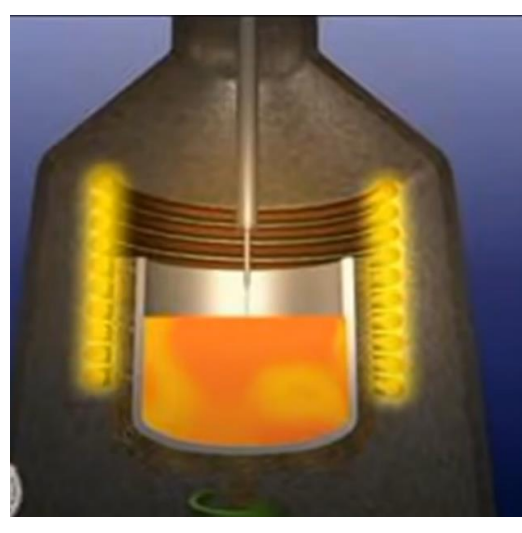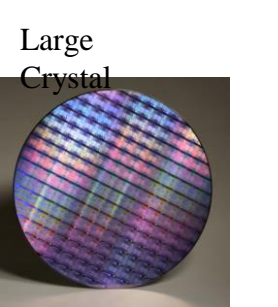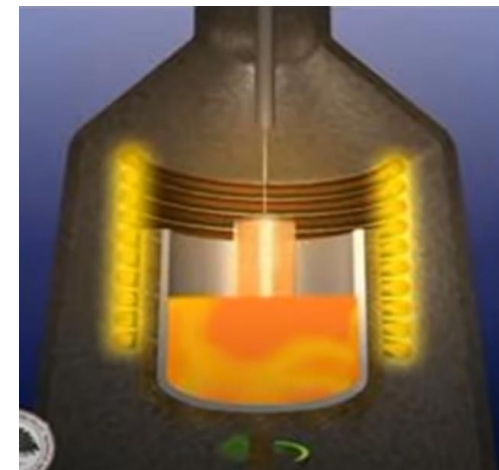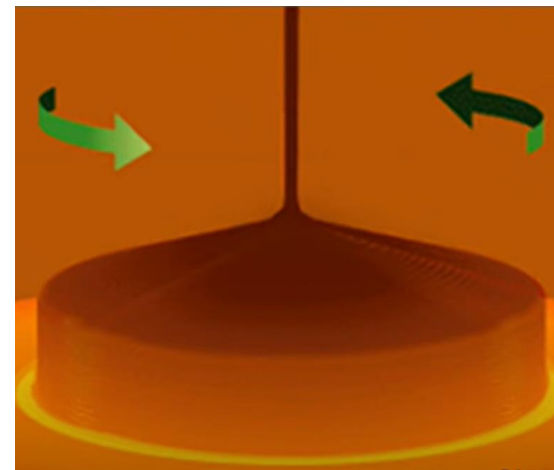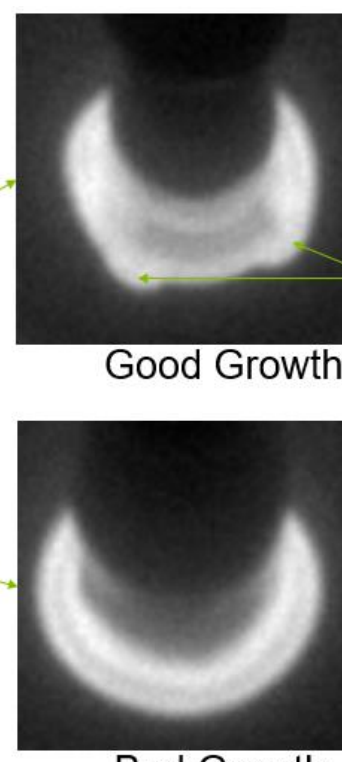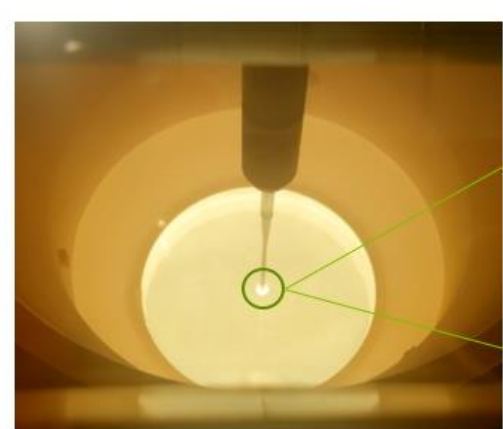- Automate the process.

Scientific Merit

- Similar optimization can be extended to metal industry where CZ process is used for the metal crystal growth.
- Contributing towards sustainable environment.
- Minimize resources and energy.

Silicon crystal waste

Data Sources

Image Data


Good Growth — Facets

Bad Growth

- Continuous recordings of images of crystal formation
- Images with facets are good indicators
- Process monitoring through various sensors
- Historical log generation of recordings
- Time-based data in tabular format for each crystal growth

Log Data

Process monitoring using sensors

Sensors time series data
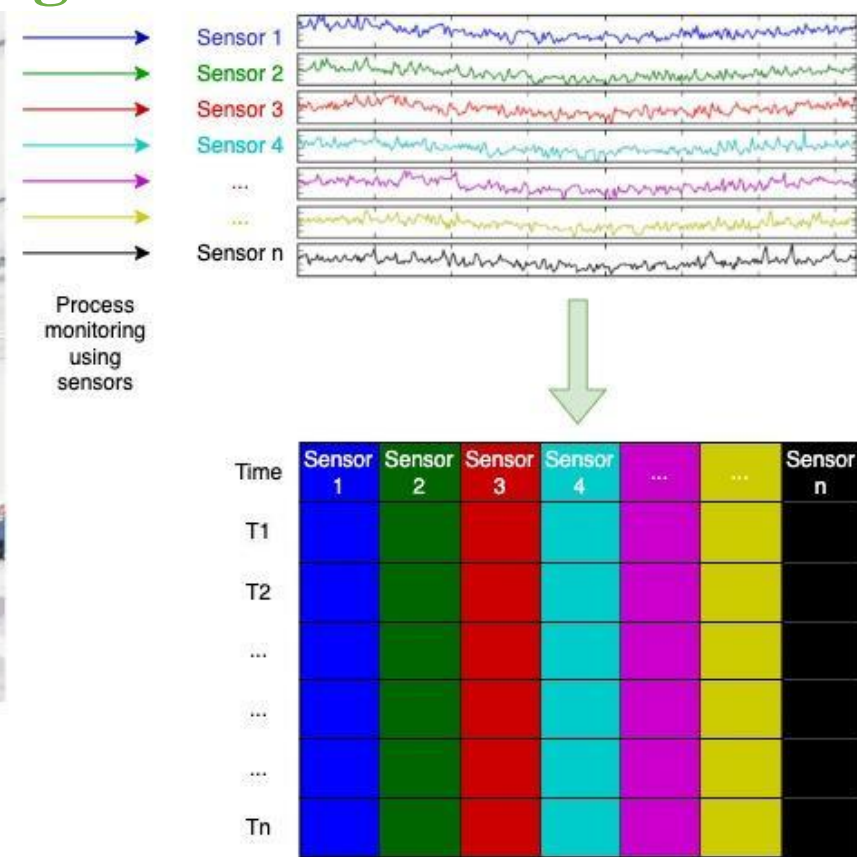
Data Preparation and Model selection

- Labelled facets and NoFacet images.
- Number of classes: 2
- Dataset: Train – 104, Validation: 23
- Model: Yolov5 for
  1. Realtime detection
  2. Ease of labeling
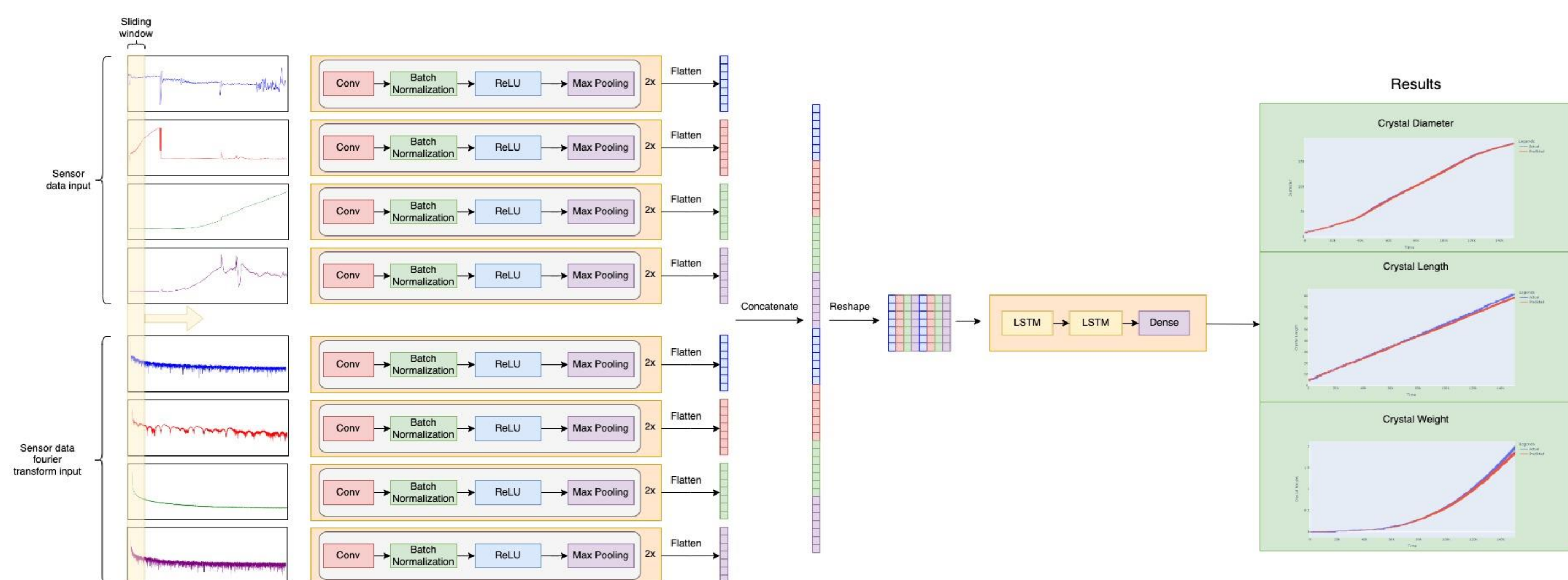 3. Invariant to facet location
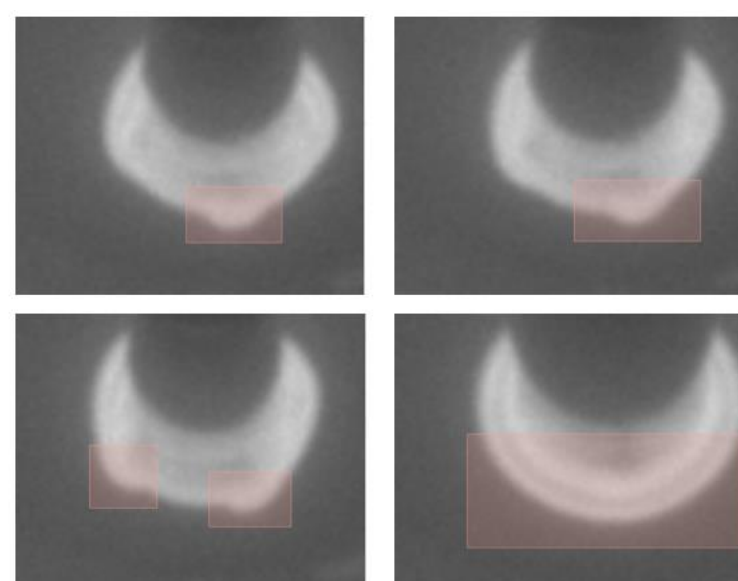
Labelled train data

Challenges

- Limited data availability, i.e., only 5 good runs and bad runs.
- More good runs data as compared to the bad runs.
- Multi-variate nature of the data.
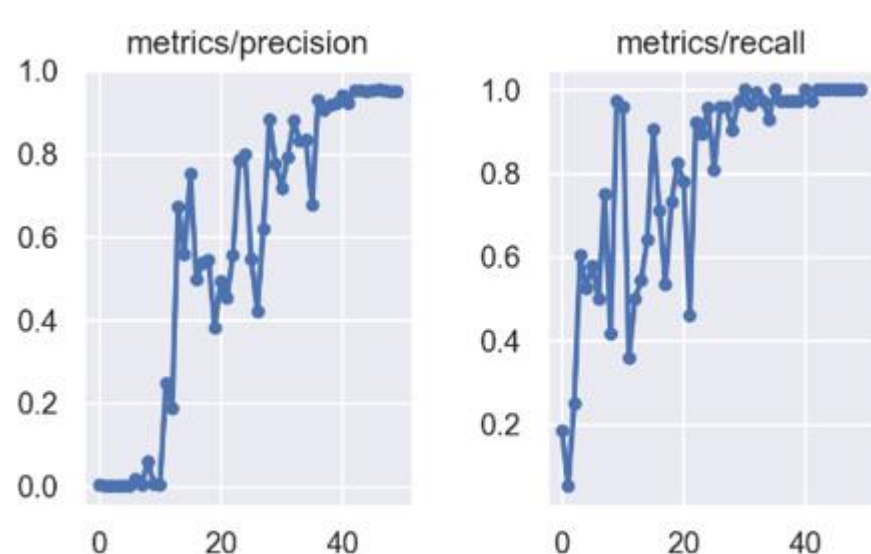- Similar growth trends for good and bad runs for most of the parameters.

Process Flow and Forecasting Results

Results

Results of YOLOv5

Precision and Recall

Results on the test set

Loss curve

Confusion Matrix

docker
Streamlit

- Incorporated on the fly image resize and crop functionality.
- Integrated with **streaming image API.**
- Created user-interface using streamlit.
- Successfully deployed the prototype using **docker**.
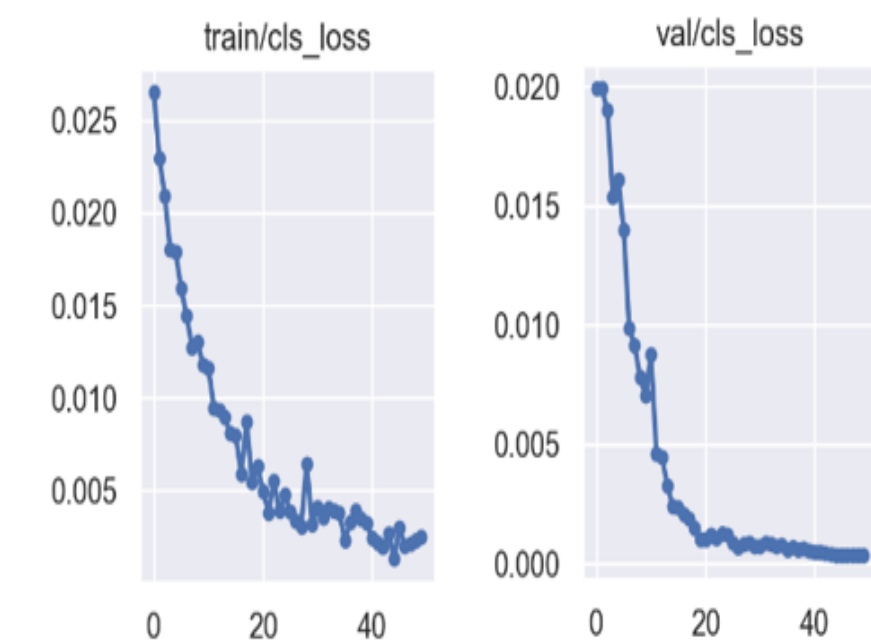

Works well with real-time video

Future Scope

- A hybrid approach using image flow and time-series flow for detection.
- Analyzing on a larger dataset.
- Improving the prediction time of the image model.
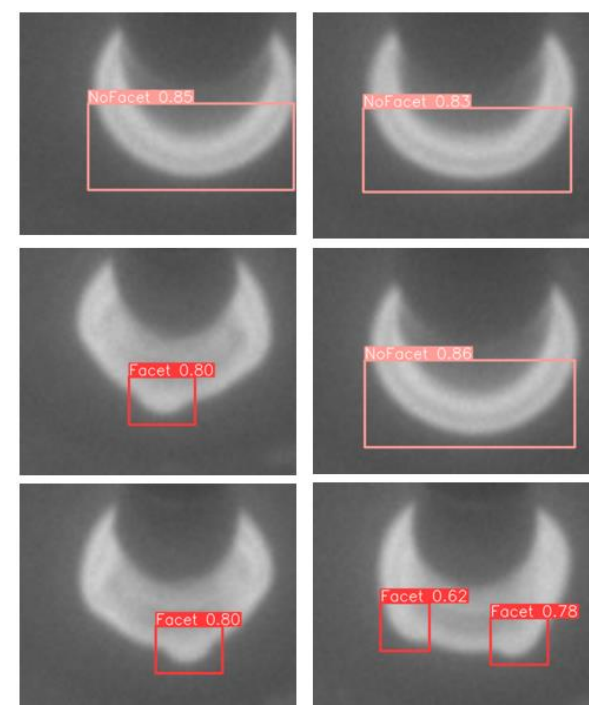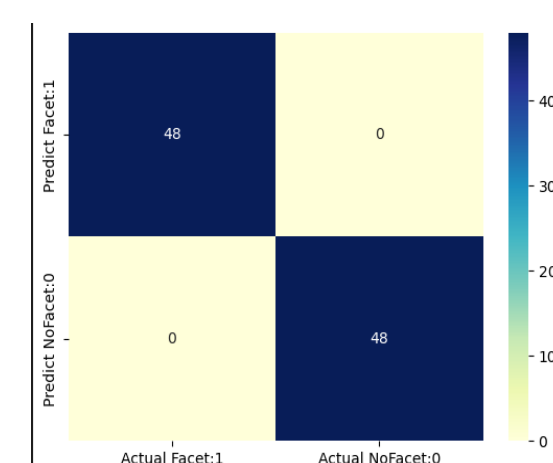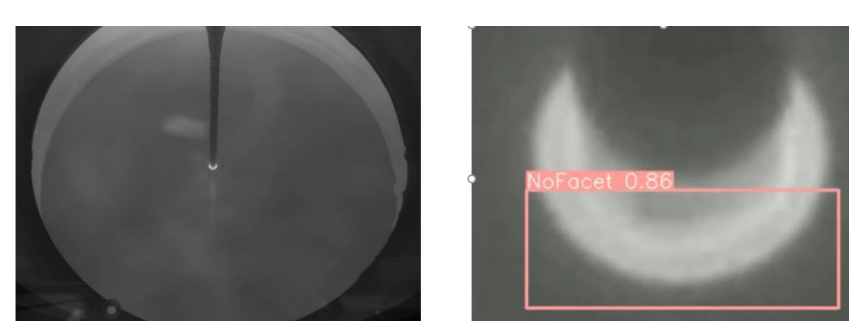- Forecasting input parameters for process optimization.

First Successful Deployment