CNC MACHINING TOOL-WEAR DETECTION

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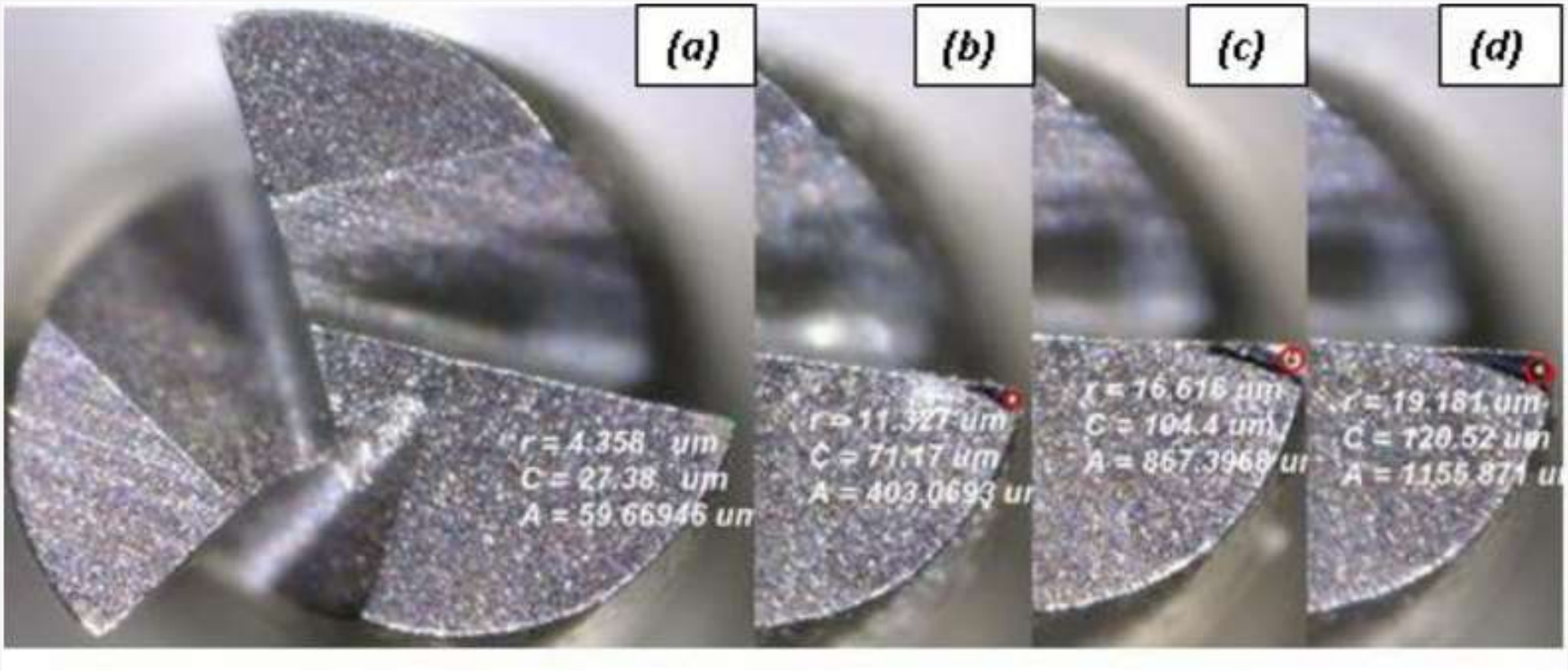
Background

Tool Ware



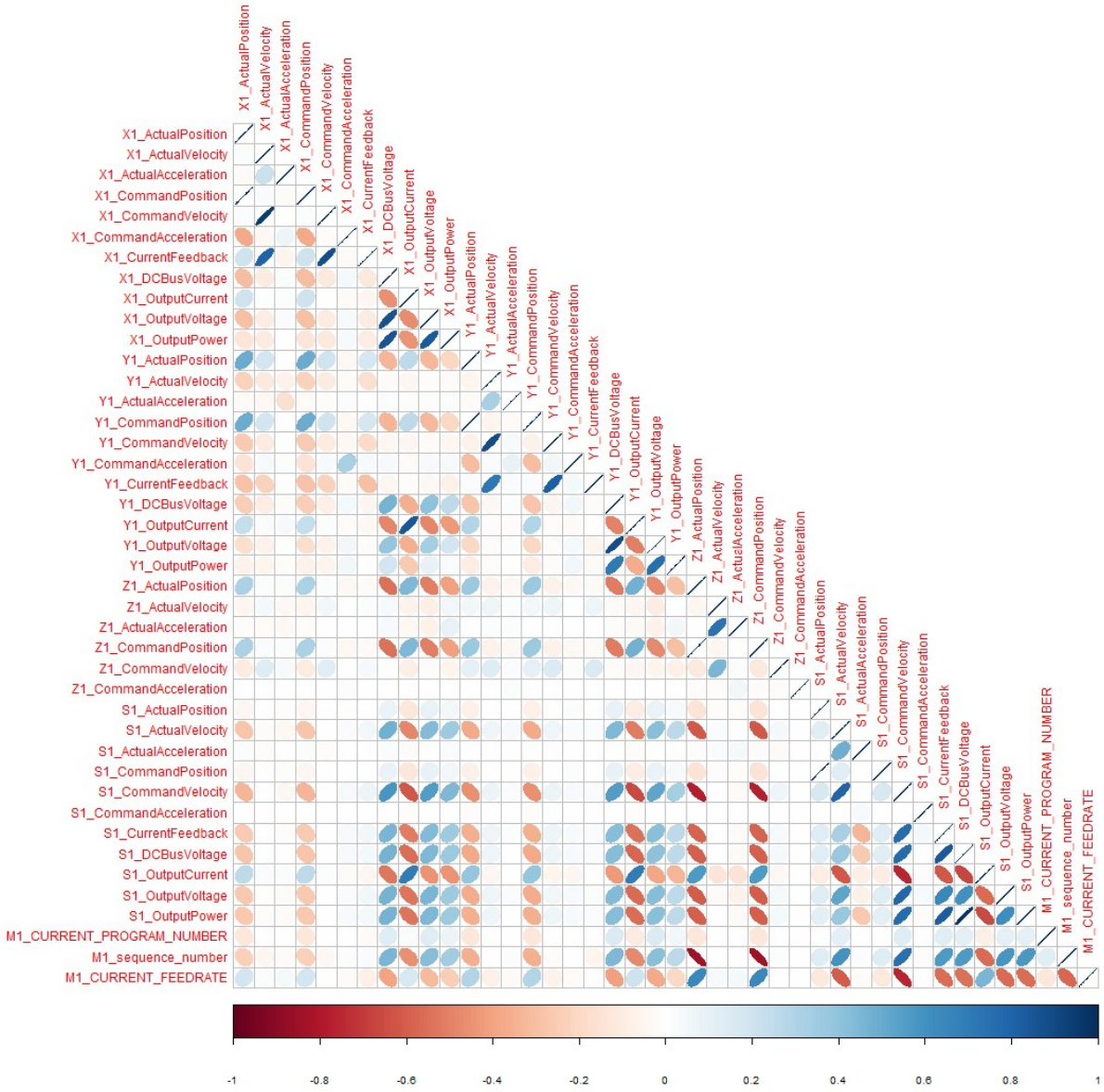
Tool wear evolution of end milling: (a) a new tool, (b) a worn tool, (c) and (d) severely worn tools

Tool Wear in Micro-End milling: Material Microstructure Effects, Modeling and Experimental Validation

Data Set

- 18 experiments
- 45 Variables
  - X,Y,Z,S dimensions
  - Position, Velocity, Acceleration
    - Command and Actual
    - Output power
    - Current feedback
  - Sequence (G-code Line) and group
  - Feedrate

DATA SET


X1_ActualPosition
X1_ActualVelocity
X1_ActualAcceleration
X1_CommandPosition
X1_CommandVelocity
X1_CommandAcceleration
X1_CurrentFeedback
X1_DCBusVoltage
X1_OutputCurrent
X1_OutputVoltage
X1_OutputPower
Y1_ActualPosition
Y1_ActualVelocity
Y1_ActualAcceleration
Y1_CommandPosition
Y1_CommandVelocity
Y1_CommandAcceleration
Y1_CurrentFeedback
Y1_DCBusVoltage
Y1_OutputCurrent
Y1_OutputVoltage
Y1_OutputPower
Z1_ActualPosition
Z1_ActualVelocity
Z1_ActualAcceleration
Z1_CommandPosition
Z1_CommandVelocity
Z1_CommandAcceleration
S1_ActualPosition
S1_ActualVelocity
S1_ActualAcceleration
S1_CommandPosition
S1_CommandVelocity
S1_CommandAcceleration
S1_CurrentFeedback
S1_DCBusVoltage
S1_OutputCurrent
S1_OutputVoltage
S1_OutputPower
M1_CURRENT_PROGRAM_NUMBER
M1_sequence_number
M1_CURRENT_FEEDRATE
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

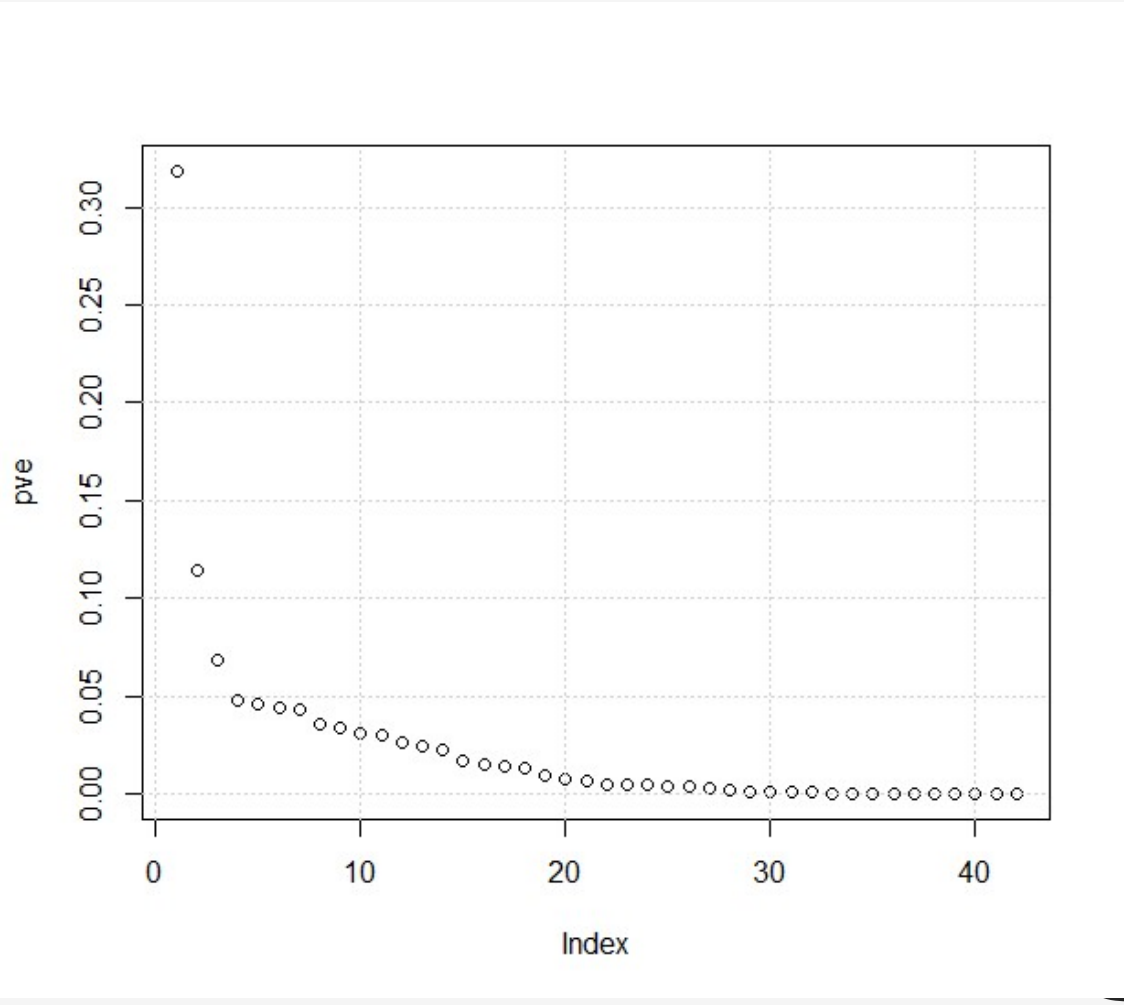
PCA

Goals: Reduce

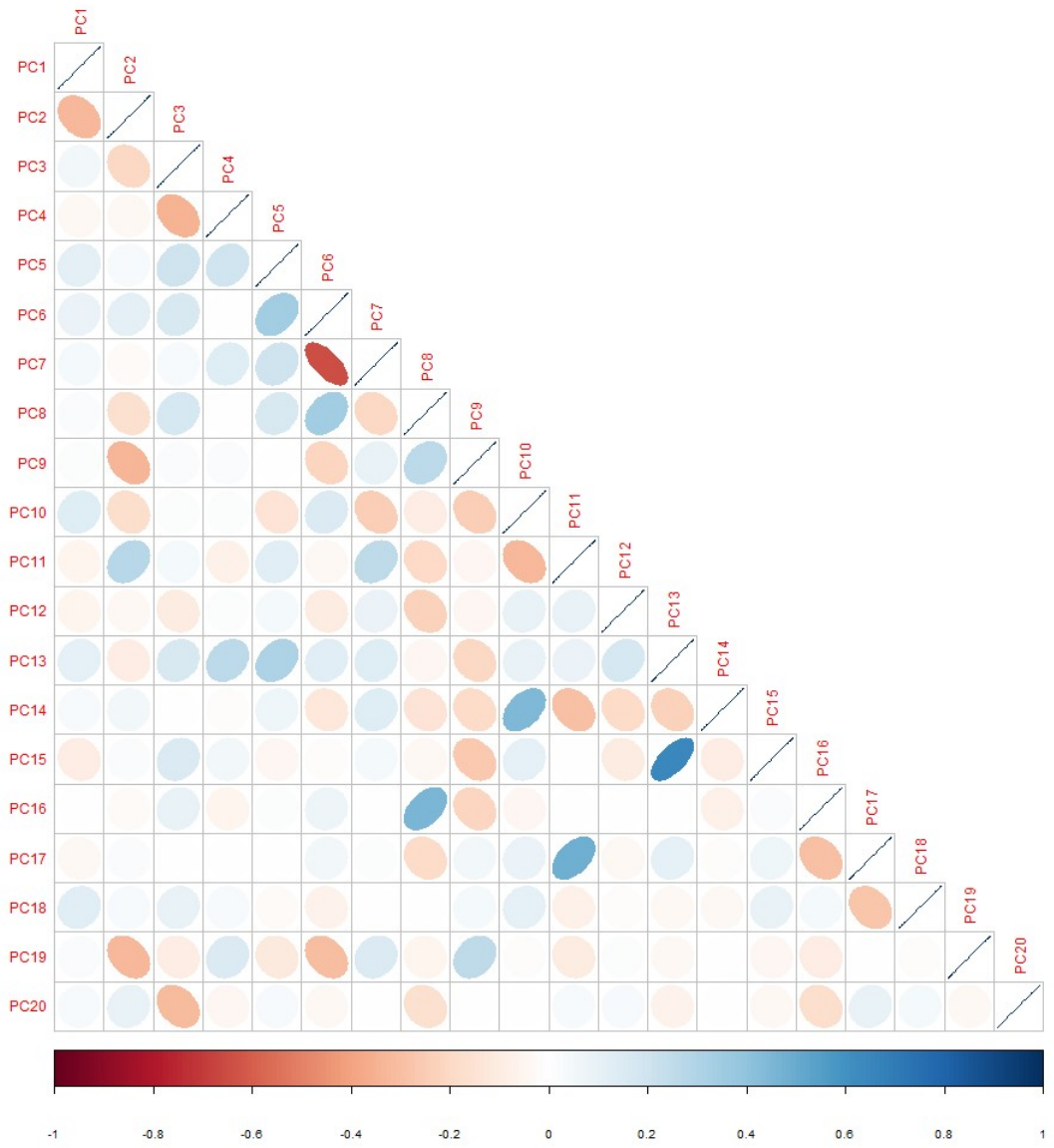
- Dimensionality
- Correlation

Results:

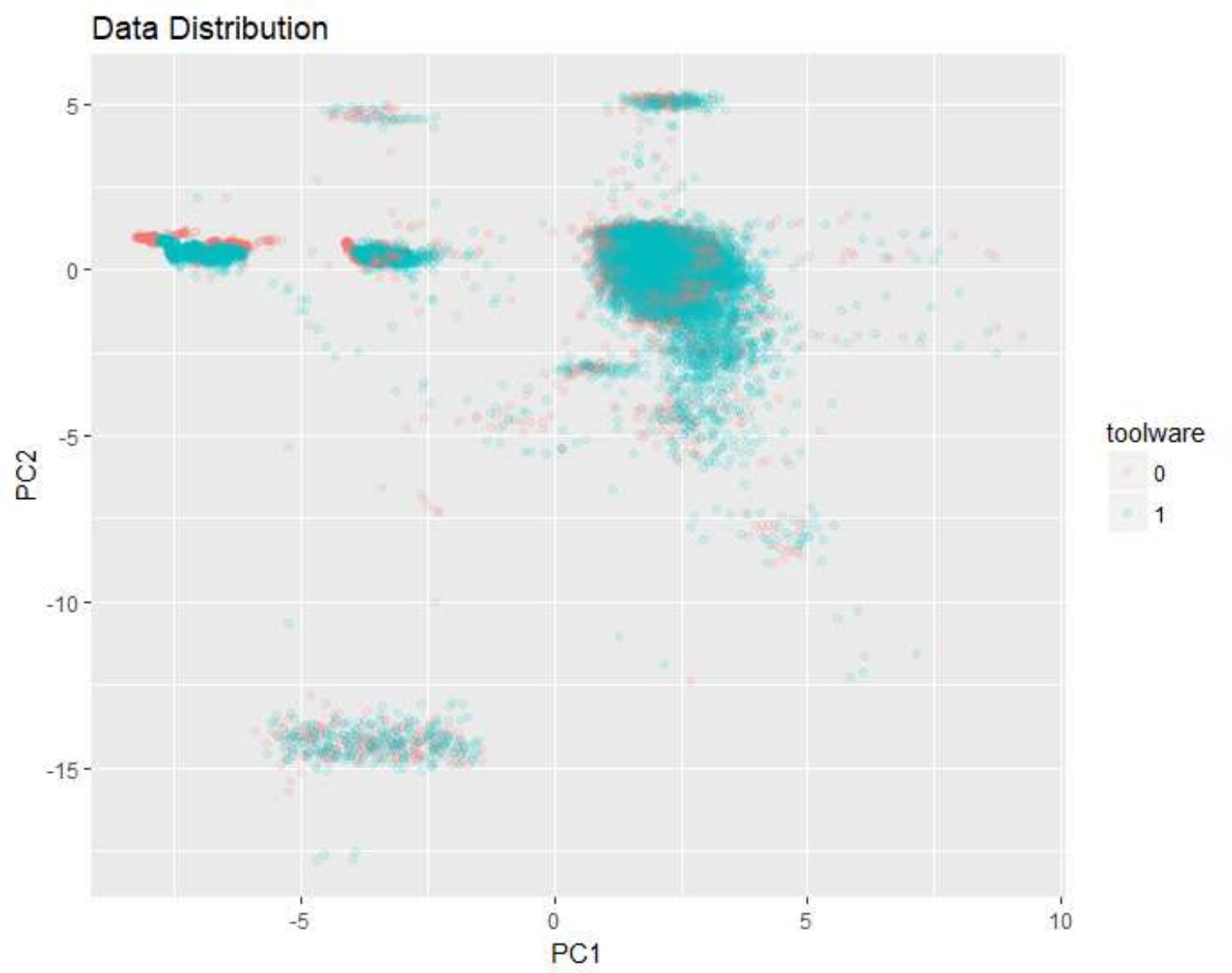
- First 20 Components
  - Preserved 96% of Variance



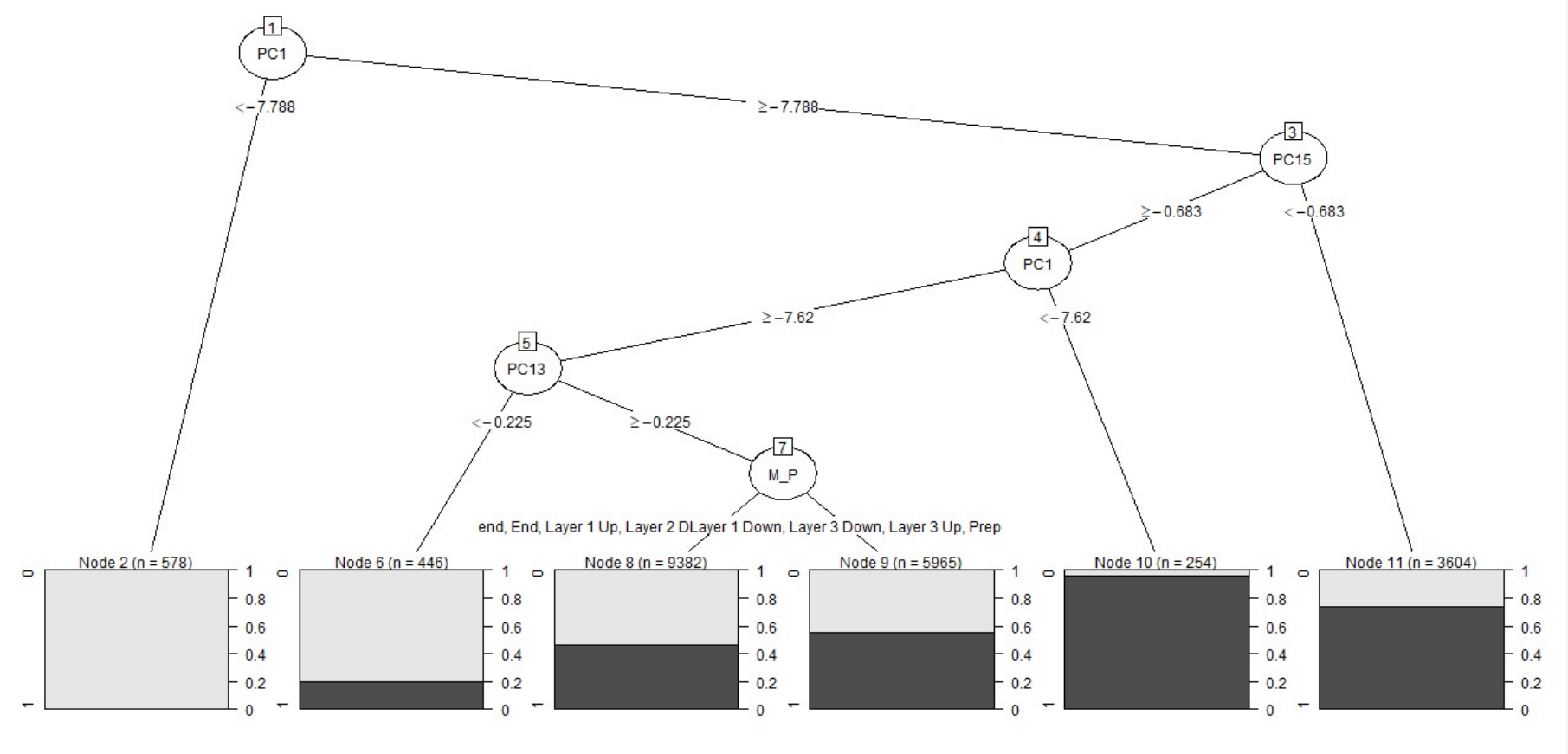
PCA


PC1
PC2
PC3
PC4
PC5
PC6
PC7
PC8
PC9
PC10
PC11
PC12
PC13
PC14
PC15
PC16
PC17
PC18
PC19
PC20
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Clustering?

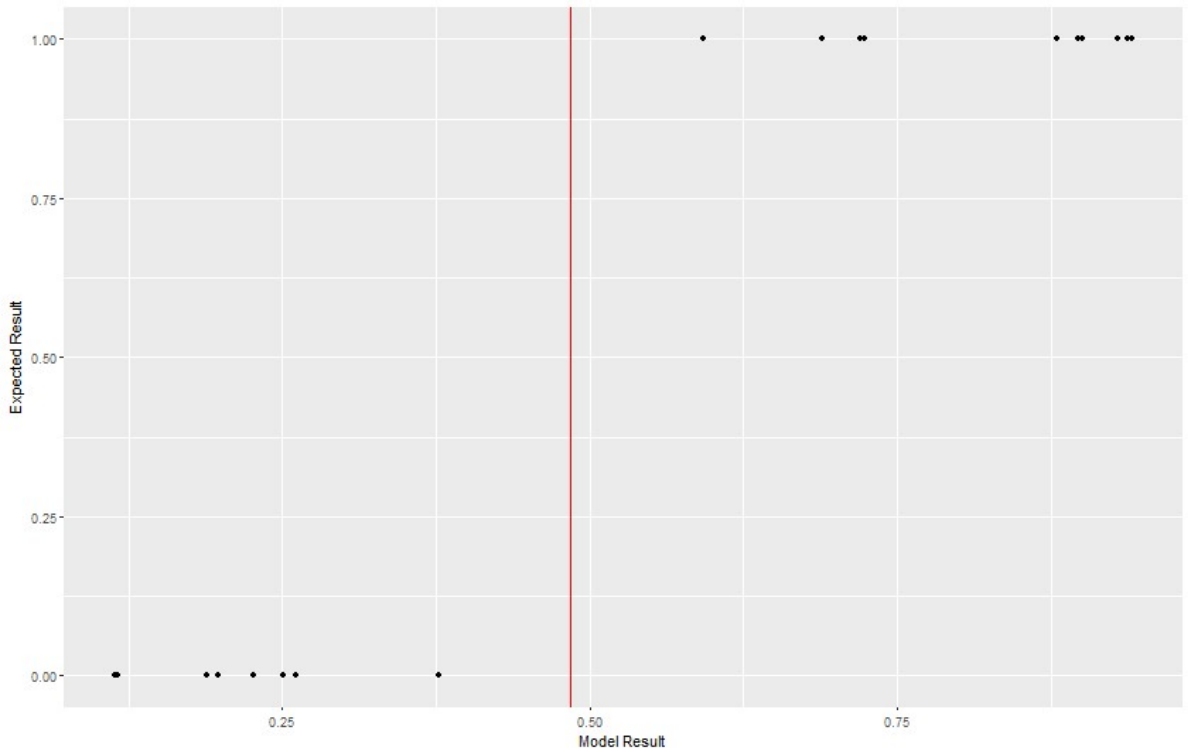


Tree Model: PCA



Tree Model: PCA

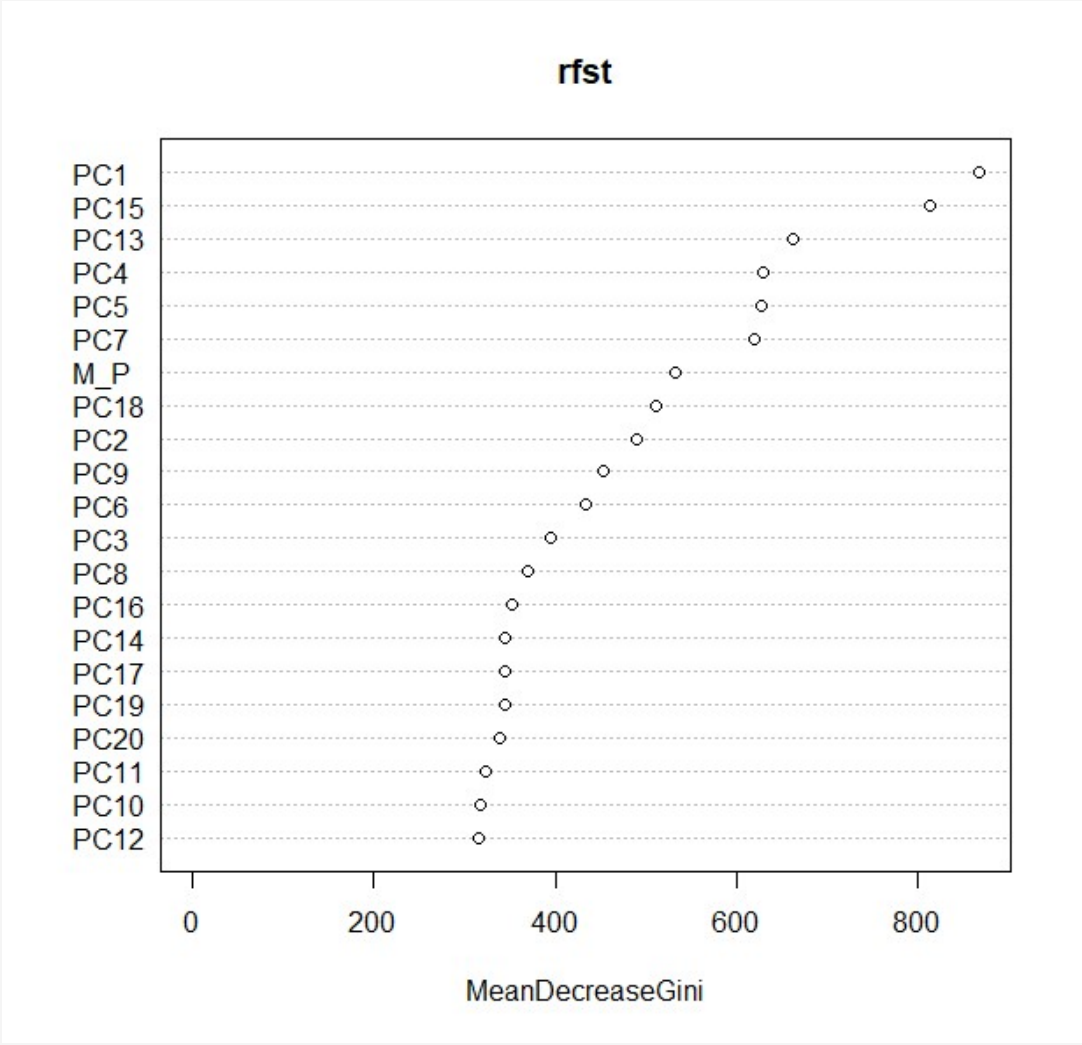
Compiled Results Over Time-Series



Confusion Matrix	0	1
0	41%	7%
1	6%	46%

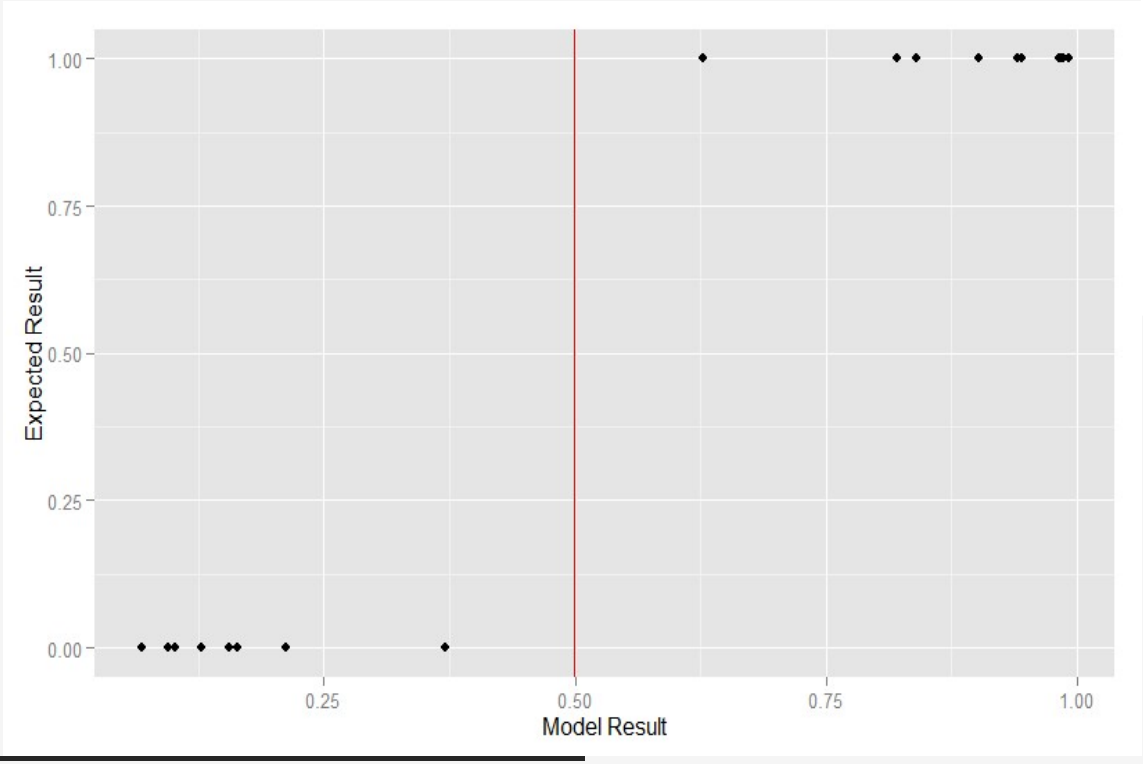
Important Variables

- PC1
  - Actual and Command Position and Current in Spatial Dimensions
  - Velocity and Current of Rotational Dimension
- PC15
  - X,Y Output Current
  - Sequence Number
- PC13
  - Dominated by Current Program Number



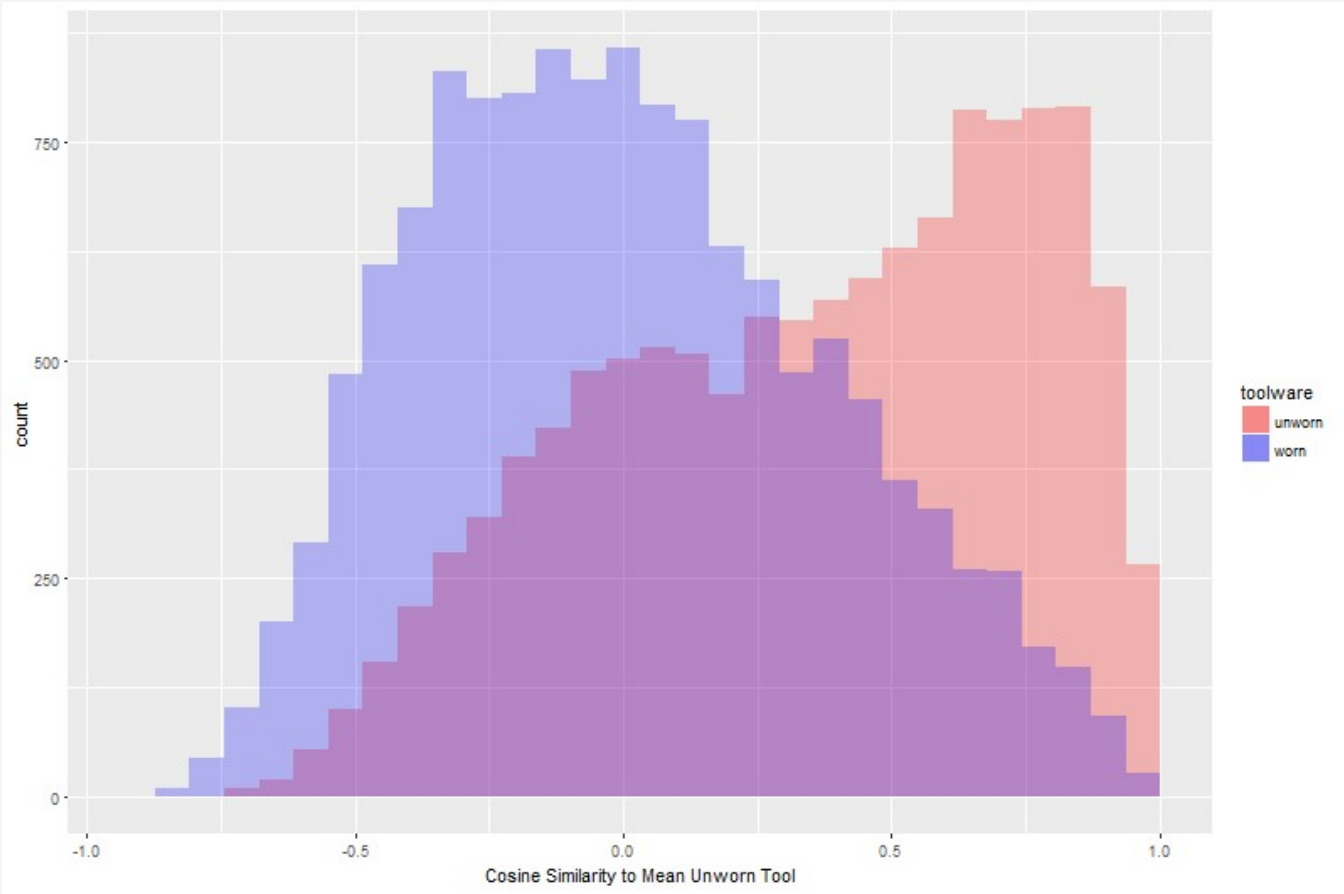
Random Forest: PCA

Compiled Results Over Time-Series

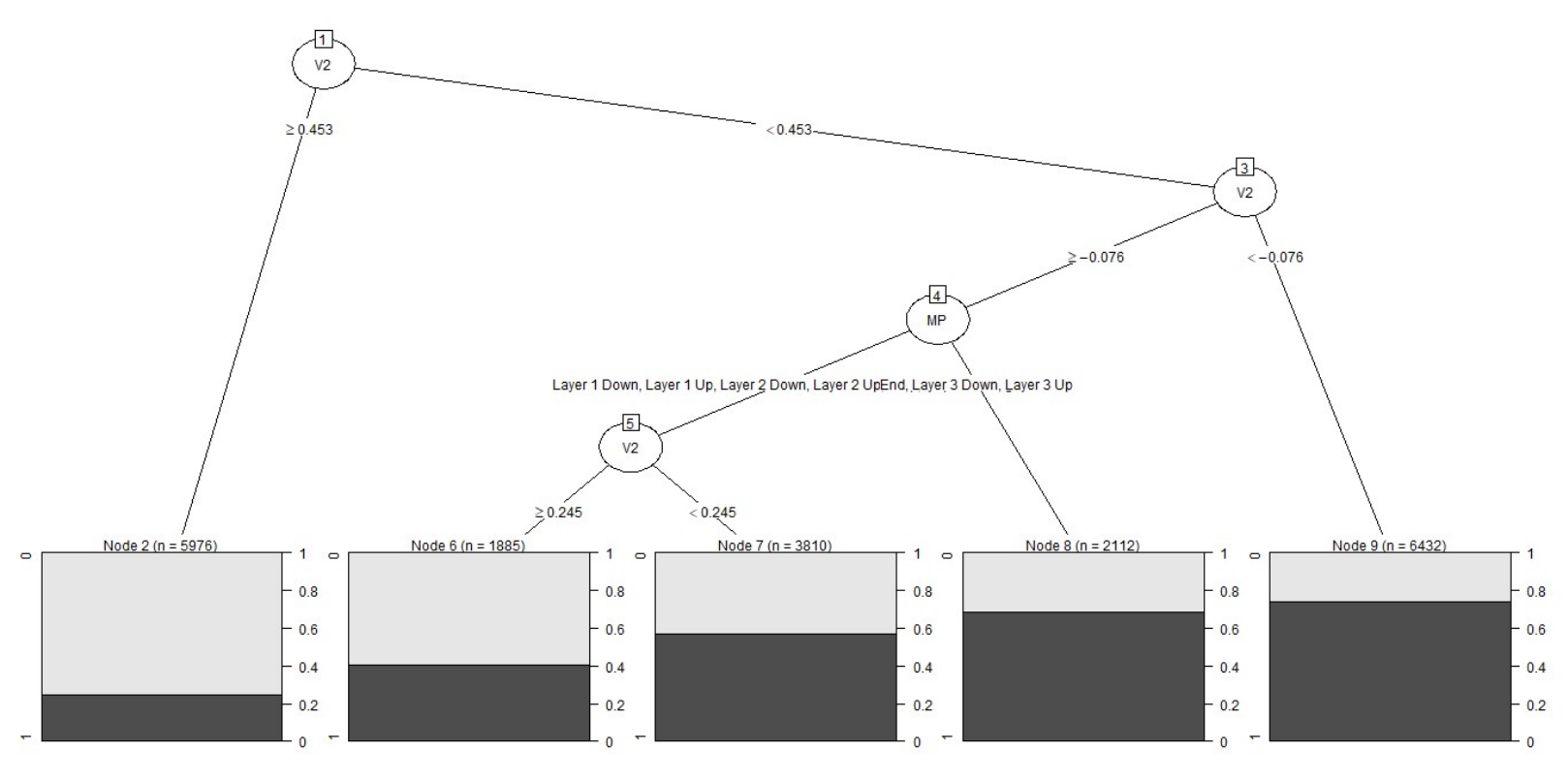


Confusion Matrix	0	1
0	41%	7%
1	6%	46%

Cosine Similarity

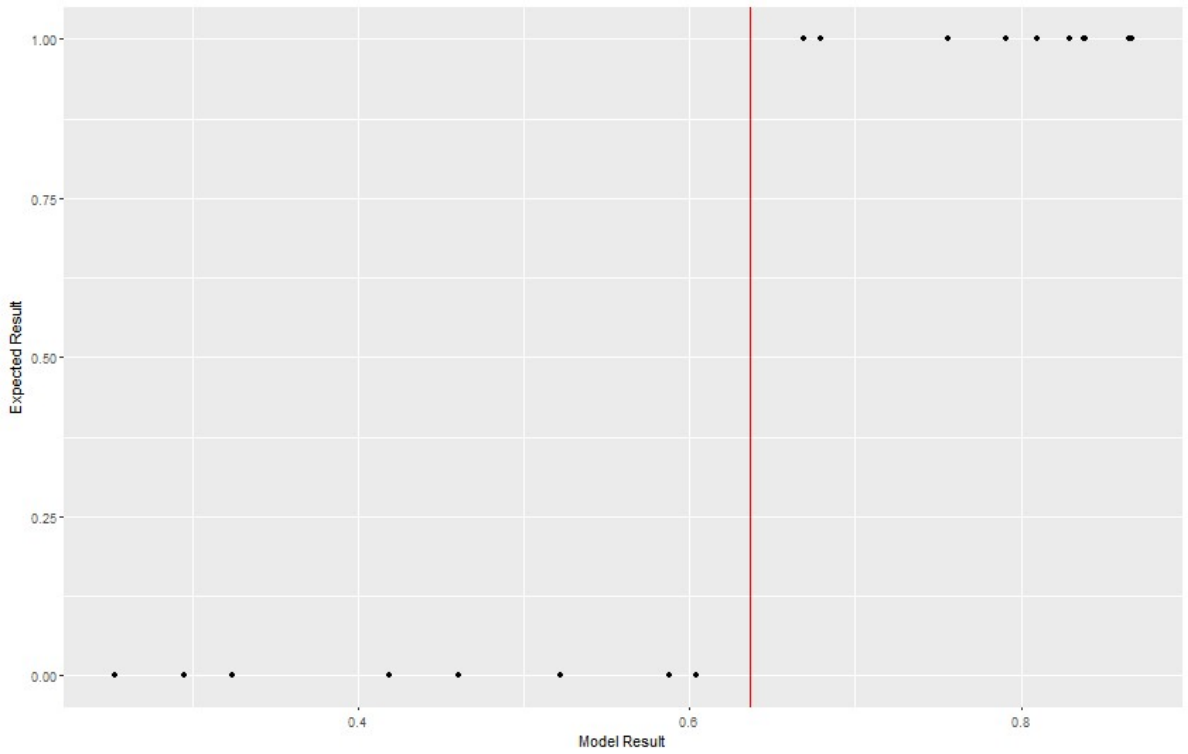


Tree Model: Cosine Similarity



Tree Model: Cosine Similarity

Compiled Results Over Time-Series



Confusion Matrix	0	1
0	27%	12%
1	20%	41%

Future Actions

- Tool-wear happens slowly over time
  - Not necessarily a binary response
- Used 1 tool in 1 program