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2023-2 Mechatronics Integration Project

Basic Research on Steel Type Distinction Technology Based on Spark Video

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Steel bar pass → **Inspection** → **Classification**

Steel bar Rolling Process

Problems with inspection equipment

1. **Expensive** inspection equipment (More than **100 million ₩**)
2. Distinguishes **different metal**, but **not carbon content** in steel

C55 Steel

C35 Steel

C20 Steel

A technology to Distinguish Steel based on Carbon Content is necessary

- Mixing steel in **continuous process** causes **mass recalls**
- Severe **Economic Losses**

1. Introduction

How Can We Distinct Based on Carbon Content?

Spark Test

What is Spark Test?

- A technique to **distinguish steel types** through the different **spark shapes** generated by various metal materials

- Skilled experts are capable of distinguishing these **visually**

Development of a **steel classification** algorithm based on **spark characteristics** through image processing

Incidents of mixed steel types can be prevented

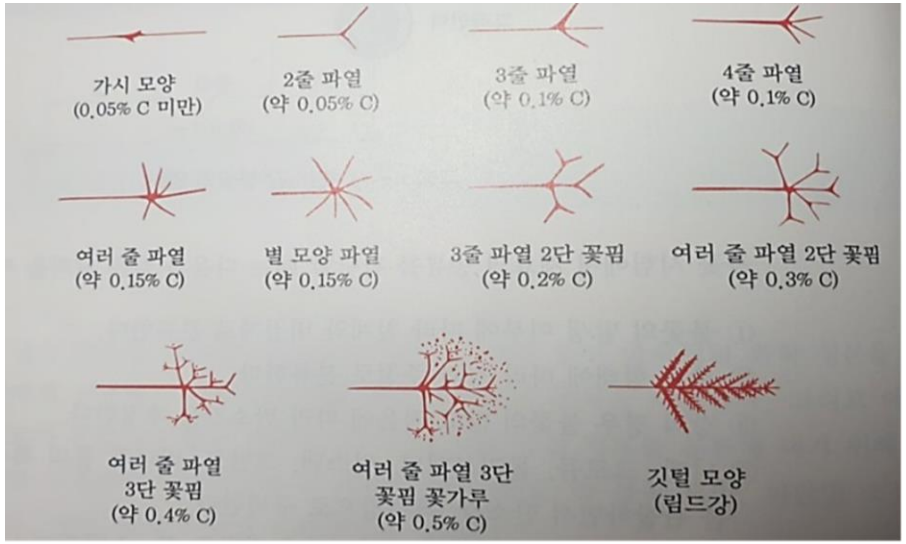
http://www.woodutch.com/portfolio-items/028-%ED%98%84%EB%8C%80%EC%A0%9C%EC%B2%A0-%EC%83%9D%EC%82%B0%EA%B3%B5%EC%A0%95-_3d%EB%AA%A8%EC%85%98/

1. Introduction

Spark Characteristics according to Carbon Content

0.1% Carbon

0.55% Carbon



Burst shape depending on carbon content

0.1% Carbon

0.35% Carbon

0.55% Carbon

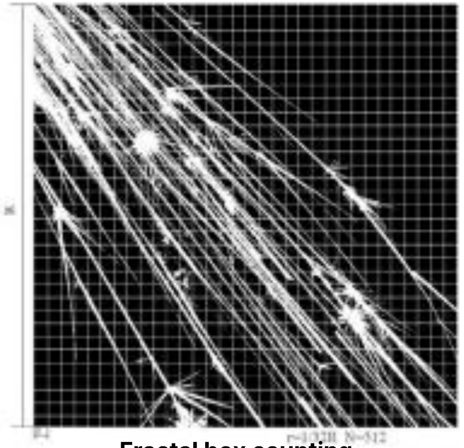
As the carbon content **increases**

- The number of **exploding branches** increases
- The **length of the spark** shortens
- **Brighter** light is emitted

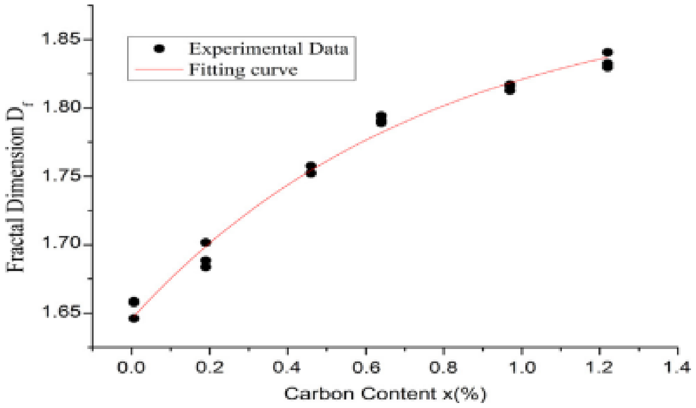
1. Introduction

Paper 1

Spark testing to measure carbon content in carbon steels based on fractal box counting

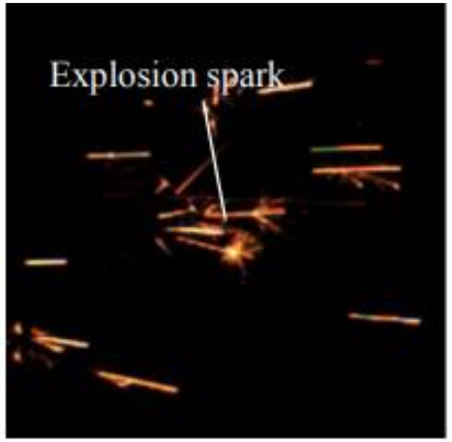


Fractal box counting

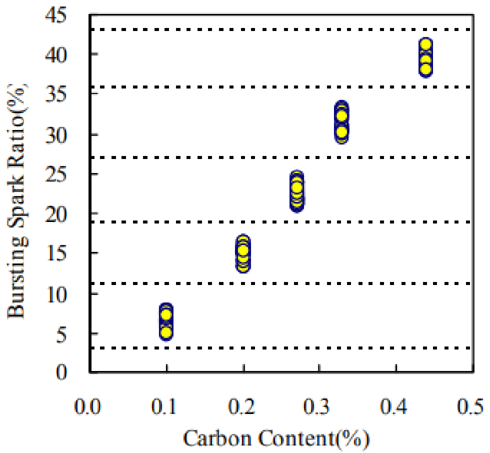


Paper 2

Development of Automated Spark Testing Technique by Image Processing to Measure Carbon Content in Steel Materials



Explosion spark ratio



- Does not reflect **spark characteristics** according to **carbon content**
- **Not** applicable in **real-time**
- The **gap in carbon content** is more than 0.1%

Distinguishing steel types with a carbon content gap within 0.1%

verifying real-time applicability by proceeding with video instead of images

2. Research Flow

Data Preprocessing → **Feature Extraction** → **Classification**

Data Preprocessing

Preprocessing to use only Exploding Sparks

Feature Extraction

Statistical Feature Extraction for Spark Characteristics based on Carbon Content

Classification

Classification using machine learning based on the extracted Statistical Features

Method 1
Spark Area Detection

Advantage

- A relatively **lightweight algorithm**
- Capable of detecting **explosion spark** areas

Disadvantage

- **Stem sparks** other than explosion sparks are also detected
- The **accuracy decreases**

Method 2
Streamline Elimination

Advantage

- Only the point of **explosion** can be detected

Disadvantage

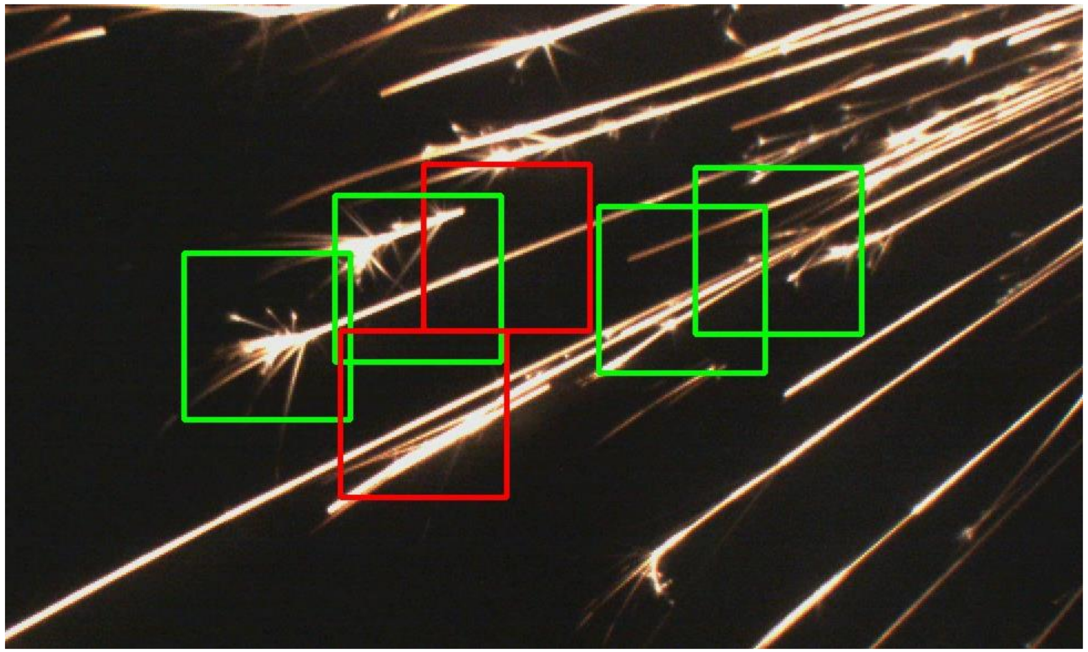
- Significant **impact of parameters**
- **Data loss** occurs

* Above image is enhanced visibility through color inversion

Method 1 : Spark Area Detection

Original Spark

Preprocess Result

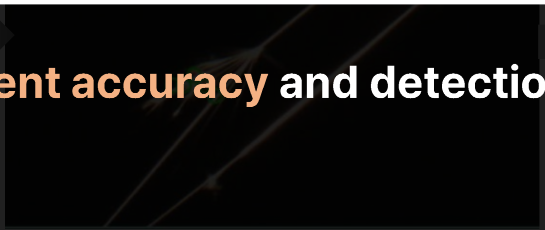


Things filtered as burst sparks among PCA outliers

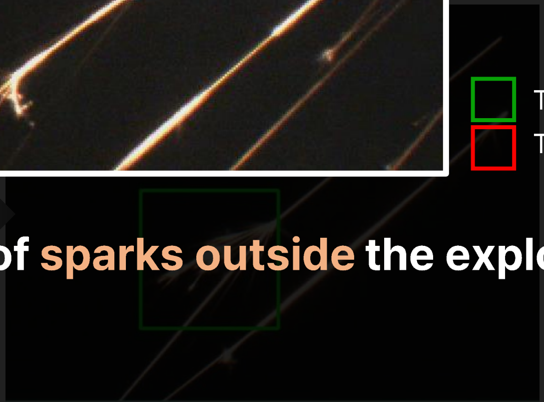
Things not filtered as burst sparks among PCA outliers

Insufficient accuracy and detection of sparks outside the explosion point

Detection of abnormal PCA values



Detecting abnormal PCA values of the explosion point with DBSCAN



Detect as explosion spark when a certain number of clusters are satisfied

Image Processing

Video Capture → Video to Image Sequence → Gray Scale → Binary Thresholding → Canny → PCA in Grid → Gradient Outlier

Flow Chart

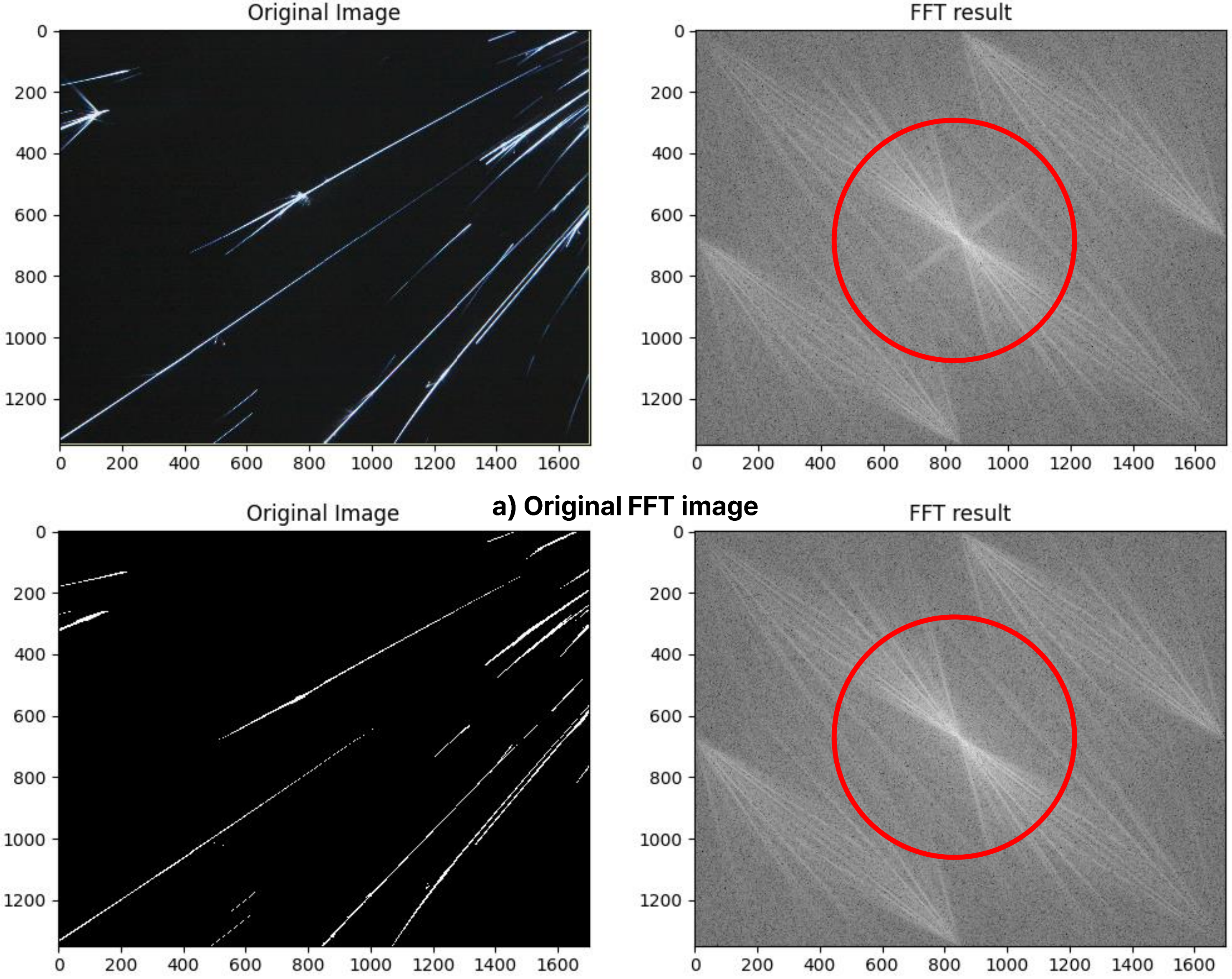
Method 2 : Streamline Elimination

0.1% Carbon

0.35% Carbon

As the **carbon content increases**, the number of explosion spark **branches increases**
(Rapidly Changing Points)

Filtering only data of exploding points using **High Frequency** areas



a) Original FFT image

b) FFT image with explosion spark deleted

Streamline Elimination

FFT Image

IFFT Image

Image Processing

Raw Spark Image

Filtering with Exploding Spark

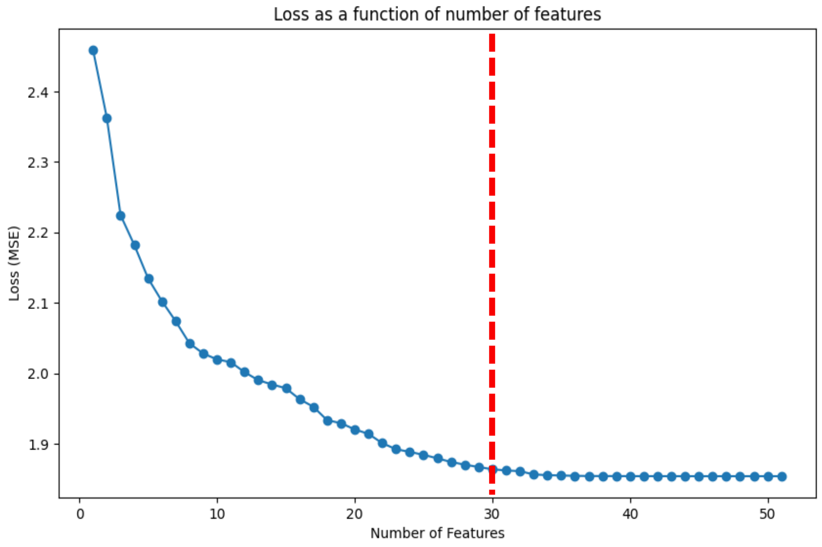
IFFT

Filtering primarily on data from Exploding spark points

Flow Chart

Recover FFT components of exploding spark

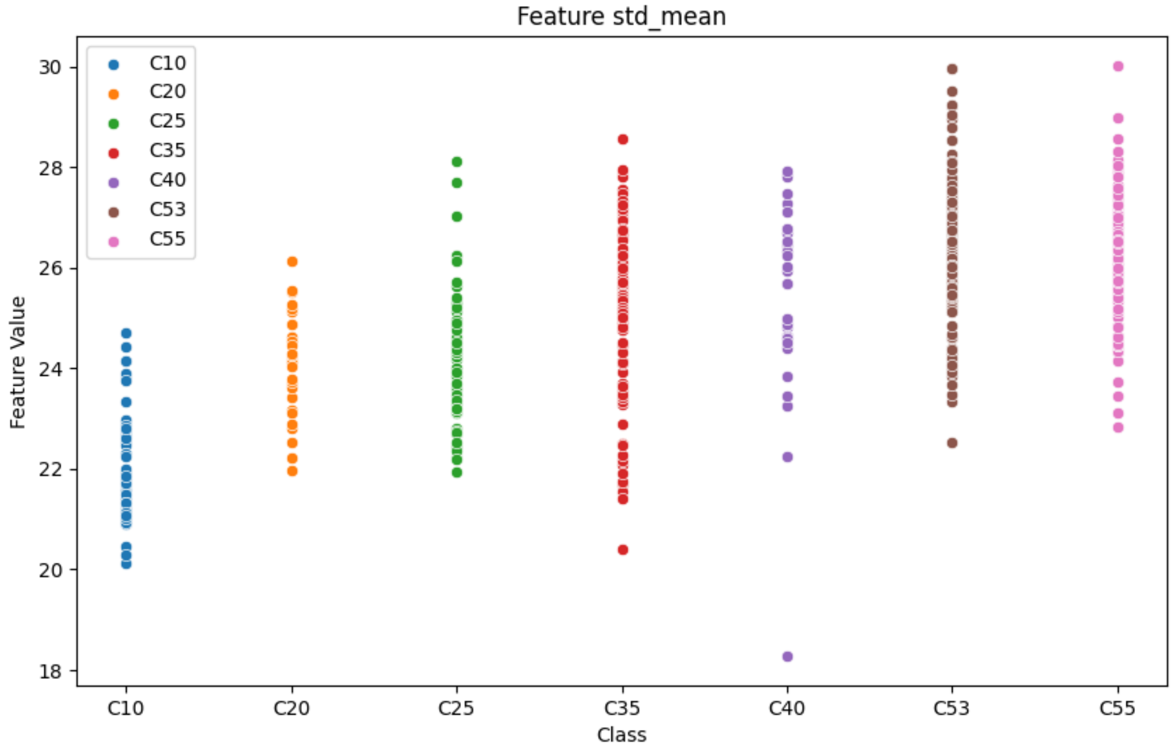
51 Features Extracted

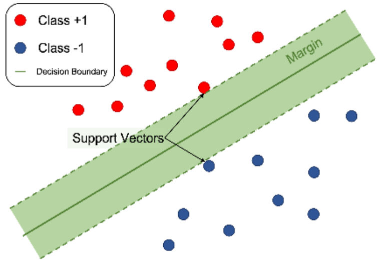


Optimal learning determined at **30 features** based on MES loss

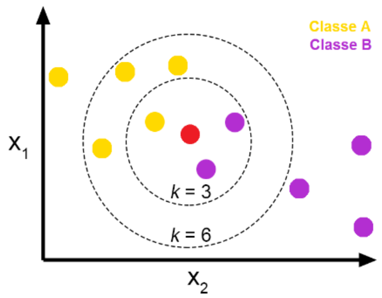
SFS
(Sequential Forward Selection)

Selecting **30 Features** that Well Represent the **Characteristics of Steel**

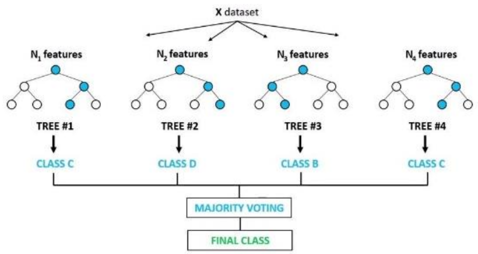




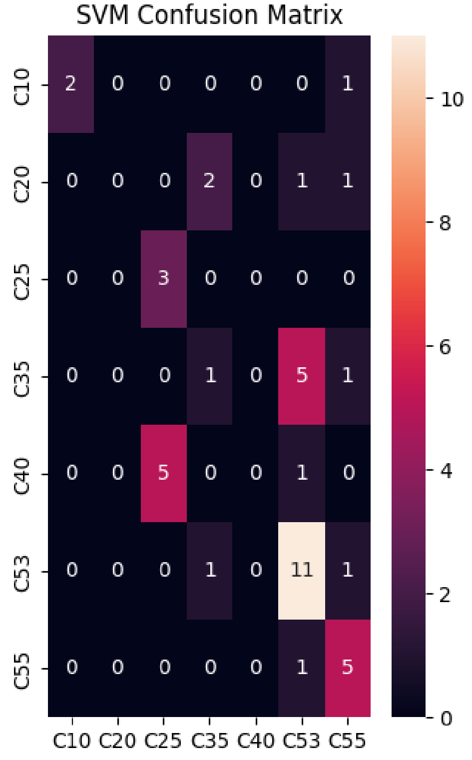
SVM

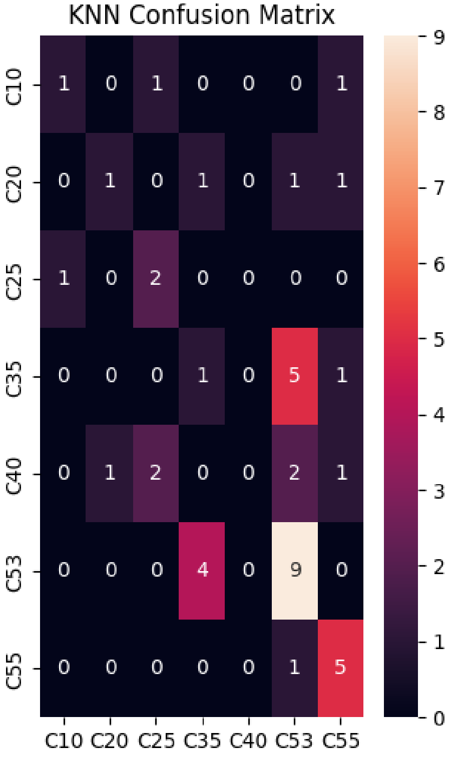


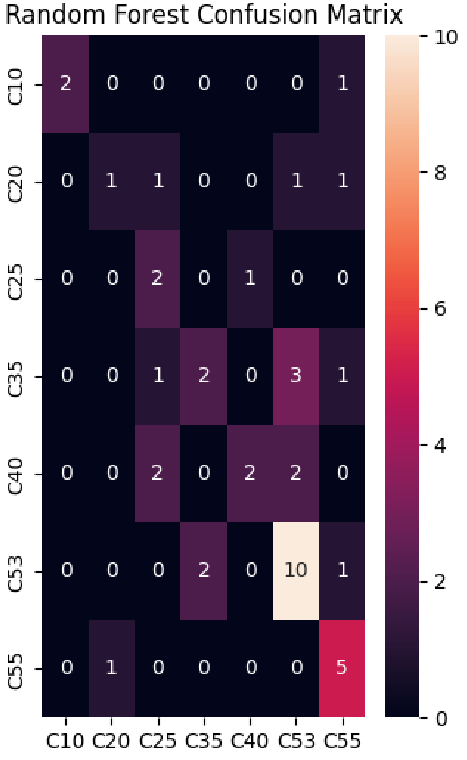
KNN



Random Forest







	SVM[%]	KNN[%]	Random Forest[%]
Accuracy	52.38	45.24	57.14
Precision	63.59	51.67	59.42
Recall	53.38	45.23	57.14

Classification Results Table

Reason for Low Accuracy

- Due to the **lack** of the **Test set**, the **accuracy is lower**
- With **more** classes in the **Test set**, **accuracy improves**

Difference in Performance Between Models

- **SVM** excels with high-dimensional data due to its **complex decision boundaries**
- **Random Forest** is adept at learning complex patterns due to its **random feature selection**

4. Result

Distinguishing classes **above 0.1% was possible**, but **accuracy dropped** below that due to **data shortage**

Since features were extracted and learned **from the video**, it is expected to be applicable in **real-time** videos as well

Case Specifications

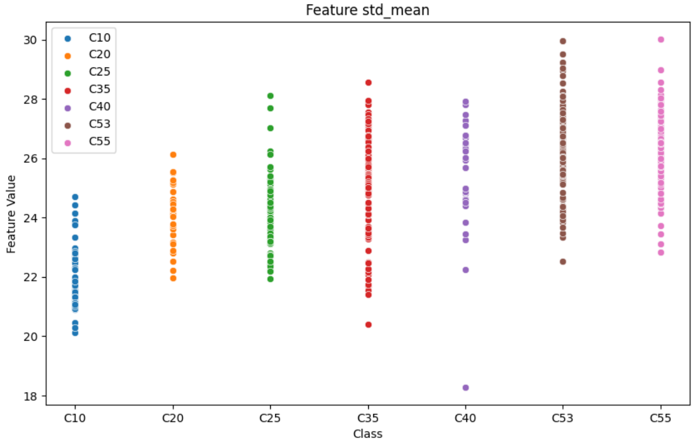
0.1% Carbon

0.35% Carbon

0.55% Carbon

The number of **Exploding Branches increases**

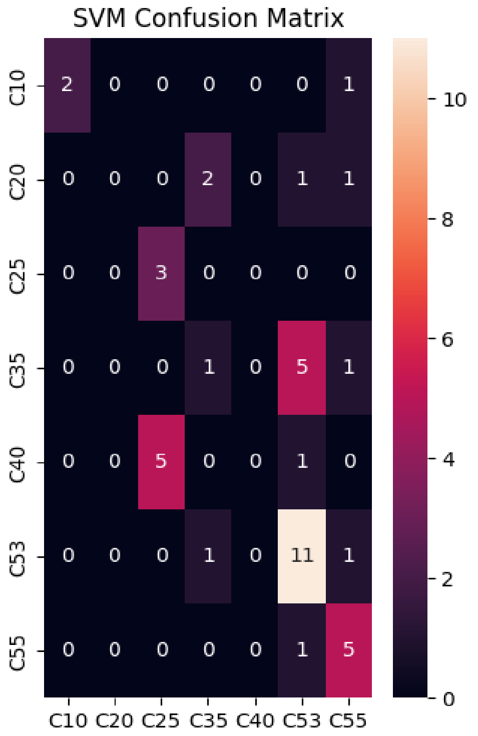
Feature Selected

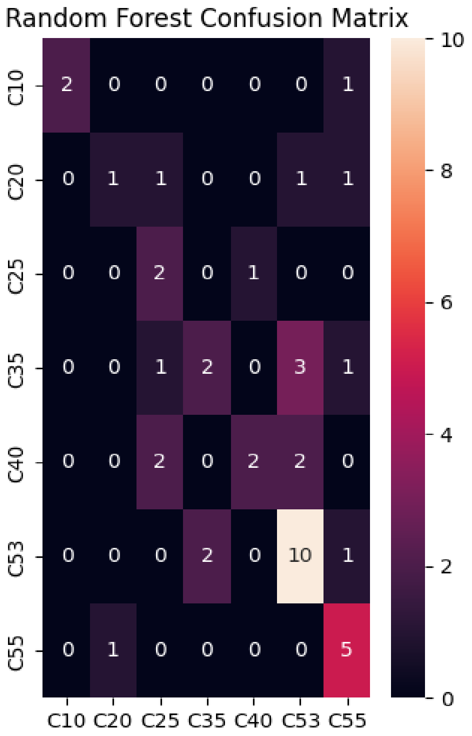


Top features, reflecting **Data Distribution**,
include **standard deviation**, **kurtosis**, and **skewness**

Increased carbon leads to more **spark branches**, equivalent to **greater pixel dispersion**
Using this **dispersion** for **steel type differentiation** improves classification performance

5. How to Improve the performance



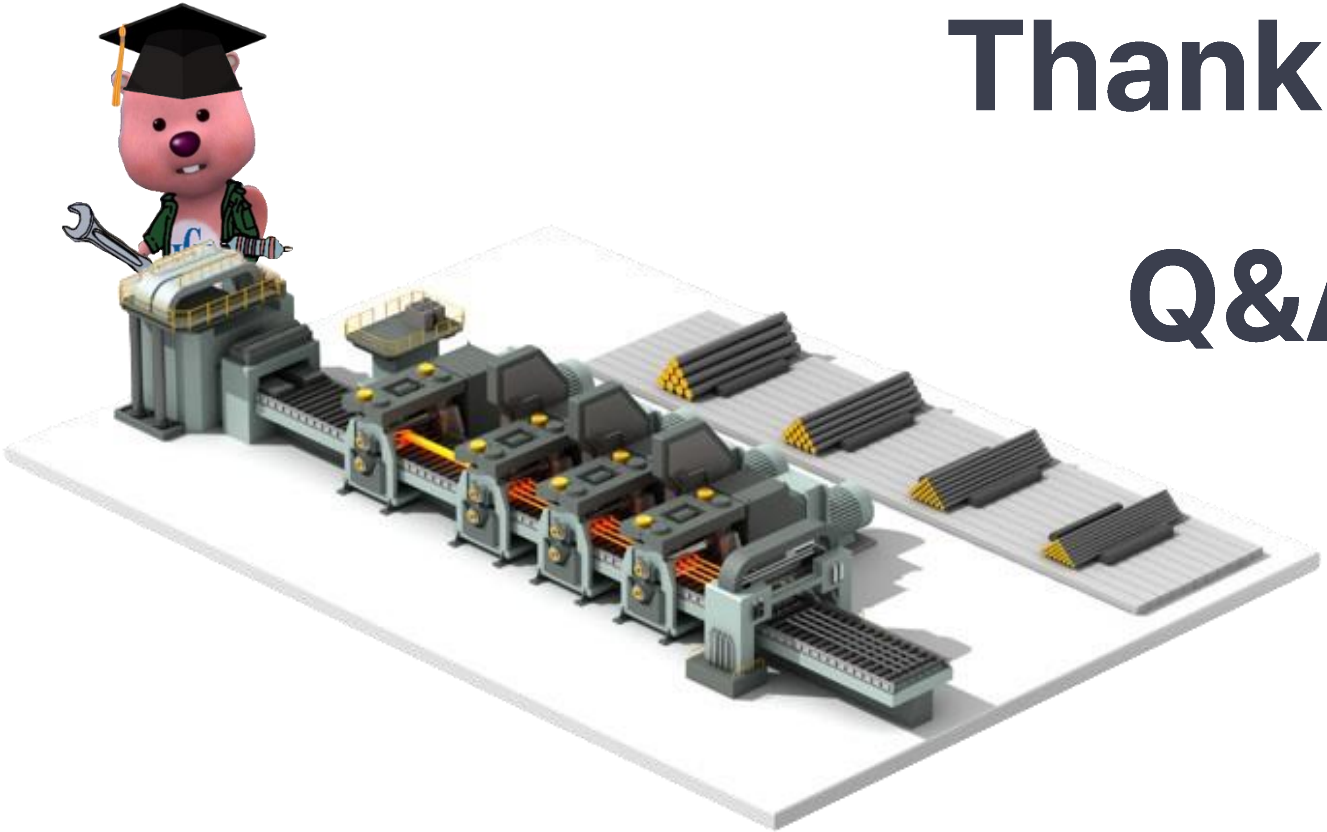


Spark Set	C10	C20	C25	C35	C40	C53	C55
Train	1,543	914	1,804	2,764	994	3,964	3,388
Test	120	180	114	341	293	620	289

Training and Test Data Sets Used

The **more data sets**, the **better the learning performance** tends to be.

Increasing spark data can improve performance.



Thank you

Q&A