PRODUCTION TIME SERIES – CONTROL AND PREDICTION OF PROCESS ERROR

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AUGUST, 2017

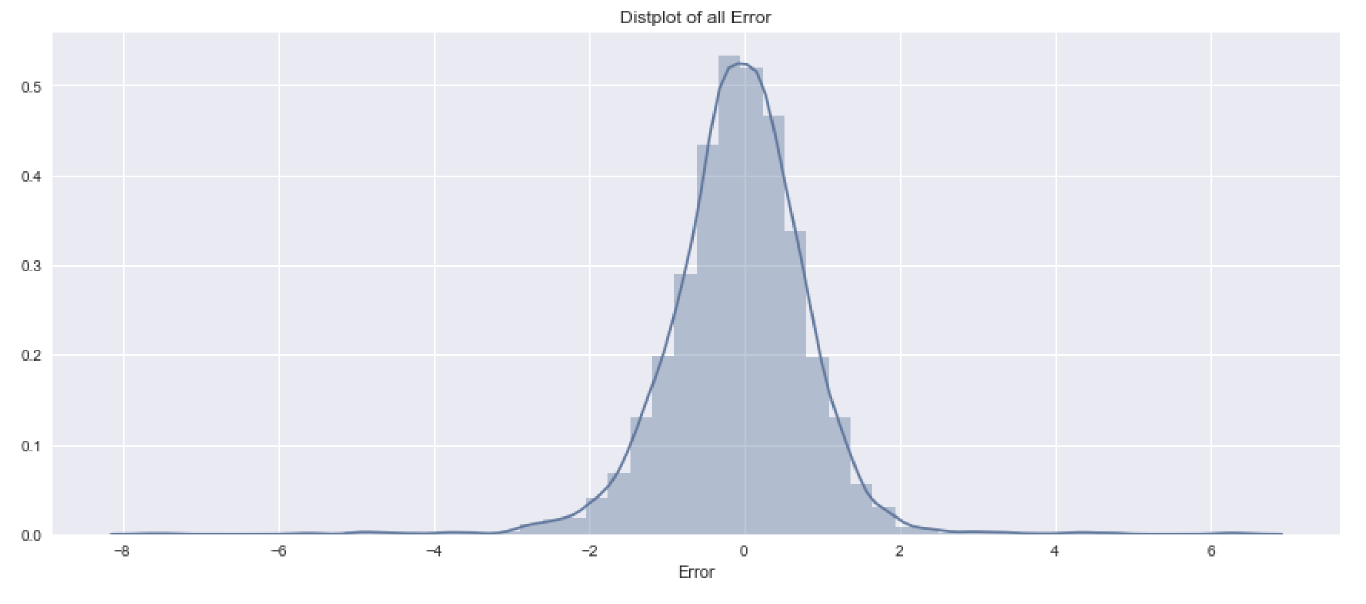
PROJECT OVERVIEW & GOALS

- Overview:
  - Customer has come to me with a dataset that gives historical run sequence through several toolsets suitable for time series lagging. (detailed descriptions provided in “Data Dictionary.txt” on Github)
  - The process uses statistical process control in a manufacturing environment.
  - The key starting assumption from the customer is that other noise/error sources are not important and this assumption may not be true.
- Key Goals:
  - Find any correlations between lagged data and larger |Error| which would be suitable for implementation of run rules in the production line (i.e. prevent these sequences from occurring).
  - Determine if any models can be developed to predict Error based on previous runs through the tool under the assumption of no other dominant error sources.
  - Advise on next steps to improve modeling capability

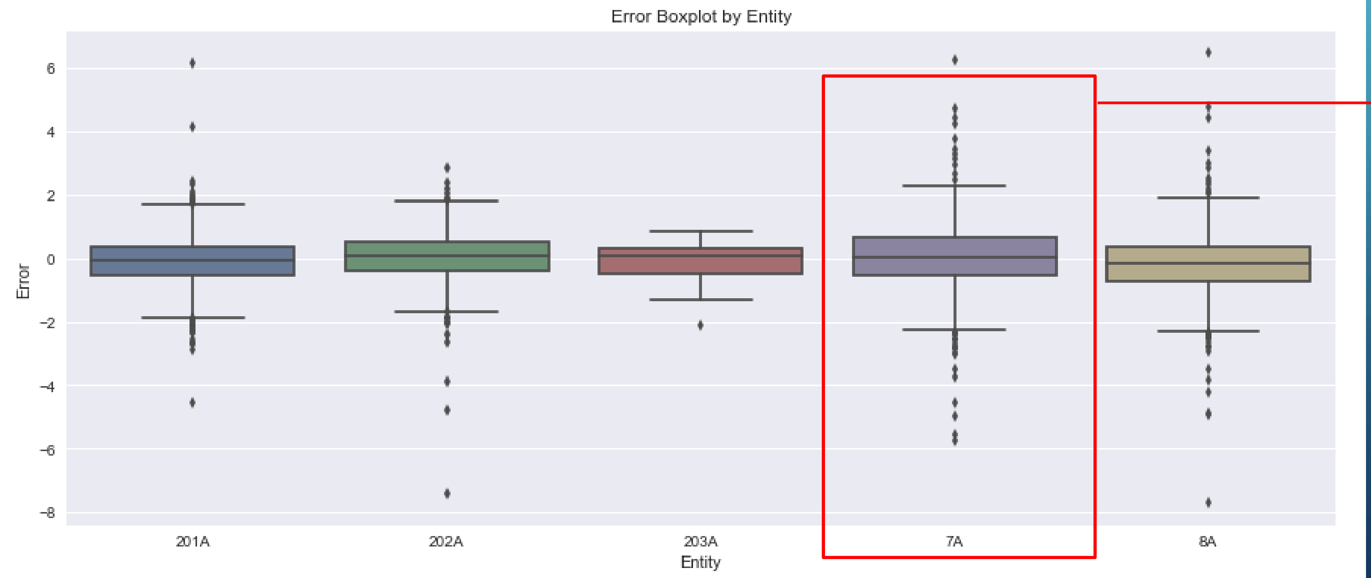
DATA CLEANING

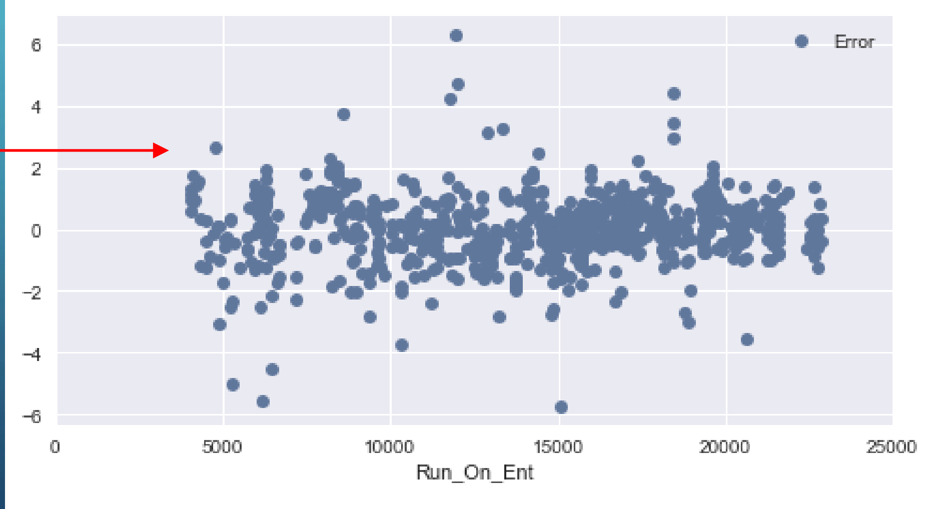
- **Cleaning:**
  - Customer supplied dataset contains a large anonymized dataset of time series sequence through several identical toolsets.
  - Timestamps are removed and converted to sequential runs, thus protecting IP metrics.
  - Error columns were normalized to zero
  - Error is available for smaller subset of the data, but the entire run history is relevant for lagging previous runs, thus NaN were not removed/altered prior to lagging. The key features/attributes of previous 'lagged' runs is what is being correlated to each instance of Error.
  - See "final_text" on Github for more explicit summary

DATA

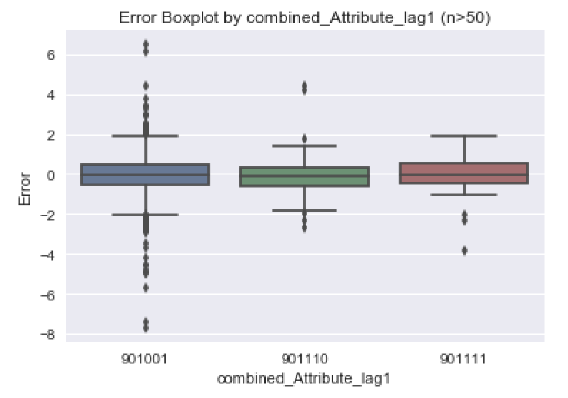


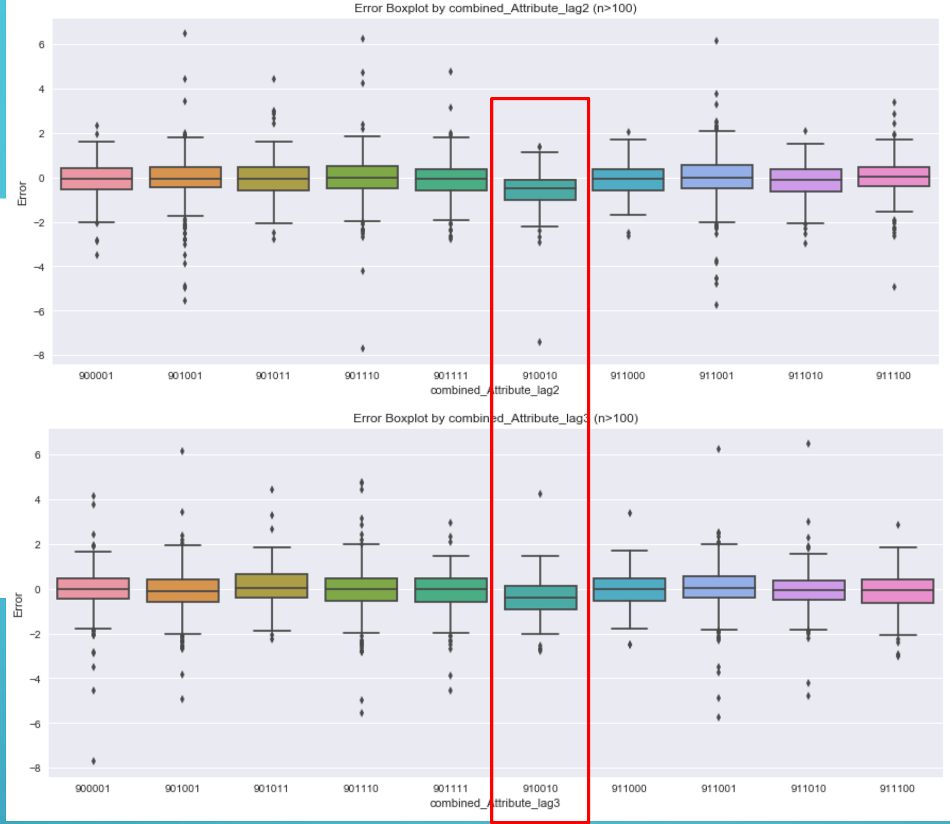
	Count_Nulls
Data_Column	
Error	67583
DIC_Design	65961
Fam_Type	65961
Attribute5	0
Attribute4	0
Attribute3	0
Attribute2	0
Attribute1	0
Feature4	0
Feature3	0
Feature2	0
Feature1	0
Op	0
Lot	0
Run_On_Ent	0
Entity	0

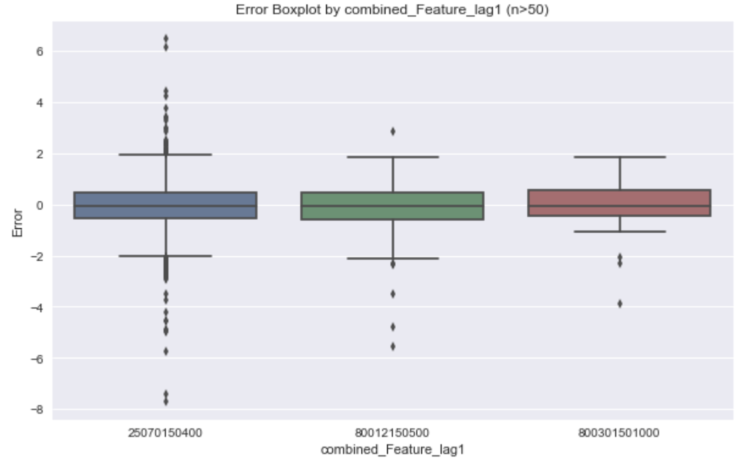


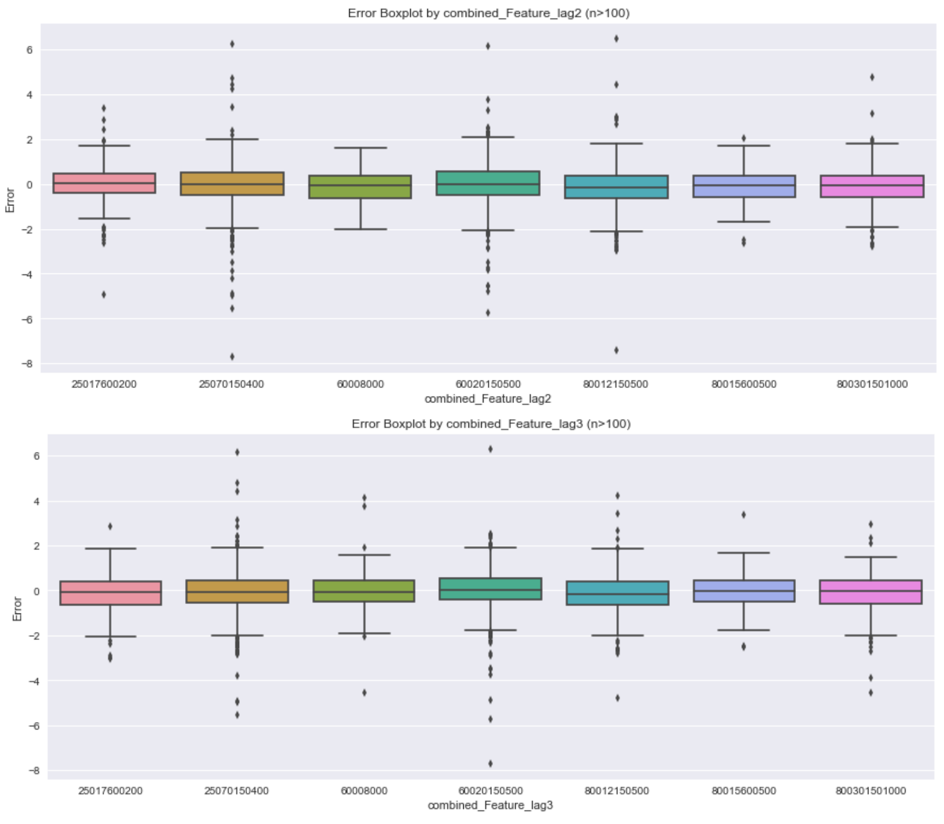


DATA LAG SUMMARY









TUKEY HSD – 910010

```
mc = MultiComparison(CAL2['Error'], CAL2['combined_Attribute_lag2'])

Multiple Comparison of Means - Tukey HSD,FWER=0.05
=============================================
group1 group2 meandiff  lower   upper  reject
---------------------------------------------
900001 910010  -0.518  -0.8024 -0.2335  True
901001 910010 -0.5299  -0.8072 -0.2526  True
901011 910010 -0.5594  -0.8673 -0.2515  True
901110 910010 -0.5653  -0.8429 -0.2878  True
901111 910010 -0.4675  -0.7425 -0.1926  True
910010 911000  0.462    0.1126  0.8113  True
910010 911001  0.5879   0.3159   0.86   True
910010 911010  0.4072   0.1115  0.7029  True
910010 911100  0.6203   0.3352  0.9054  True
---------------------------------------------
['900001' '901001' '901011' '901110' '901111' '910010' '911000' '911001'
 '911010' '911100']
```

```
mc = MultiComparison(CAL3['Error'], CAL3['combined_Attribute_lag3'])

Multiple Comparison of Means - Tukey HSD,FWER=0.05
=============================================
group1 group2 meandiff  lower   upper  reject
---------------------------------------------
900001 910010 -0.3634  -0.6291 -0.0977  True
901001 910010  -0.325  -0.5723 -0.0777  True
901011 910010 -0.5151  -0.8247 -0.2055  True
901110 910010 -0.3872  -0.6374 -0.1369  True
901111 910010 -0.3309  -0.5951 -0.0666  True
910010 911001  0.4425   0.1761  0.7088  True
910010 911010  0.336    0.0526  0.6194  True
910010 911100  0.2823   0.0138  0.5508  True
---------------------------------------------
['900001' '901001' '901011' '901110' '901111' '910010' '911000' '911001'
 '911010' '911100']
```

Customer has clear outlier for one particular combined attribute (910010):

Recommendation to investigate run rules to prevent this sequence and improve overall control of process error.

PREDICTION

Model:	Linear SGD	Linear Lasso	Linear Ridge
CV MSE score	0.9238	0.9341	0.9231
explained variance	0.0218	0	0.0234
R^2 coef of determination	0.0215	-0.0003	0.0232

Model:	Random Forest	SVM poly	kNN
CV MSE score	0.8714	0.8714	0.9152
explained variance	-0.1319	0.0028	0.0054
R^2 coef of determination	-0.1395	-0.0155	0.0053

All models indicate good fitting but very low explained variance.
Likely cause is unaccounted for noise sources in the data.

SUMMARY

- Goals and assumptions:
  - Find any correlations between lagged data and larger |Error| which would be suitable for implementation of run rules in the production line.
  - See if any models can predict Error based on previous runs through the tool.
  - Key initial assumptions: other noise/error sources are not important (may/may not be true)
- **Findings and recommendations:**
  - very strong outliers in the Error found that are suitable to perform DOE to prove run rules are indeed needed. *Customer was able to confirm this with DOE and begin pilot to prevent occurrence
  - Regressions yield models w ~0.9 MSE and are scores are reproducible on test
    - none of the models are very good at explaining variance in the data. Conclusion is that the assumption of other noise/errors sources being unimportant is likely false. Recommendation to further improve the model is to retrieve other sources of data that can me incorporated into the model.
  - Recommendation for next phase of modeling is to incorporate Heat maps of optical emission spectra for the fixed setup run (aka lag1) and each critical plate that measures Error.