Fault Detection in Uni-directional Tape Production using Image Processing

Somesh Devagekar
Dr.Ing. Ahmad Delforouzi , Prof. Dr. Paul G. Plöger

January 10th, 2020

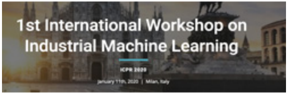


Table of Contents

Introduction

- Quality of unidirectional tapes (UD-Tapes)
  - Production process (temperature and production speed)
- Foresee the end value product

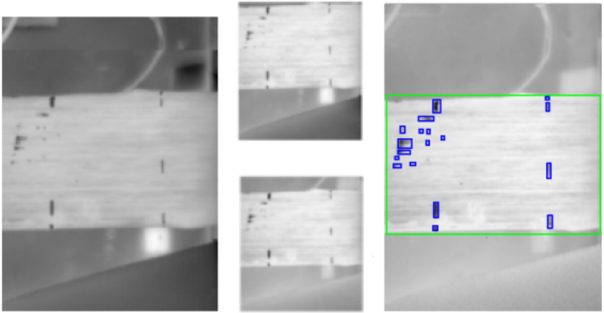


Figure 1: A vision-based thermography system is used to control the quality of a tape production process.

Motivation and Challenges

Motivation

- Efficient quality assessment
- Understanding of local fiber deviations
- 30% reduced scrap rate and decreased production cycle time [1]

Challenges

- Poor quality images
- Changing position of the tape
- Faults appearing in diverse shapes and sizes

Experimental Pipeline

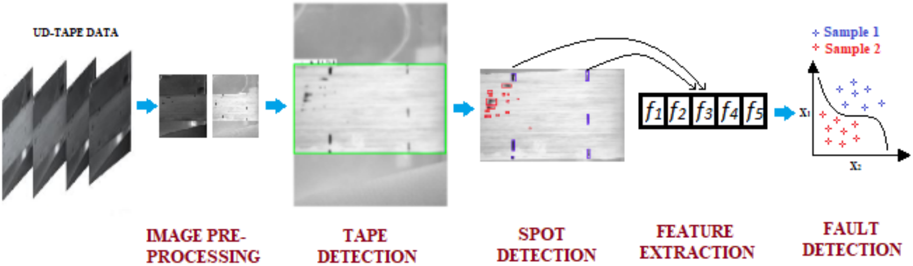


Figure 2: Experiment Pipeline

UD-Tape dataset and Image Pre-processing

Dataset

- 450 Thermographic images ofthe size 768x1024 pixels.
- Changing illumination

Image Pre-processing

- Structural similarity analysis
- Histogram analysis
- Histogram Equalisation

Tape Detection

Grab-Cut ROI

- Create labels and cluster pixels according to their intensity via a Gaussian Mixture Model (GMM) [2]

Faster-RCNN ROI

- Faster-RCNN [3] trained on 60 augmented images with a detection accuracy of 95.7%.

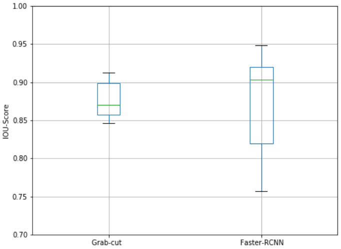


Figure 3: Quantitative IoU results for predicted images shows Grab-cut gives averagely better results than Faster-RCNN.

Spot Detection

Image enhancement

- Enhancement using morphological operations such as dilation and erosion
- Linear filter, in convolution with a point structuring element

Feature Descriptors

- Histogram of Oriented Gradients (HOG) [4]
- Features from Accelerated Segment Test (FAST) [5]
- Oriented FAST and Rotated BRIEF (ORB) [6]
- Scale Invariant Feature Transform (SIFT) [4]
- Speed-up Robust Features (SURF) [5]
- Canny edge detection (CANNY) [7]

Spot Detection Results

- Canny edge detection provides the best edge completeness and noise suppression

Feature descriptor	Total number of detections (TP+FP)	Correctly detected (TP)	Incorrectly detected (FP)
HOG	14	9	5
FAST-TRUE	254	20	234
FAST-FALSE	1650	20	1630
SIFT	87	17	67
SURF	295	20	275
ORB	318	20	298
CANNY	24	20	4

Table 1: Quantitative results of feature descriptors to detect the markers and the faults on a tape

Spot Detection

Feature Descriptors

- Aspect-Ratio
- Approximate number of sides of a void
- Relative location of a void in the image
- Shape of the void
- Center of mass

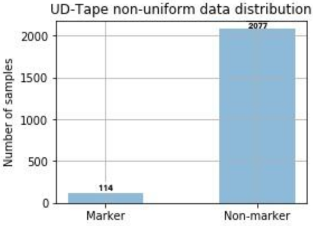
Features	Feature 1	Feature 2	Feature 3	Feature N
Aspect-Ratio	1.5	0.3	1.17	...
Position	352,692	0,688	212,648	...
Shape	Half-circle	NA	Circle	...
Approx sides	9	14	17	...

Table 2: Features from UD-Tape dataset.

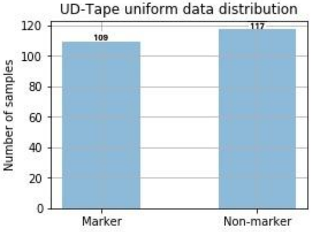
- Feature set has two classes as 'marker' and 'non-marker/faults'

Machine Learning Techniques

- Support Vector Machines(SVM)
- Decision trees
- K-Nearest Neighbour(K-NN)
- Logistic Regression
- Naive Bayes
- Random forests



(a) Unbalanced data distribution



(b) Stratified data distribution

Figure 4: UD-Tape data distribution of data over the two classes of markers and tape faults is shown.

Fault Detection Results

- Random forest and logistic regression outperform the other classifiers
- Similarity of performance is influenced by the type of dataset rather than the model selection [8]

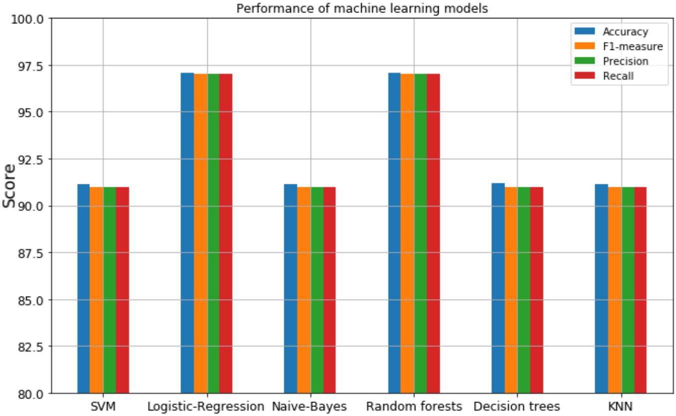


Figure 5: Performance of stratified distribution

Fault Detection Results

- Considering micro averaged accuracy for each class outcome in imbalanced classification task

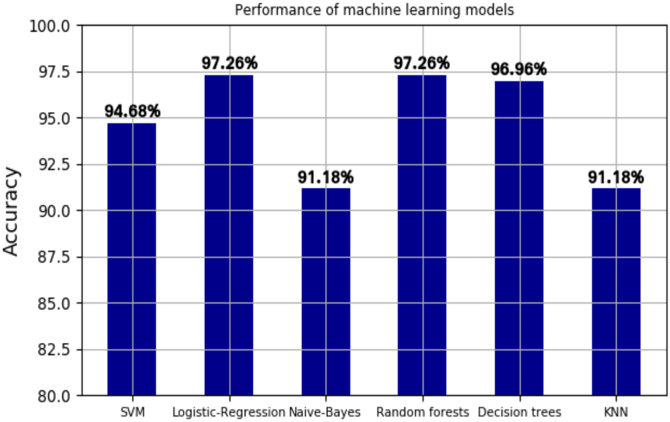


Figure 6: Performance of unbalanced distribution

Conclusion

- With the extraction of relevant information of faults from Canny edge detection, summarised as shape/size/area/position of a fault, the proposed framework is able to work with different machine learning strategies for classification over markers and tape faults.
- It is concluded that Logistic-Regression and Random-Forests performed better, in terms of micro aver-aged accuracy and F_1 measure.
- For future research, a study on feature extraction algorithms to understand the fiber alignment and delamination can improve overall performance and help assess the the material grade.

Thank you!

Questions?

References

[1] M. Kropka et al. "From UD-tape to final part–a comprehensive approach towards thermoplastic composites". In: Procedia CIRP 66 (2017), pp. 96–100.

[2] X. Y. Wu et al. "An Interactive Video Foreground Segmentation System Based on Modeling and Dynamic Graph Cut Algorithm". In: Advanced Materials Research. Vol. 532. Trans Tech Publ. 2012, pp. 1770–1774.

[3] S. Ren et al. "Faster r-cnn: Towards real-time object detection with region proposal networks". In: Advances in neural information processing systems. 2015, pp. 91–99.

[4] Ş. Öztürk and A Bayram. "Comparison of HOG, MSER, SIFT, FAST, LBP and CANNY features for cell detection in histopathological images". In: HELIX 8.3 (2018), pp. 3321–3325.

[5] M. El-Gayar, H Soliman, et al. "A comparative study of image low level feature extraction algorithms". In: Egyptian Informatics Journal 14.2 (2013), pp. 175–181.

[6] A. Amaricai, C.-E. Gavriliu, and O. Boncalo. "An FPGA sliding window-based architecture harris corner detector". In: 2014 24th International Conference on Field Programmable Logic and Applications (FPL). IEEE. 2014, pp. 1–4.

[7] Machine Vision. http://www.cse.usf.edu/~r1k/MachineVisionBook/MachineVision.files/MachineVision_Chapter5.pdf. Accessed: 18.08.2019.

[8] A. Wålinder. Evaluation of logistic regression and random forest classification based on prediction accuracy and metadata analysis. 2014.