A Dynamic Threshold Based Approach for Detecting the Test Limits

Regression methods for Final Test Yield prediction and test optimization

Cristina Landin

PDU PTD Kumla

Outline

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- Solution approach
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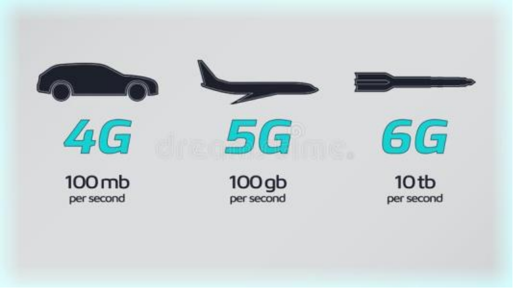
- Discussion
- Conclusions
- Challenges

Problem statement

- Getting ready for new radio generation products where statistical approximation are not enough to cope the quality standards
- Trade off between test coverage and test time (resources) ->needs optimization
- Test results are dependent on test limits (fixed limits do not considered changes or direction within those ranges)
- Current thresholds are defined by SME after the standards and/or previous experience
  - i.e., Power <30 dBm (one limit but testers need to limit the lower bound based on the expected uncertainty and the sensitivity of the instrument)
- Too loss or too strict thresholds influence directly on the final production yield, which shows the efficiency of the manufacturing process



An analogy comparison between the new telecom technologies and what is expected

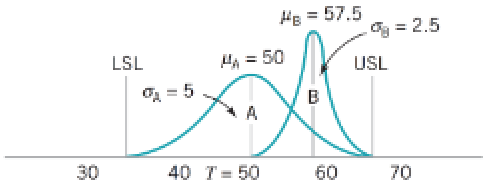


Figure 1: Two processes with $C_{pk} = 1.0$ (Montgomery, 2009).

Background

- What is a Base station (RBS within Ericsson) -> HW allows connectivity (Transceiver)

- Why to test?
  - Analog components – electromagnetic waves – critical applications (e.g., medical, self driving cars)
- Traditional Production process (non-data-driven)

  - Standards regulators ->Requirement specifications (test limits) ->

    Manual coding (Test plan) -> Test suite execution -> Test results

    If fail -> yield loss analysis (fault diagnosis- check logs)
- Final Test yield (non-Gaussian distribution)

$$FY = \frac{Pass\ units}{Total\ processed\ units}$$

TABLE I. TEST REQUIREMENTS EXAMPLE IN THE DIFFERENT STAGES OF TESTING.

Test Requirement according 3GPP	Test Case	Test point
6.6.2 of 3GPP TS36.141 ACLR upper limit $44.2dBc$	Test Case 1: This test case will measure the Adjacent channel leakage power ratio (ACLR) of product A *Configuration* *Procedure* *Passcriteria* $> 45dBc$	*Configuration* Test point 1.1: Send the right settings to the product Test point 1.2: Set up the carrier Test point 1.3: Send the right settings to the instrument to start measuring the ACLR *Procedure* Test point 1.4: Measure the ACLR *Passcriteria* Test point 1.5: Compare the results to the pass criteria

Stricter limit to secure compliance

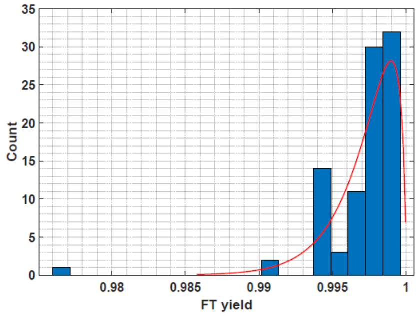
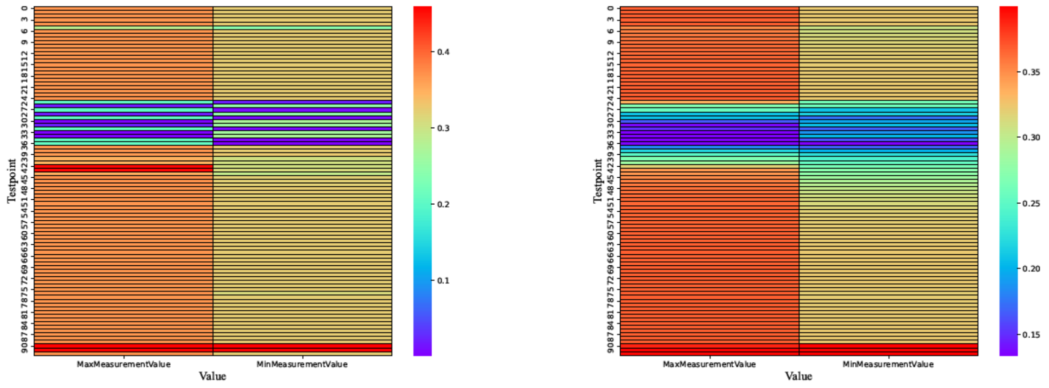


Figure 1. The 4G RBS production final yield (FY) distribution. The FY aims to reach 1 (100%) viz. It is a negatively skewed.

Background

- Data smoothing -> exponential
- Regression analysis
  - Linear, polynomial, Ridge and XGBoost
- Imbalanced classification
  - First balance using SMOTE and then
  - SVM for auto labeling inputs
- Anomaly detection -> see divergent points
- Transfer learning in two products a 4G (herein called A) and a 5G (herein called B)



(a) Captured data before smoothing. (b) Captured data after smoothing.

Figure 2. Heatmap of feature inputs before after smoothing, for a 4G radio product.

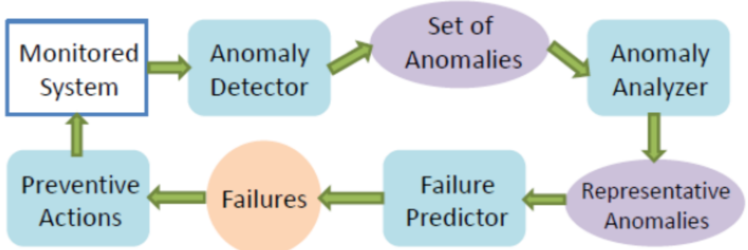


Figure 3. Data-driven prognostic health management (see [7]).

Solution approach

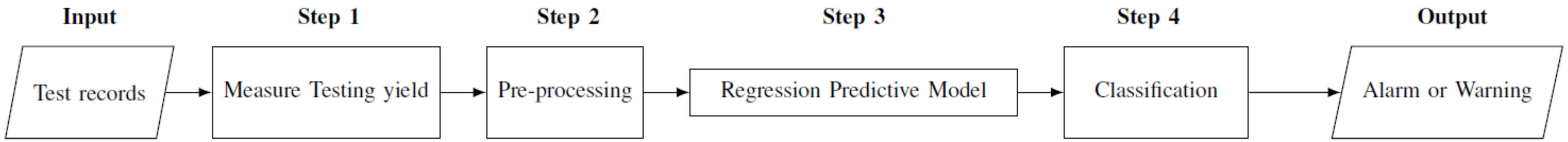
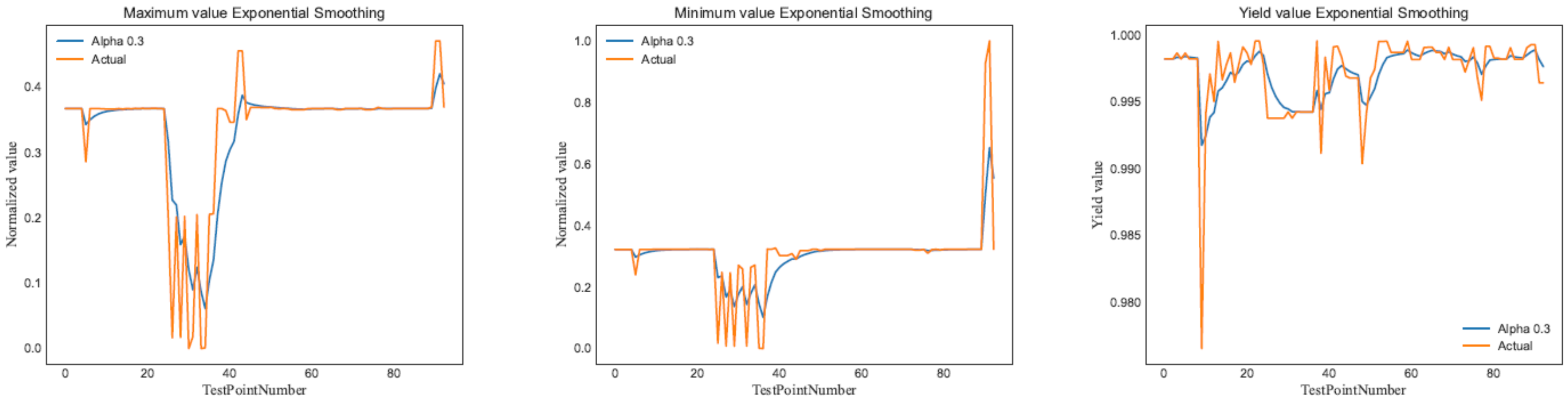


Figure 4. The required input, steps and expected output of the proposed solution in this study.

- Input : Test records
  - X: test points
1. Calculate final test yield (FY)
2. Pre-processing
   - Normalization (multiple inputs with different scales)
   - Smoothing (inputs, yield)



(a) Maximum test inputs. (b) Minimum test inputs. (c) Target test inputs.

Figure 5. The original and smoothed versions of maximum, minimum, and target test inputs for product A.

Solution approach

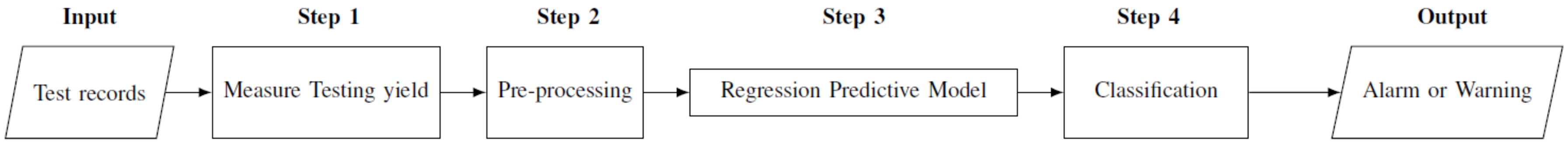


Figure 4. The required input, steps and expected output of the proposed solution in this study.

3. Regression predicting model (based on product A)
   - Linear, polynomial, exponential and XGBoost
4. Classification (SVM)
   - SMOTE (create synthetic new samples of the minority class)

$$X_{new} = X_{origin} + \text{rand}(0,1) * |X_{origin} - X_i| \qquad (1)$$

   - Auto-labeling of the inputs and show a message when a new test input (test point) will influence the FY, thus avoid further execution or retest

Results and validation

- Regression

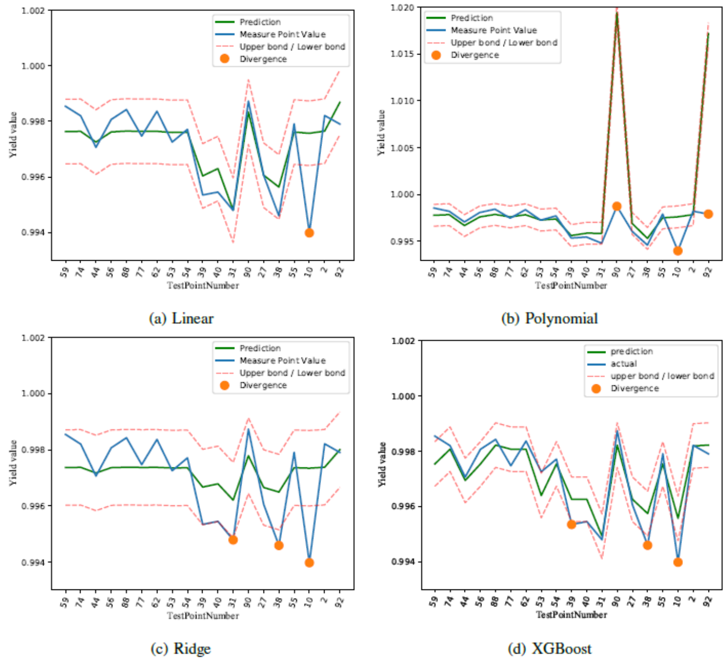


Figure 6: The smoothed data utilized regression models on product A. The dashed lines are the predicted thresholds.

TABLE III. A SCORES SUMMARY OF THE SMOOTHED DATA VALIDATION.

Model Name	RMSE	MAE
Linear Regression	0.00099	0.067
Polynomial regression	0.0049	0.202
Ridge regression	0.0012	0.095
XGBoost	0.00073	0.00014

- Model performance evaluation

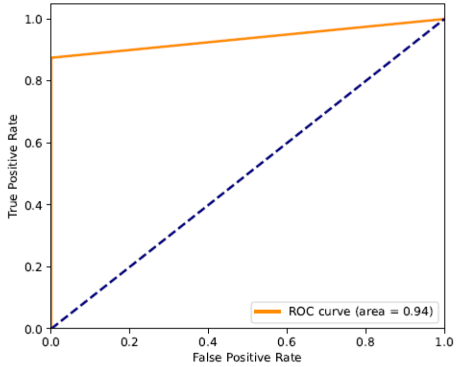


Figure 7. Classification evaluation using ROC for product A.

- Transfer learning (using model trained in A)

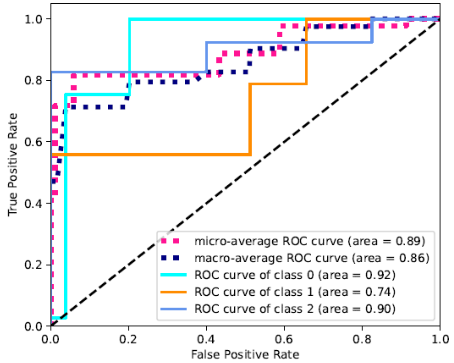


Figure 8. Classification evaluation ROC using unseen data captured from product B.

Discussion

- Normalization of the input features (test points)
- Smoothing to remove noise and outliers (test points and yield)
- Assumptions: Test points independence (future work) and neglect the test sequence

Conclusions

- New infrastructure to pre-process, predict and classify anomalies from processes with multidimensional inputs
- Dynamic thresholds based on the predicted FY using multiple regression models -> best regression model XGBoost
- Find the divergent points from the dynamic thresholds
- Auto labeling the input features using SVM
- Prediction error RMSE and MAE
- Validation of the classification using ROC
- Tool can help to find the source of yield drop in an early stage
- Transfer learning possibilities between two radio generations with similar properties

Challenges and future work

- Evaluate the test points dependencies, we cannot consider that all test cases are independent in real-world application
- Test sequence order -> the test yield may be influenced by the sequence the test cases are executed and change according the time stamps in the production
- Implementation in a production site, first as prototype and then as part of another bigger software for test production. The tool needs to be compatible and scalable to work within the company standards
- Evaluate not only numerical test inputs but also categorical and natural text
- Extend this work by predicting the test points new dynamic limits
- How much in percentage can we transfer the knowledge learnt in another product?

Thanks for attending!

- Questions or comments are welcome!
- Please contact me at:

cristina.landin@oru.se
cristina.landin@ericsson.com