BROCHALIGN

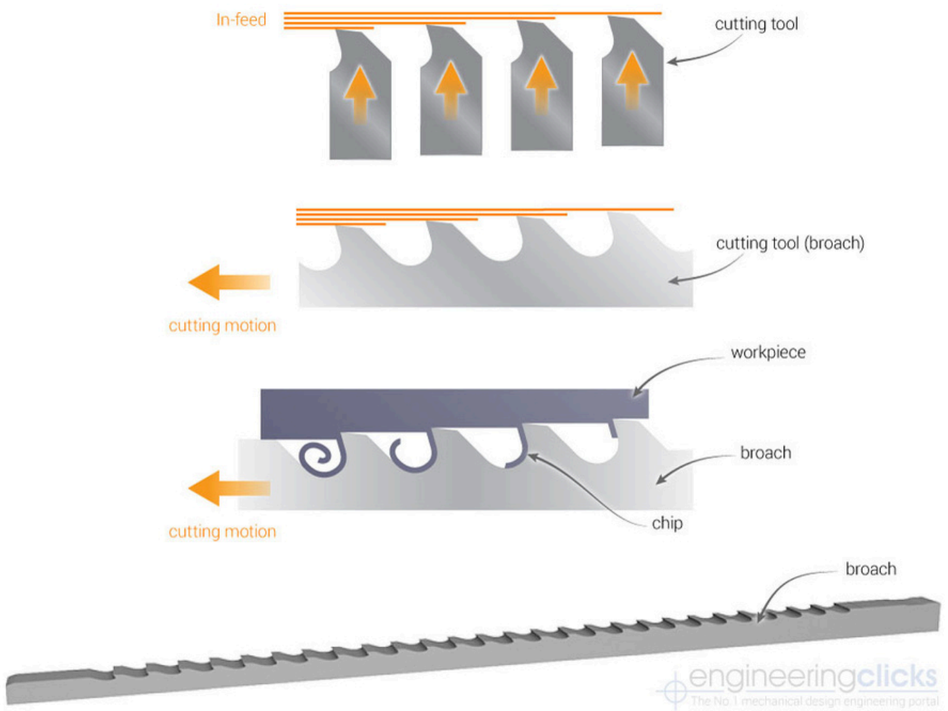
A Multi-Axis Regression Approach for **ITP Aero Manufacturing Data**

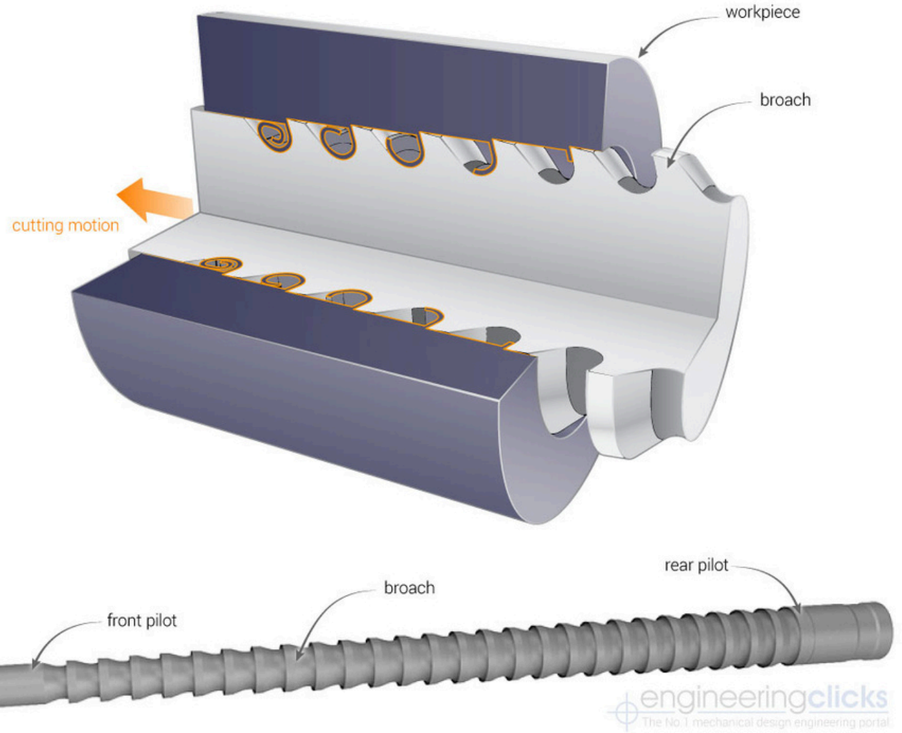
Dante Schrantz and Miguel Diaz

https://youtu.be/3xYRqZze3V0

Purpose

IMPLEMENT A MACHINE LEARNING MODEL TO PREDICT WHEN BROACHING COMPONENTS NEED TO BE REPLACED, REDUCING COSTS AND OPTIMIZING PRODUCTION LINE EFFICIENCY.





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Metrics and Requirements

THE MAXIMUM ABSOLUTE ERROR OF THE MODEL ON THE VALIDATION DATASET MUST BE LESS THAN 1 FOR THE CORRECTOR ON THE X-AXIS AND 0.15 FOR THE OTHER AXES. ADDITIONALLY, THE RMSE MUST BE LESS THAN 0.25 FOR THE CORRECTOR ON THE X-AXIS AND 0.025 FOR THE OTHER AXES.

Objective

Improve the quality of products manufactured by ITP Aero and reduce their production costs.

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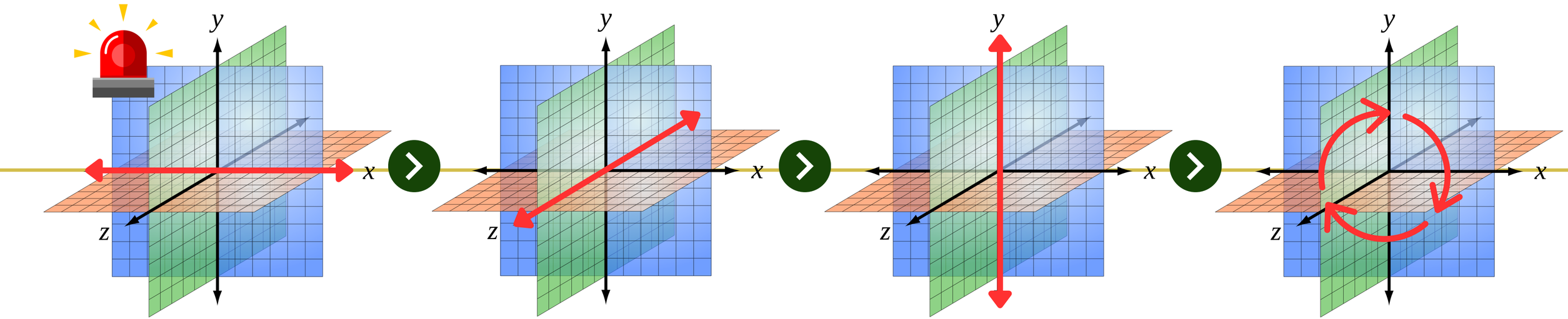
Target Variables - Correctors

WE HAVE 4 TARGET VARIABLES CORRESPONDING TO **EACH AXIS**
OF THE BROACHING PROCESS



XCMM

RIGHT TO LEFT

ZCMM

FORWARD TO BACKWARD

CCMM

FROM TOP TO BOTTOM

BCMM

ROTATIONAL

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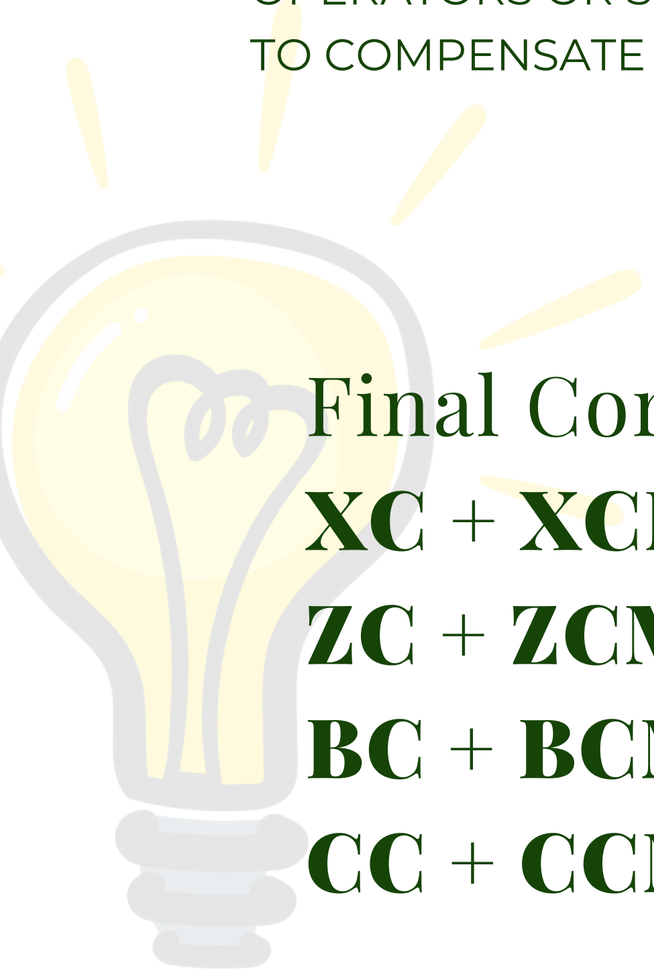
Actual Corrections

VALUES DIRECTLY APPLIED BY OPERATORS OR SYSTEMS TO ATTEMPT TO COMPENSATE FOR DEVIATIONS.

CMM Corrections

OUR MODEL PREDICTS MACHINE-MEASURED DEVIATIONS (XCMM, ZCMM, BCMM, AND CCMM) BASED ON HISTORICAL SYSTEM DATA.



Final Corrections:

XC + XCMM ⇝ Final correction on X-axis.

ZC + ZCMM ⇝ Final correction on Z-axis.

BC + BCMM ⇝ Final correction on B-axis.

CC + CCMM ⇝ Final correction on C-axis.

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Explanatory Variables

c("Brocha", "PartNumber", "OrdenFabricacion", "FBrochado", "Utillaje", "Maquina", "TpoIndexador", "NUso", "NDisco")

9

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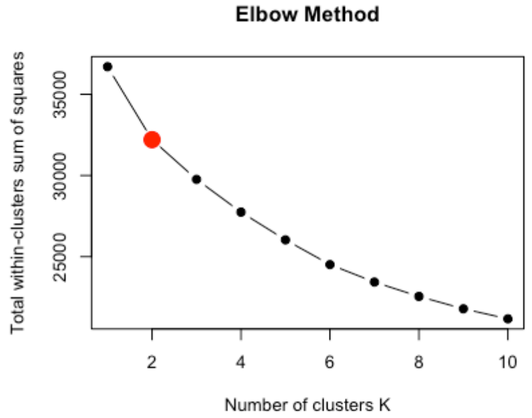
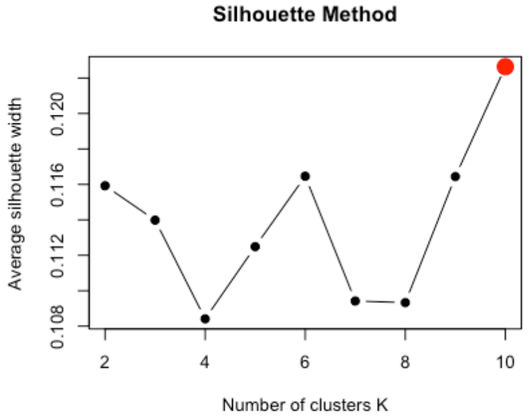
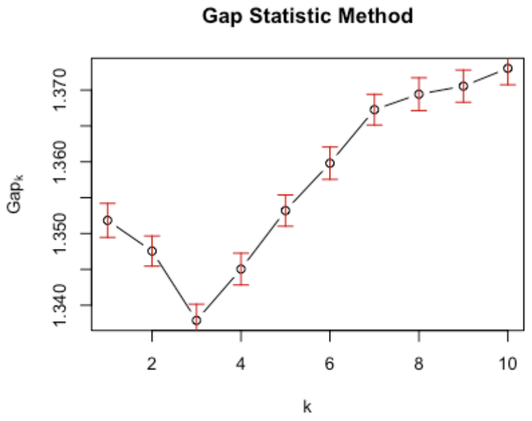
Unsupervised Clustering

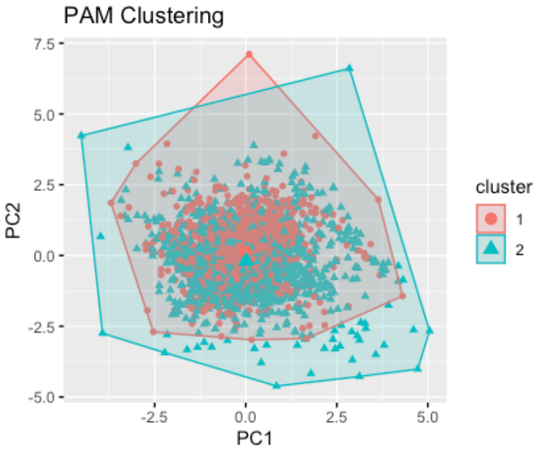
Total time taken: 2.06 mins

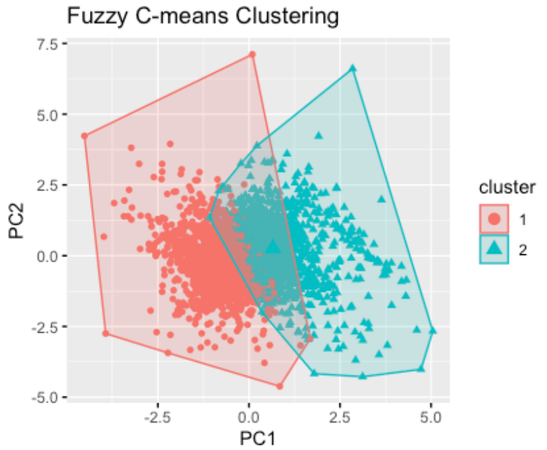
HAVING ONLY 2 CLUSTERS IS THE MOST OPTIMAL FOR OUR DATA. IN FACT, THE CLUSTERS ARE WELL-SEPARATED, AND THERE IS NO OVERLAPPING.











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Supervised Regression

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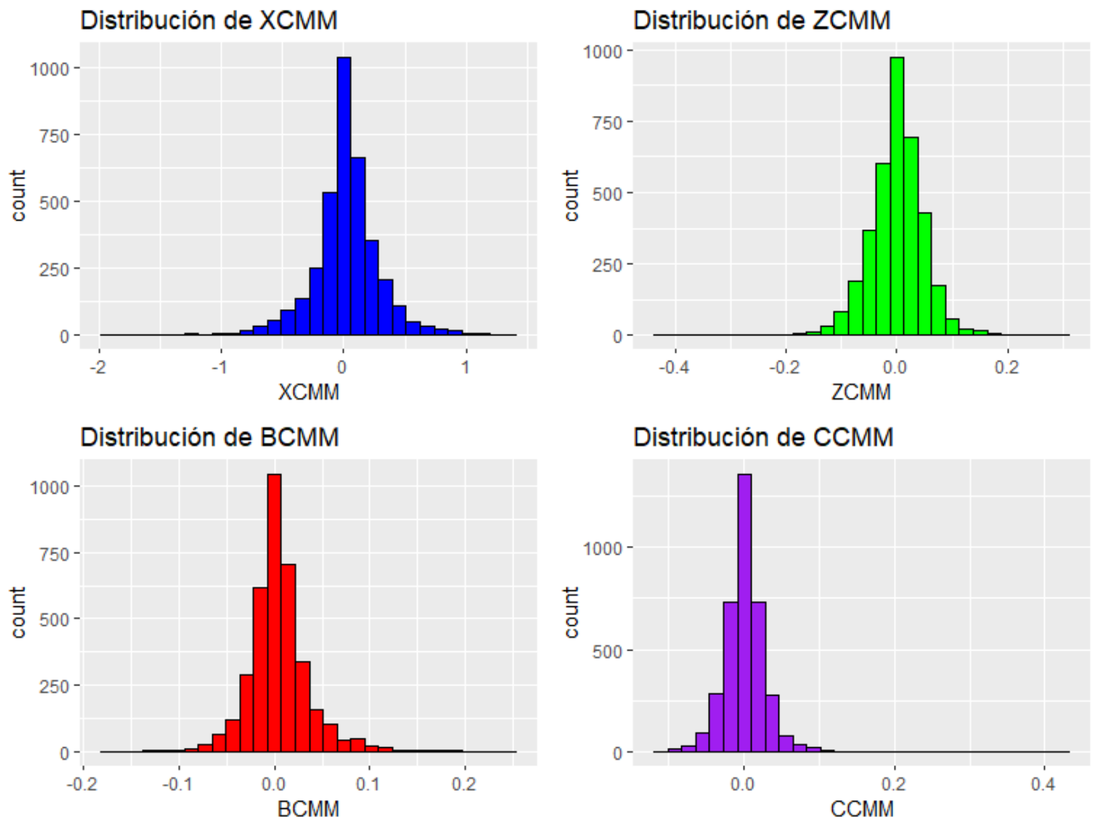

Distribution of Target Variables

ALL TARGET VARIABLES HAVE A FAIRLY NORMAL DISTRIBUTION. XC IS THE VARIABLE WITH THE HIGHEST VARIANCE AND IS THE MOST DIFFICULT TO PREDICT.

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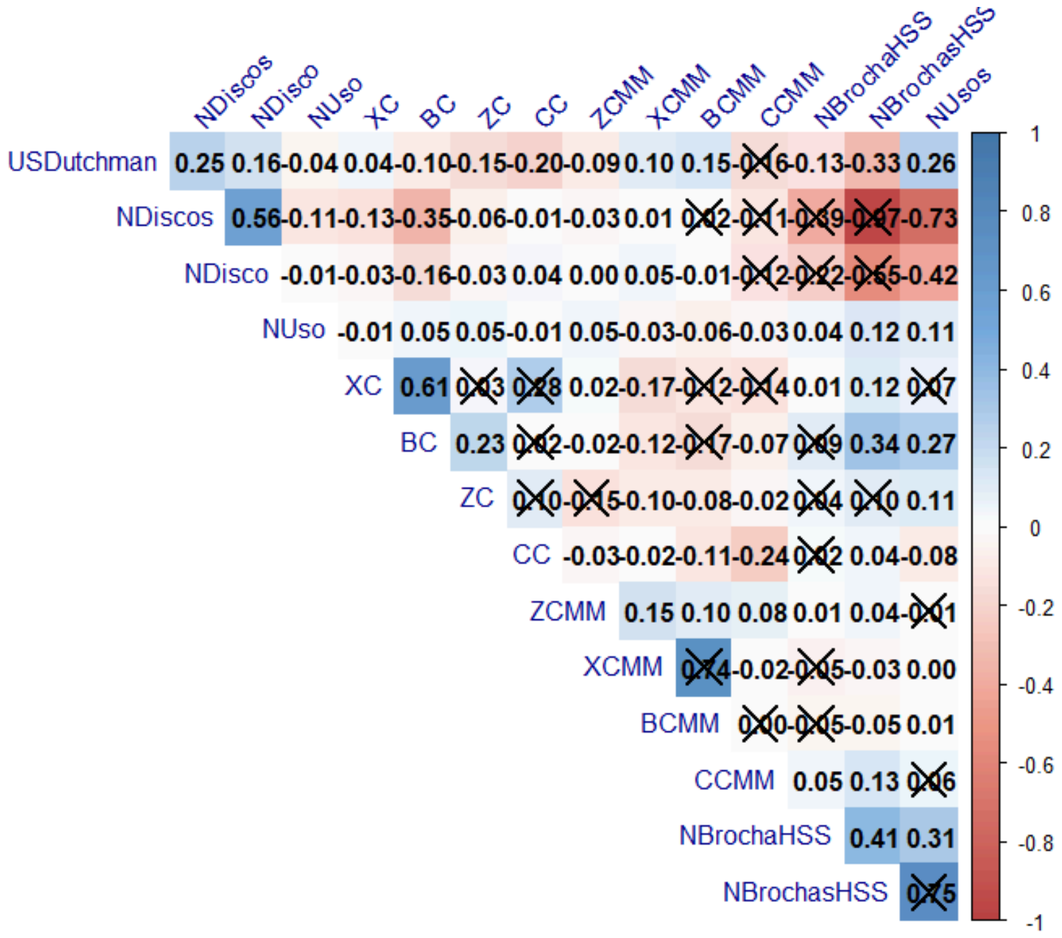

FEATURE ENGINEERING
Correlation

THERE ARE CERTAIN VARIABLES THAT ARE HIGHLY CORRELATED WITH EACH OTHER. FOR EXAMPLE, THE X-AXIS CORRECTOR (XCMM) IS HIGHLY CORRELATED WITH THE B-AXIS CORRECTOR (BCMM). THERE IS ALSO A HIGH CORRELATION BETWEEN NBROCHASHSS AND NUSOS OF 0.75.

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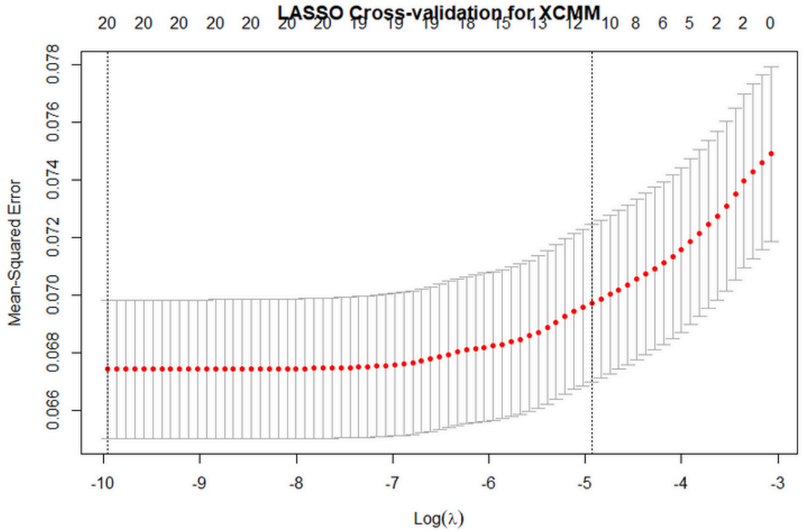
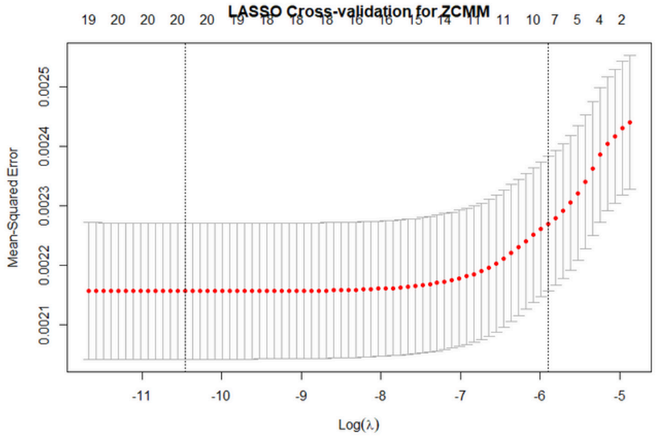
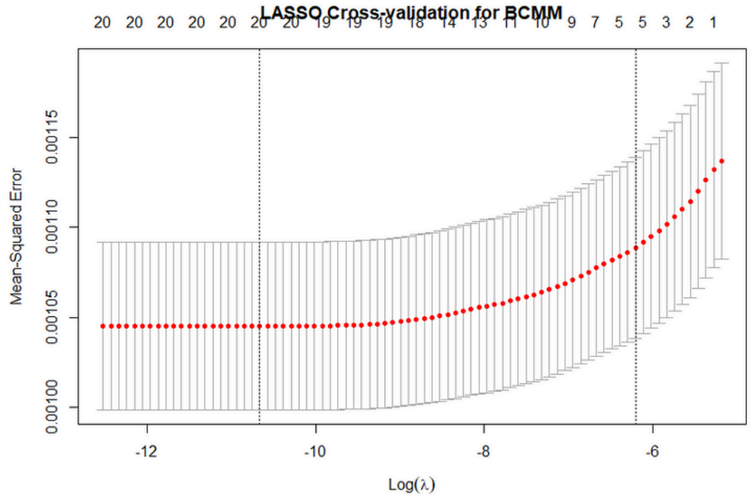
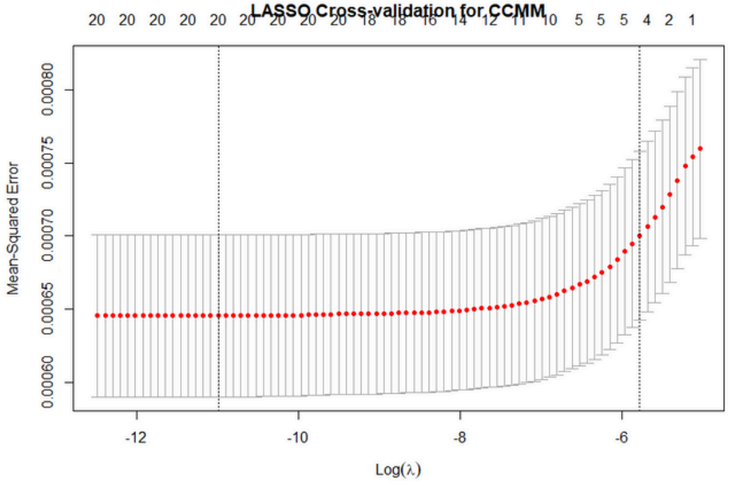
Results Lasso Regression

ALL OUR VARIABLES ARE SIGNIFICANT, SO WE CANNOT OMIT ANY VARIABLE FROM OUR MODEL.









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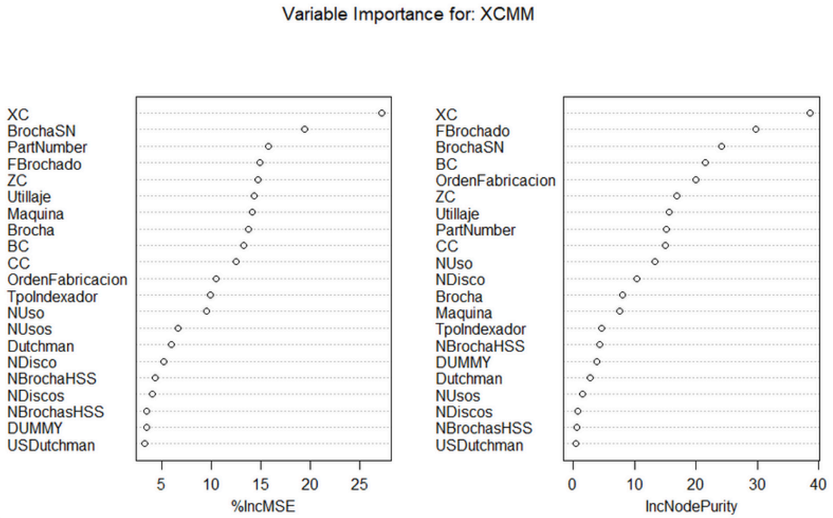
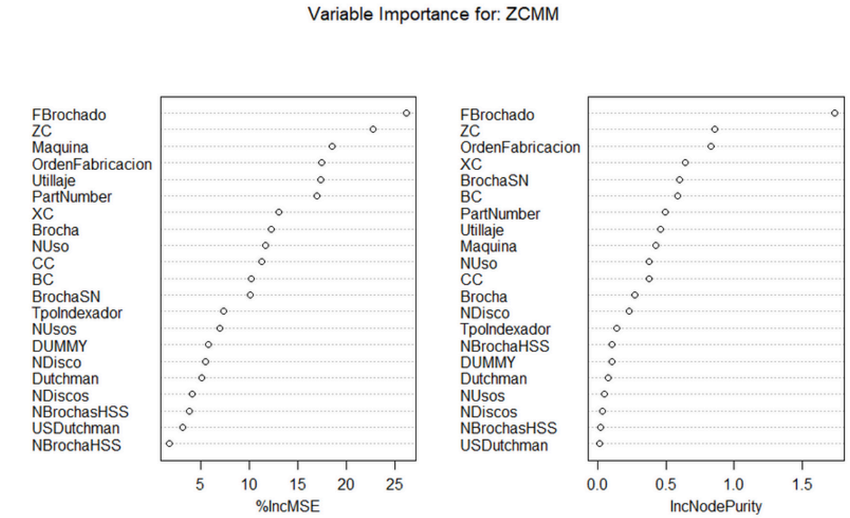
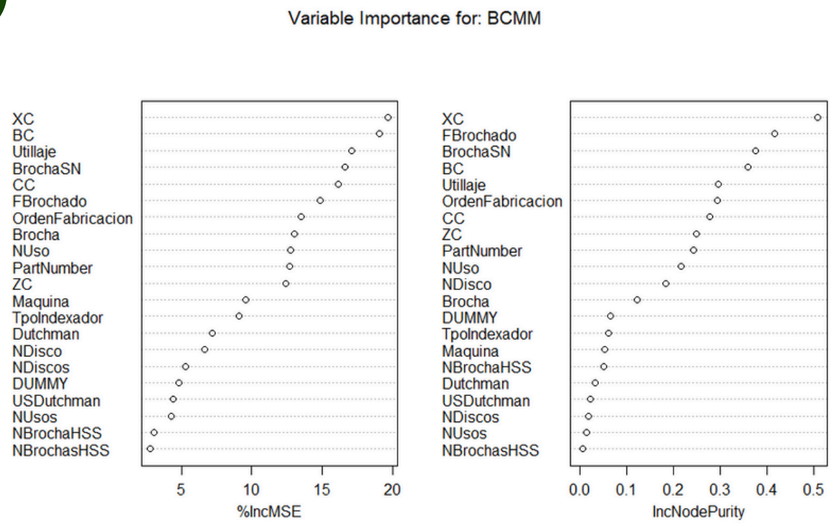
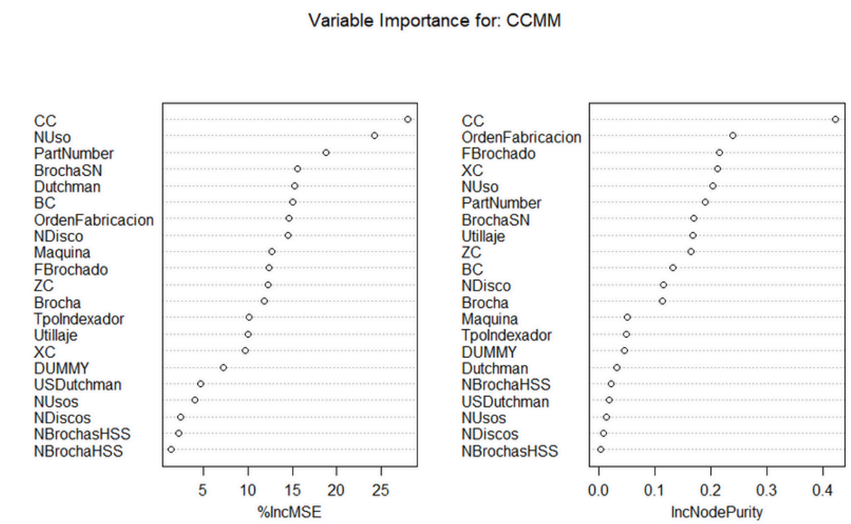
Importance of Dependent Variables

THE MOST SIGNIFICANT DEPENDENT VARIABLES ARE UTILLAJE, MAQUINA, BROCHA, TIPO INDEXADOR, Y ORDENFABRICACION









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--- Results of the **Linear Regression Model** ---

WE COMPARED ALGORITHMS USING THE PROFESSOR'S BASE CODE, MOSTLY WITHOUT MAJOR MODIFICATIONS TO ESTABLISH A BASELINE AND EVALUATE THE PERFORMANCE OF EACH MODEL FOR OUR PROBLEM.
SURPRISINGLY, THIS MODEL PERFORMS REMARKABLY WELL COMPARED TO THE OTHERS IN TERMS OF METRICS, WHICH COULD BE DUE TO THE NATURE OF THE DATA OR THE SIMPLE STRUCTURE OF THE UNDERLYING RELATIONSHIPS.

```
Resultados de predicción para la variable objetivo: XCMM
RMSE: 0.1550174
R-squared: 0.6843451
MAE: 0.04489245
Error Máximo: 1.633272

Resultados de predicción para la variable objetivo: ZCMM
RMSE: 0.02517703
R-squared: 0.7468559
MAE: 0.006653993
Error Máximo: 0.3834275

Resultados de predicción para la variable objetivo: BCMM
RMSE: 0.01738762
R-squared: 0.7255102
MAE: 0.004878562
Error Máximo: 0.2149986

Resultados de predicción para la variable objetivo: CCMM
RMSE: 0.01322425
R-squared: 0.7776438
MAE: 0.003706829
Error Máximo: 0.1905544
```


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--- Results of the **KNN Model** ---

It presented a very inferior performance, with low R-squares and high errors, this algorithm does not capture well the relationships in the data for this case.

```
Resultados de predicción para la variable objetivo: XCMM
RMSE: 0.2636578
R-squared: 0.08721923
MAE: 0.1861007
Error Máximo: 1.658

Resultados de predicción para la variable objetivo: ZCMM
RMSE: 0.04515444
R-squared: 0.185913
MAE: 0.03395983
Error Máximo: 0.3351538

Resultados de predicción para la variable objetivo: BCMM
RMSE: 0.03156794
R-squared: 0.09542559
MAE: 0.02192389
Error Máximo: 0.228

Resultados de predicción para la variable objetivo: CCMM
RMSE: 0.02633628
R-squared: 0.1182487
MAE: 0.01869477
Error Máximo: 0.4001538
```

--- **Random Forest Model** and **XGBOOST** Results ---

Although the initial versions showed improvements over KNN, with some simple tuning, these algorithms achieved exceptional performance in our final implementations.

Although Linear Regression shows acceptable results, more advanced models such as Random Forest and XGBoost provide better metrics with the adjustments made, making them our top choices for the final solution.

```
Resultados de predicción para la variable objetivo: XCMM
RMSE: 0.2591713
R-squared: 0.1628821
MAE: 0.18256
Error Máximo: 1.895682

Resultados de predicción para la variable objetivo: ZCMM
RMSE: 0.04607985
R-squared: 0.1542638
MAE: 0.03279023
Error Máximo: 0.3811703
```

```
Resultados de predicción para la variable objetivo: BCMM
RMSE: 0.03206198
R-squared: 0.1464778
MAE: 0.02239358
Error Máximo: 0.2153056

Resultados de predicción para la variable objetivo: CCMM
RMSE: 0.02132959
R-squared: 0.4215671
MAE: 0.01509529
Error Máximo: 0.1689157
```

```
Variable: XCMM
RMSE: 0.2622925
R-squared: 0.3012022
MAE: 0.1792448
Error Máximo: 1.873897

Variable: ZCMM
RMSE: 0.04701426
R-squared: 0.3103153
MAE: 0.03380073
Error Máximo: 0.4143787

Variable: BCMM
RMSE: 0.03079629
R-squared: 0.3396659
MAE: 0.02078967
Error Máximo: 0.2449264

Variable: CCMM
RMSE: 0.02598246
R-squared: 0.3319564
MAE: 0.01786588
Error Máximo: 0.386086
```

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Time to get serious...

WE NEED A MORE INTRICATE MODEL IN
ORDER TO REACH OUR GOALS

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Data Cleaning

We remove de NA’s and convert all of our variables to factors or numeric values

```
Training models for XCMM (1/4)

Before preprocessing: XCMM
Number of rows: 3671
Number of NA values in target: 1
Range of target values: -1.872 1.411

After preprocessing: XCMM
Number of rows: 3671
Number of NA values in target: 0
Range of target values: -1.872 1.411
```

```
Training models for ZCMM (2/4)

Before preprocessing: ZCMM
Number of rows: 3671
Number of NA values in target: 1
Range of target values: -0.42 0.307

After preprocessing: ZCMM
Number of rows: 3671
Number of NA values in target: 0
Range of target values: -0.42 0.307
```

```
Training models for BCMM (3/4)

Before preprocessing: BCMM
Number of rows: 3671
Number of NA values in target: 1
Range of target values: -0.17 0.251

After preprocessing: BCMM
Number of rows: 3671
Number of NA values in target: 0
Range of target values: -0.17 0.251
```

```
Training models for CCMM (4/4)

Before preprocessing: CCMM
Number of rows: 3671
Number of NA values in target: 1
Range of target values: -0.105 0.43

After preprocessing: CCMM
Number of rows: 3671
Number of NA values in target: 0
Range of target values: -0.105 0.43
```

Brocha	NBrochasHSS	NDiscos	NUsos	USDutchman	BrochaSN	OrdenFabricacion	PartNumber	NUso	NBrochaHSS	NDisco	FBrochado	DUMMY	Dutchman	Maquina	TpoIndexador	Utillaje	XC	ZC	BC	CC	XCMM	ZCMM	BCMM	CCMM
011.0082.300	2	2	11	7	E0473	142	12	7	1	2	2023-10-01 22:29:34	FALSE	FALSE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0029	0.020	0.130	-0.010	-0.010	0.063	-0.024	0.020	0.032
011.0081.300	2	2	11	7	E0454	62	11	10	1	1	2023-10-02 01:20:03	FALSE	TRUE	HOFFMANN	IND-4 WALTER 900	UBR.0028	-0.450	-0.020	0.000	-0.030	0.020	-0.020	0.000	0.000
011.0070.300	2	2	11	7	E0462	146	16	11	1	1	2023-10-02 04:25:41	FALSE	TRUE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0017	0.190	0.070	0.000	0.090	-0.260	-0.020	-0.020	0.000
011.0082.300	2	2	11	7	E0473	86	9	7	2	1	2023-10-02 10:52:05	FALSE	FALSE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0031	0.100	0.120	0.020	0.020	0.017	-0.020	0.004	-0.020
011.0070.300	2	2	11	7	E0450	151	17	3	2	1	2023-10-02 16:30:07	FALSE	FALSE	HOFFMANN	IND-4 WALTER 900	UBR.0018	0.700	0.060	0.070	0.020	0.090	0.030	0.030	0.000
011.0081.300	2	2	11	7	E0454	63	11	10	1	2	2023-10-02 16:32:56	FALSE	TRUE	HOFFMANN	IND-4 WALTER 900	UBR.0028	-0.450	-0.020	0.000	-0.030	0.520	-0.070	0.060	-0.020
011.0070.300	2	2	11	7	E0462	147	16	11	1	2	2023-10-02 16:58:27	FALSE	TRUE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0017	0.190	0.070	0.000	0.090	-0.210	-0.051	-0.030	0.011
011.0070.300	2	2	11	7	E0450	212	17	3	2	2	2023-10-02 20:20:07	FALSE	FALSE	HOFFMANN	IND-4 WALTER 900	UBR.0018	0.700	0.060	0.070	0.020	0.200	0.052	0.041	0.005
011.0082.300	2	2	11	7	E0473	64	9	7	2	2	2023-10-02 23:34:52	FALSE	FALSE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0031	0.100	0.120	0.020	0.020	-0.047	0.024	0.007	-0.011
011.0081.300	2	2	11	7	E0454	61	11	10	2	1	2023-10-03 03:11:01	FALSE	TRUE	HOFFMANN	IND-4 WALTER 900	UBR.0028	0.000	-0.020	0.040	-0.030	0.308	-0.044	0.045	-0.001
011.0070.300	2	2	11	7	E0462	175	16	11	2	1	2023-10-03 04:13:50	FALSE	TRUE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0017	0.190	0.070	-0.010	0.090	0.200	0.020	0.030	-0.040
011.0070.300	2	2	11	7	E0462	205	16	11	2	2	2023-10-03 11:50:51	FALSE	TRUE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0017	0.190	0.070	-0.010	0.090	0.240	0.000	0.030	-0.020
011.0082.300	2	2	11	7	E0478	139	12	10	1	1	2023-10-04 00:01:18	FALSE	TRUE	LAPOINTE	IND-5 LAPOINTE 900	UBR.0029	0.090	0.130	0.020	-0.010	-0.400	0.006	-0.047	0.026
011.0077.300	2	2	11	7	E0388	130	20	5	1	1	2023-10-04 03:05:07	FALSE	FALSE	HOFFMANN	IND-4 WALTER 900	UBR.0014	0.500	0.070	0.090	-0.020	-0.560	-0.034	-0.056	-0.010

Analysis and Interpretation

FINALLY, WE EVALUATE OUR BEST MODELS AND FIND WHICH MODEL IS BEST SUITED FOR OUR DATA

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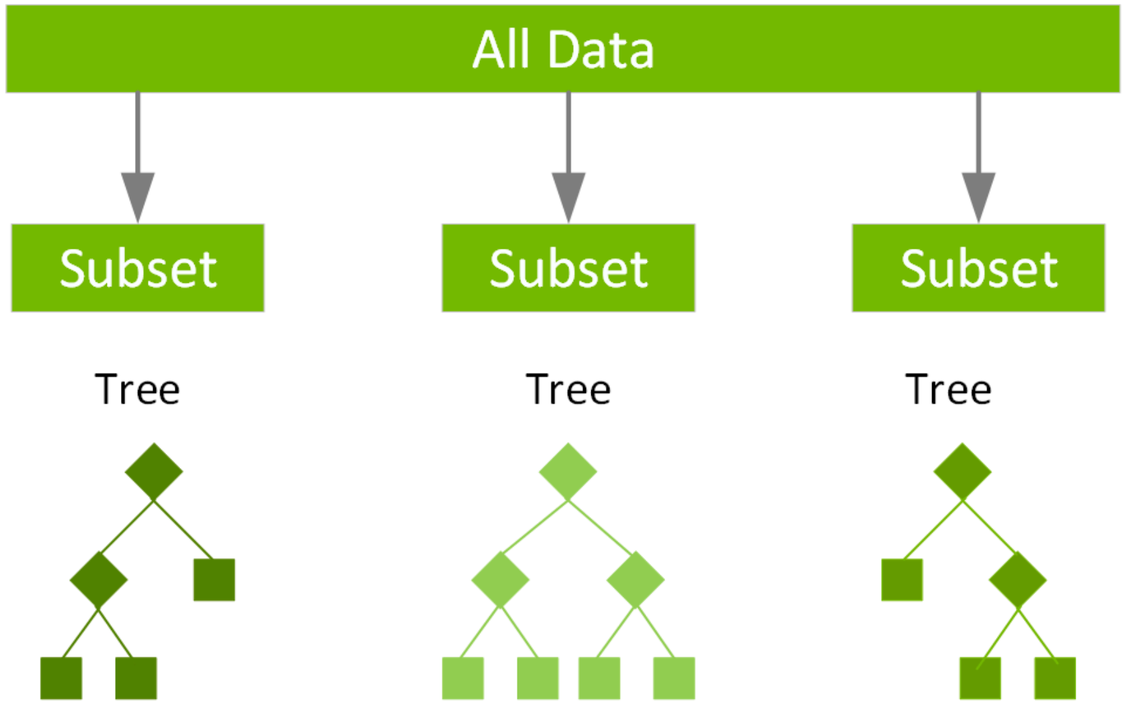

Best Model

OUR BEST MODEL UTILIZES
THE GBM LIBRARY

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Results

Total time taken: 44.94 mins

ALL OF OUR MODELS ARE COMPLIANT WITH THE REQUIREMENTS FOR ITP AERO. OUR MODELS ARE NOT ONLY EFFICIENT BUT THEY ARE ALSO PRECISE

Impact

ALGORITHM THAT CORRECTLY PREDICTS THE ADJUSTMENTS NEEDED FOR THE BROACHES

XCMM Performance:
RMSE: 0.08814414
MAE: 0.0501303
R-squared: 0.9001386
Max Error: 0.7921584

Best Model: XGBoost
Parameters:
eta: 0.05
max_depth: 8
min_child_weight: 3
subsample: 0.7
colsample_bytree: 0.9
gamma: 0
lambda: 0
alpha: 0
nrounds: 883

ZCMM Performance:
RMSE: 0.01409206
MAE: 0.01016351
R-squared: 0.9185699
Max Error: 0.07996002

Best Model: XGBoost
Parameters:
eta: 0.05
max_depth: 8
min_child_weight: 5
subsample: 0.9
colsample_bytree: 0.9
gamma: 0
lambda: 0
alpha: 0
nrounds: 530

BCMM Performance:
RMSE: 0.01161132
MAE: 0.007638338
R-squared: 0.8693849
Max Error: 0.06695456

Best Model: XGBoost
Parameters:
eta: 0.05
max_depth: 8
min_child_weight: 5
subsample: 0.9
colsample_bytree: 0.7
gamma: 0
lambda: 0
alpha: 0
nrounds: 761

CCMM Performance:
RMSE: 0.007964692
MAE: 0.005251023
R-squared: 0.9085278
Max Error: 0.06480309

Best Model: XGBoost
Parameters:
eta: 0.05
max_depth: 8
min_child_weight: 5
subsample: 0.7
colsample_bytree: 0.7
gamma: 0
lambda: 0
alpha: 0
nrounds: 607

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Thank You

Note: All the code of the three R scripts can be executed entirely within the R environment. In addition, it is recommended to have a computer with sufficient resources to ensure a reasonable run time and training of the models.

Access to the code: The complete code of the three R scripts will be available in the GitHub links after December 20 deadline. You can access them by clicking on each corresponding name in the text of this presentation.

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Bibliography

TIDYVERSE

CLUSTER

FPC

FACTOEXTRA

E1071

NBCLUST

GRIDEXTRA

CARET

DPLYR

XGBOOST

RANDOMFOREST